Neoclassical Investment Theory and Evolution: Trend and Policy Intervention in the UK

Qi He

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THE BARTLETT SCHOOL OF SUSTAINABLE CONSTRUCTION
UNIVERSITY COLLEGE LONDON

Declaration

I, Qi He, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Abstract

This thesis reports three main findings within the neoclassical investment framework, providing a perspective on the evolution of capital investment. It begins by establishing a new method to measure marginal capital return. With this method, it reveals discoveries that the capital investment intensity has been declining in the UK over the last three decades due to diminishing investment returns. Furthermore, it shows from an example named Help to Buy (HtB) that a suitable policy intervention could help alleviate the sluggish investment and return trend.

Measuring investment return has posed a significant challenge within the field. Chapter 2 delves into the key aspects of the challenges from a theoretical aspect. Building upon this review, I introduce a production function based method to calculate markup and elaborate on how it addresses the difficulty in observing the key variable of marginal Q empirically, which was previously constrained by its marginal and forward-looking mathematical nature. This method plays a key role in the study of the subsequent chapters.

Assisted by the new metric introduced in Chapter 2, Chapter 3 re-examines the corporate investment pattern over the last three decades within British firms. It reports a notable finding regarding the investment-cash flow sensitivity (ICFS), a significant financial indicator of capital investment intensity, which has shown a declining trend among unquoted firms over the past three decades. This discovery corresponds to a new puzzle of the diminishing ICFS primarily discovered in the US. The study examines

data from British firms and identifies asset tangibility as the primary factor influencing the ICFS, indicating that the ICFS is, in fact, an investment-cash flow-tangible capital sensitivity. The decline in investment in tangible assets emerges as the key driving force behind the diminishing ICFS. The sustained decline of capital investment over the last thirty-six years is a consequence of decreasing returns on tangible capital. This reduced investment activity leads companies to depend less on cash flow financing, resulting in a declining ICFS within the firms. These findings highlight the importance of addressing the issue of low capital returns for fixed assets, particularly in traditional, non-public firms heavily dependent on tangible assets.

This thesis presents a remedy for the declining investment in Chapter 4 by probing the influential effects of a credit expansion policy, Help to Buy, on developers' investments and finances. The study employs the HtB scheme as a quasi-random experiment and uses a Difference-in-Differences (DID) method to determine the policy's causal effects. The research outlines a detailed cost-benefit framework that considers the pure demand shock brought about by the policy. It demonstrates that the policy has led to increased costs and sales for participating firms and has resulted in surplus profitability, against the backdrop of a general decline in capital productivity outlined in Chapter 3. Notably, it shows that the HtB scheme does not boost builders' market power (as measured by markups). Instead, it promotes excess profitability by encouraging builders to sell more properties at relatively lower margins - margins that would have been higher in the policy's absence. Lastly, the Q theory framework examination suggests that the policy has facilitated stable growth expectations for firms, substantially mitigating their adjustment and financing costs. This dynamic predominantly drives the observed higher profits and lower margins, facilitating continued investment and construction from developers. The HtB boosts homeownership from the demand perspective and provides financial advantages from the supply perspective, creating a profound impact on the British economic and social landscape. This could serve as a policy example for mitigating the general under-developed productivity issue studied in Chapter 3.

Impact statement

This study conducts extensive research on corporate investment based on the neoclassical investment Q theory. The theoretical benefit of this research is to provide new measurement insights into building a modern investment theory. The empirical contribution of this research uncovers new phenomena and provides explanations, which hold the potential to enrich economic discourse, inform corporate investment strategies, and promote sustainable economic development.

Firstly, this thesis introduces a new and more accurate measurement of marginal productivity. In an exploration of investment theory, I suggest using production-based markup as a measure for marginal Q, and offer three distinct methods for its empirical estimation. This approach is not only simple to implement using balance sheet data, but it also addresses the challenge of measuring Q (i.e. marginal productivity) in unquoted firms. Unquoted firms do not have a Tobin Q to measure Q, which makes this new measurement method particularly valuable. Marginal productivity frequently functions as a critical explanatory or control variable in comprehensive empirical research. The application encompasses measuring financing costs, evaluating investment efficiency, aiding in policy evaluation, and other relevant aspects. The broad utility underscores its central role in assessing the effectiveness and impacts of economic policies and business strategies. The research used to suffer from the bias brought by mismeasured marginal Q. The inclusion of markup, which provides a more precise Q, could enhance the precision of model estimation.

Secondly, the study sheds light on the prevalence of ICFS and its decline among British firms, providing insights into the effect of asset tangibility on ICFS and the potential impact on the underdevelopment of capital productivity. This metric is used in investment studies for assessing borrowing conditions, investment costs, or evaluating policy impact. The evolution of ICFS over time in small and medium-sized enterprises has not been widely explored, leaving room for further investigation in other countries. This thesis highlights that firms that rely heavily on fixed assets for production exhibit lower capital investment returns. The low investment return leads them to decrease investment in capital. This challenges the current research which attributes the decline in ICFS to improved financing conditions, derived from large quoted firms. My findings can spark more research into productivity and investment in small and traditional non-tech-based firms, particularly regarding their comparatively lower investment and slower growth rates compared to publicly listed firms. Unquoted firms are primary contributors to the UK's business landscape. Such studies can potentially initiate policy discussions and draw more attention to the repercussions of post-deindustrialisation, possibly addressing the nation's persistent productivity dilemma.

Thirdly, this thesis provides a possible policy suggestion to mitigate the declining investment issue. By examining the impact of Help to Buy (HtB), a credit expansion policy, on firm profitability, it presents a structured framework for understanding a firm's response to a policy-induced demand shock. The study reveals that HtB has boosted the financial performance of participating firms. This prompts further inquiry into the policy's overall effectiveness for the Department for Levelling Up, Housing and Communities (DLUHC) and Homes England. Furthermore, the findings suggest that HtB does not lead to increased market power for firms, indicating that the rise in profitability stems from increased sales rather than pricing power. This can provide major information for evaluating the performance of the HtB scheme. The analysis framework is useful for researchers investigating the impact of credit expansion policies on market suppliers and policymakers seeking to understand the impact of such policies on participating developers' wealth. With more policies being introduced to incentivise the economy in the wake of COVID-19, this study can serve as an example for evaluating their impact on social welfare and potential hidden consequences.

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Dear friends and family, thank you all for your invaluable contributions to my academic and personal growth.

Sincerely,

Qi He

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List of Abbreviations

2SLS Two Stage Least Squares.

ACF TFP estimation method of Ackerberg et al. (2006; 2015).

DCFS Debt Cash Flow Sensitivity.

DID Difference In Differences.

ECM Error Correction Model.

FAME Financial Analysis Made Easy (Name of a database).

GLS Generalised Least Squares.

GMM Generalised Method of Moments.

HtB Help to Buy.

ICFS Investment Cash Flow Sensitivity.

LLM Weighted Least Squares.

LP TFP estimation method of Levinsohn and Petrin (2003).

MLE Maximum Likelihood Estimation.

OCR Optical Character Recognition.

OLS Ordinary Least Squares.

OP TFP estimation method of Olley and Pakes (1992).

PAIT Profit After Interest and Tax.

PBIT Profit Before Interest and Tax.

ROCE Return on Capital Employed.

SDH Stamp Duty Holiday.

SEM Shared Equity Mortgage.

SIC Standard Industrial Classification.

SMEs Small and Medium-sized Enterprises.

TFP Total Factor Productivity.

TR Tangibility Ratio.

WLS Large Language Model.

Chapter 1

Introduction

Economists have long been delving into the dynamics of economic growth, aiming to understand the complex systems that propel productivity, allocate resources, and enhance living standards. This necessitates a holistic perspective because fast economic growth, marked by a quick increase in a country's total output, is often accompanied by unbalanced development. In such cases, certain regions or sectors might enjoy disproportionate growth, while others encounter stagnation or even decline[1]. Unbalanced development can lead to various economic challenges, such as income inequality, financial instability, and financial constraints (De Loecker et al. 2020). This requires researchers to adopt a more holistic perspective that prioritises long-term sustainable growth and to develop more comprehensive investment frameworks that allow for the evaluation of efficiency, patterns, and returns in capital deployment (Acemoglu 2012).

The thesis examines the evolution of the neoclassical investment framework by addressing various questions, using financial data sourced from the UK [2]. In Chapter 2,

[1]For instance, Bellocchi et al. (2021) document a slowdown in the growth of total factor productivity among European companies, contributing to an overall dampening of economic progress. Similarly, Goodridge et al. (2018) unravel the enigma of stagnant growth in total factor productivity in the UK. De Loecker et al. (2020) demonstrate that in the US, the aggregate markup has surged from 1.2 to 1.6 over the last four decades, largely driven by the rise in top quantile superstar firms. This surge has produced negative implications for capital investment and the labour market.

[2]The data is obtained from the database of Bureau Van Dijk Electronic Publishing's Financial

a new method to measure marginal capital return is proposed. This metric is then applied in Chapter 3, revealing a decline in both capital investment intensity and return over the last three decades in the UK. This fading investment trend corresponds to the sluggish productivity puzzle identified in recent years (Bellocchi et al. 2021; Goodridge et al. 2018). However, Chapter 4 investigates the Help-to-Buy (HtB hereafter) scheme and demonstrates that a properly designed policy intervention may incentivise demand without boosting suppliers' market power. It can potentially help to boost capital productivity and alleviate the under-development issue identified in Chapter 3. The chapters are intrinsically linked in terms of their theoretical backgrounds. While the empirical analysis in Chapters 3 and 4 can stand independently, all the empirical discussions are grounded in the neoclassical investment model and the econometric estimation techniques discussed in Chapter 2.

Chapter 2 starts by revisiting the investment theories and the relevant estimation methods employed in this thesis. The development of the investment model spans several decades, which underlies many economic models, policy discussions, and much heuristic thinking. The pertinent research can be divided into two primary branches: stochastic models and econometric estimations. These branches underpin the rationale behind constructing baseline models, selecting specific estimation methods over others, recognising potential problems, and implementing robustness checks to support arguments. This chapter carries out theory-based work across three facets.

The first objective is to demonstrate how the investment Q model has evolved from dynamic stochastic general equilibrium (DSGE) modelling into a widely researched subfield, showing its connection to the empirical model employed in this thesis. The modern investment theory seeks to answer three fundamental questions: (1) whether to invest, (2) when to invest, and (3) how much to invest. The neoclassical investment model and Q model posit that a firm should invest if the marginal Q ratio is greater

Analysis Made Easy (FAME). FAME collects information including financial and accounting data from balance sheets, cash flow statements, and profit and loss statements. It also encompasses relevant legal entity details, merger and acquisition activity, news, corporate structures, and ownership.

than 1 (i.e., if the market value of capital surpasses the replacement cost of capital). In this sense, firms are maximising their value by increasing their capital investments when they anticipate that the marginal returns will surpass the associated costs. The first section offers a detailed exploration of how marginal Q, the principal determinant of investment, is derived and why it remains unobservable in empirical applications. Building on this foundation, I also offer a theoretical rationale for the models used in the empirical investigations in Chapter 4.

The second aim is to suggest a theoretical resolution to the puzzle of unobservable marginal Q. The net marginal productivity of capital investment, commonly referred to as marginal Q, cannot be directly observed due to its unpredictable and forward-looking nature (Blundell et al. 1992b)[3]. In practice, researchers and investors often measure marginal Q through the average productivity of capital investment, known as average Q[4]. But this surrogate measurement has often been deemed inadequate in empirical financial decision-making. Numerous studies have reported a rather limited correlation between optimal investment and this surrogate average Q[5]. Building on this, I propose a novel angle where a newly developed production-based markup formula, used to measure a firm's market power, can serve as a good metric to estimate marginal Q. This proposition integrates the fields of industrial organisation and financial economics, enabling researchers to calculate marginal productivity using annual financial data. Empirically, calculating production-based markup from the formula requires estimating the production function. I introduce three different methods to estimate using balance sheet data. This approach enhances the precision of marginal Q estimation in investment studies, which is particularly advantageous when examining smaller or unquoted firms (De Loecker et al. 2020; Fazzari et al. 1987)[6].

[3]Nonetheless, marginal Q, as the primary concept for evaluating whether firms are making optimal investment decisions, is critical for sustainable corporate management, and serves as a research object in the field of macroeconomics (Tobin 1969).

[4]Average Q forms the basis of the well-known Tobin's Q ratio, which serves as an indicator for selecting potentially promising stocks in the financial market.

[5]A detailed review regarding the mismeasured Q is provided by Blundell et al. (1992b).

[6]These firms typically lack product-level data and information available through public trade, which are key elements needed to calculate and analyze marginal Q accurately. This lack of accessible

The third objective of Chapter 2 is to provide a comparative review of econometric methods, which is a crucial aspect that significantly advances investment theory. Investment models have various complexities tied to empirical identification, including time correlation, endogeneity, and heteroscedasticity. These issues make traditional regression estimations inadequate for identifying the rationales delineated by the models. Contemporary econometric methods such as two-stage least squares and generalised method of moments are proposed to address the challenges. They are intrinsically connected and can progressively address more estimation constraints. They facilitate a more precise estimation of economic relationships and investment behaviours, and provide essential empirical feedback for the refinement of theoretical models. The third part offers a brief overview of the econometric methods pertinent to this thesis. It reviews and compares the connections among the most frequently utilised models in investment studies. This not only illustrates the evolution of theory development but also justifies the selection of specific models in subsequent empirical studies.

Chapter 3 delves into a trending topic stemming from investment theory based on the findings in Chapter 2. Fazzari et al. (1987) discover that, in addition to average Q, firms tend to invest more in capital when they have larger internal cash flows. This correlation is referred to as investment-cash flow sensitivity (ICFS hereafter), which suggests that firms may not always have unrestricted access to equity or debt financing. Firms under financial constraints often rely on their own cash flows to fund investments, leading to a significant ICFS. The existence of the ICFS is regarded as both an indicator of market friction and serves as a significant research focus for addressing certain limitations of the investment Q model. In the following years, more studies have observed a significant presence of ICFS from markets of different countries, making it a popular research topic over the past several decades (Farre-Mensa and Ljungqvist 2016; Guariglia 2008; Kaplan and Zingales 1997; Larkin et al. 2018; Moshirian et al. 2017; Whited and Wu 2006; Zhen and Chu 2021). Nevertheless, recent research indicates that this sensitivity, which remains consistent for decades, starts to fade in the 1990s

data makes it challenging to apply traditional methods of measuring marginal Q in these contexts.

and has virtually vanished post the 2000s in publicly listed firms (Jason and Jenny 2012; Larkin et al. 2018; Moshirian et al. 2017). The vanishing ICFS is robust in the US and other developed countries (Jason and Jenny 2012). The reason behind fading ICFS soon becomes an attractive puzzle, and no primary conclusion has been reached thus far. Chapter 3 unveils this new puzzle from three aspects: (1) I propose that this diminishing sensitivity has declined among non-publicly listed firms, especially among small and medium-sized enterprises that heavily rely on fixed capital for production. (2) I identify declining asset tangibility as the primary factor contributing to the vanishing sensitivity. The high asset tangibility firms experience the greatest decline in asset tangibility, which leads to the decline in overall ICFS. (3) I discover that the decline in investment return of fixed capital investment is the primary reason leading firms to invest less in fixed capital, which further causes the decline in the ICFS.

Chapter 3 fills a research gap that no prior study has explored the evolution and dynamics of ICFS in non-listed firms. It reveals findings that diverge from existing explanations. Four initial studies have attempted to explain the reason for the vanishing ICFS from perspectives of asset tangibility (Moshirian et al. 2017; Zhen and Chu 2021), financial development, and financial liberalisation (Larkin et al. 2018; X. Wang 2022). They argue that the declining ICFS arises due to positive elements such as the increased capital returns yielded by technological progress, financial innovations, or the improvement of financial and economic conditions. A question arises regarding their general applicability, as their conclusions are all drawn from publicly listed firms. Publicly listed firms tend to be "super-star" entities that face significantly fewer financial constraints, display more flexibility in financing capital, and possess multiple channels for generating profit. These conditions do not apply to most small and medium-sized enterprises (SMEs) which often operate in a financially constrained and highly competitive environment. De Loecker et al. (2020) document that since 1980 the aggregated markup[7] has risen from 21% to 61% and this rise has mainly been driven

[7]The markup is a ratio defined as the marginal price over the marginal cost. It is used to measure the overall market power of a company. High markup signifies that a company possesses stronger bargaining power not only in terms of product pricing but also in labour, welfare, and other resource

by the upper tail of the markup distribution. As a result, a major market resource and capital investment shift from low markup companies to high markup companies. These discussions highlight the significant changes in market conditions and production paradigms spanning from 1980 to 2016, underscoring the necessity of examining the evolution and dynamics of ICFS in regular firms, particularly small and medium-sized enterprises (SMEs).

Drawing on 781,314 firm-year observations from 1984 to 2019 across six subperiods, this study identifies, for the first time, a decline in the ICFS among British firms, 99% of which are SMEs. The interaction coefficients between cash flow and the asset tangibility ratio prove to be significant in all baseline regression tests, indicating that the ICFS is, in fact, an investment-cash flow-tangible capital sensitivity. The study further shows that firms with greater asset tangibility not only exhibit a higher ICFS, but also experience a more pronounced decline in ICFS. In comparison, firms with low asset tangibility display a comparatively low ICFS that experiences a lesser decline. This indicates that the decline in ICFS among British firms is primarily driven by those with high asset tangibility.

Chapter 3 delves further into the reason for declining asset tangibility. Current literature pinpoints two channels through which it influences the ICFS — sales return on tangible capital investments and cash flow persistence. I find that the sales return on tangible assets has been decreasing more rapidly among high asset tangibility firms, supporting the first channel, while cash flow persistence has remained constant in both high and low asset tangibility firms, challenging prior conclusions from studies on publicly listed firms. Most notably, the investment return on both intangible and tangible assets is fading among firms with a high asset tangibility ratio, and the return on tangible capital remains sluggish across all firms. To validate the robustness of the first channel, I further demonstrate that firms heavily dependent on tangible assets, coupled with minimal market power, exhibit the most pronounced drop in ICFS. This

allocation aspects (De Loecker et al. 2020).

substantiates the notion that firms decrease their capital intensity when they possess a relatively higher proportion of tangible assets but struggle to maintain productivity.

The study of the ICFS trend presents two primary challenges. First, the difficulty of accurately measuring marginal Q, a key control factor in the investment model, can pose a major hurdle in estimating ICFS. Previous research has largely relied on surrogate measures such as Tobin's Q, which can lead to substantial overestimation of the ICFS (Erickson and Whited 2000; Guariglia 2008; Jason and Jenny 2012). The new production-based markup calculation, introduced in Chapter 2, offers a practical solution to this problem and enhances the precision of ICFS estimation. The second challenge arises from econometric issues related to the inclusion of multiple correlated or lagged variables in the model. Lagged data issues are particularly common among SMEs, potentially introducing biases when evaluating the investment function using traditional least squares regression methods (Erickson and Whited 2000). This study employs an error-correction model (ECM) (Cummins et al. 2006; Guariglia 2008) to address this problem. The approach does not require assumptions about short-term investment and its replacement cost. It can address concerns associated with the autoregression of investment and Q measurement, providing a more adaptable estimation.

Chapter 3 performs a series of robust tests and shows the conclusion regarding the cause of the disappearing ICFS remains steadfast. This analysis contributes to the existing literature by offering a fresh perspective on the investment-return dynamics of all sample firms. It challenges the heuristic fallacy that a decline in ICFS always signifies a significant improvement in the domestic financial and economic landscape. The study demonstrates that ordinary firms exhibit a less efficient production paradigm in terms of investment intensity, return on investment, and persistent cash flow. These findings provide additional evidence for understanding the sluggish productivity puzzle in the UK and European all sample firms (Goodridge et al. 2018).

Chapter 3 poses a significant challenge in addressing the sluggish investment and return trend. A natural question arises: is there anything that could potentially reverse this declining trend? Chapter 4 offers a promising answer by delving deeply into the criticisms of a credit expansion policy named Help-to-Buy, on the financial performance of housing providers. The Help-to-Buy scheme has been widely recognised as a salient policy in the UK that increases the affordability of first-time buyers by providing mortgage benefits (Carozzi et al. 2020). Yet debates have frequently emerged regarding whether the policy is boosting living welfare, or simply fuelling substantial profits for developers (Archer and Cole 2021) and elevating the price of new homes (Carozzi et al. 2020). To date, no study has systematically explored the impact of this policy on the sales of developers, and how changes in developer production may affect the evaluation of this policy. Building upon the conclusions drawn in Chapter 3, this chapter seeks to address this through three key research questions: (1) Does the HtB lead to higher profits for participating developers than for non-participants? (2) If so, is this increased profitability attained through higher selling margins or increased sales quantity? (3) How does the HtB policy interact with participating developers in achieving their sales targets?

Chapter 4 introduces a comprehensive counterfactual cost-benefit framework for evaluation. It applies the Difference-in-Differences (DID hereafter) method to assess the causal impact of HtB across a range of financial metrics. The counterfactual analysis builds on a quasi-natural experiment where certain new home developers, never registered for the HtB scheme, form a control group. This allows for a comparison of outcome changes before and after the policy intervention between the treatment group (HtB participants) and the control group (non-HtB participants) over the same period. By evaluating the difference in these changes, the DID method accounts for constant differences between the groups, allowing us to accurately measure the policy's impact, free from interference by unrelated factors.

The analysis begins by examining the HtB programme's effect on developer profitability. The DID results suggest the HtB programme brings about an overall increase in costs such as sales costs, administrative expenses, and wage costs, along with rises in revenue markers like inventory and sales. The HtB enables participating developers to achieve higher gross profits, profit before and after profit, and return on capital employed (ROCE) compared to non-participants, leading to shifts in firms' structures with increases in total assets, and equity. Notably, the growth in equity surpasses that of liabilities, suggesting that the policy has enhanced stakeholders' overall wealth and value. This goes against the backdrop of a general decline in capital productivity outlined in Chapter 3.

The second question explores the policy impact on marginal profitability, investigating whether increased profits result from selling more properties at the same margin or supplying fewer properties at a higher margin. This is achieved by comparing markups, which also serve as an indicator of market power. The DID study reveals that the markups in participant firms have decreased post-policy implementation. The decreased markup carries a significant implication that the HtB policy increases competition in the market. It boosts developers' profitability by facilitating them to supply and sell more properties to the market. The HtB scheme slightly erodes the market power of participating developers, yet it remains financially beneficial to them.

The third research question evaluates the HtB programme from a fixed capital investment perspective, offering a counterpoint to criticisms that assert the policy disproportionately benefits developers. The criticisms overlook the policy's role in enhancing financial efficiency related to fixed capital expenditure. I propose that the HtB introduces a stable and sustained demand increase, effectively lowering developers' adjustment costs associated with market uncertainty. This can significantly reduce firms' capital costs and enhances their marginal capital productivity. Meanwhile, the increased cash flow can provide additional funds for further investment and help alleviate the borrowing constraints faced by firms. This, in turn, reduces investment costs and leads to an increase in marginal capital productivity. The favourable financing and investment conditions enable increased capital investment, more property developments, and ultimately higher profitability for firms. Observing increased marginal productivity can be challenging, but this study provides a novel perspective by examining indicators such as increased capital stock, capital investment intensity, and debt-cash flow sensitivity.

Chapter 4 contributes to the existing literature by presenting a potential solution to the challenges associated with declining investment returns on fixed tangible assets. It demonstrates, from both theoretical and empirical perspectives, that a well-designed policy intervention can stimulate demand, enhance the financial performance of suppliers, and avoid exacerbating market inflation, thus creating a win-win scenario. Additionally, it introduces a systematic causal-based cost-benefit framework for evaluating the impact of credit expansion policies on providers. The conclusions drawn and the framework proposed in this chapter can serve as valuable tools for future studies evaluating similar policy interventions.

Chapter 2

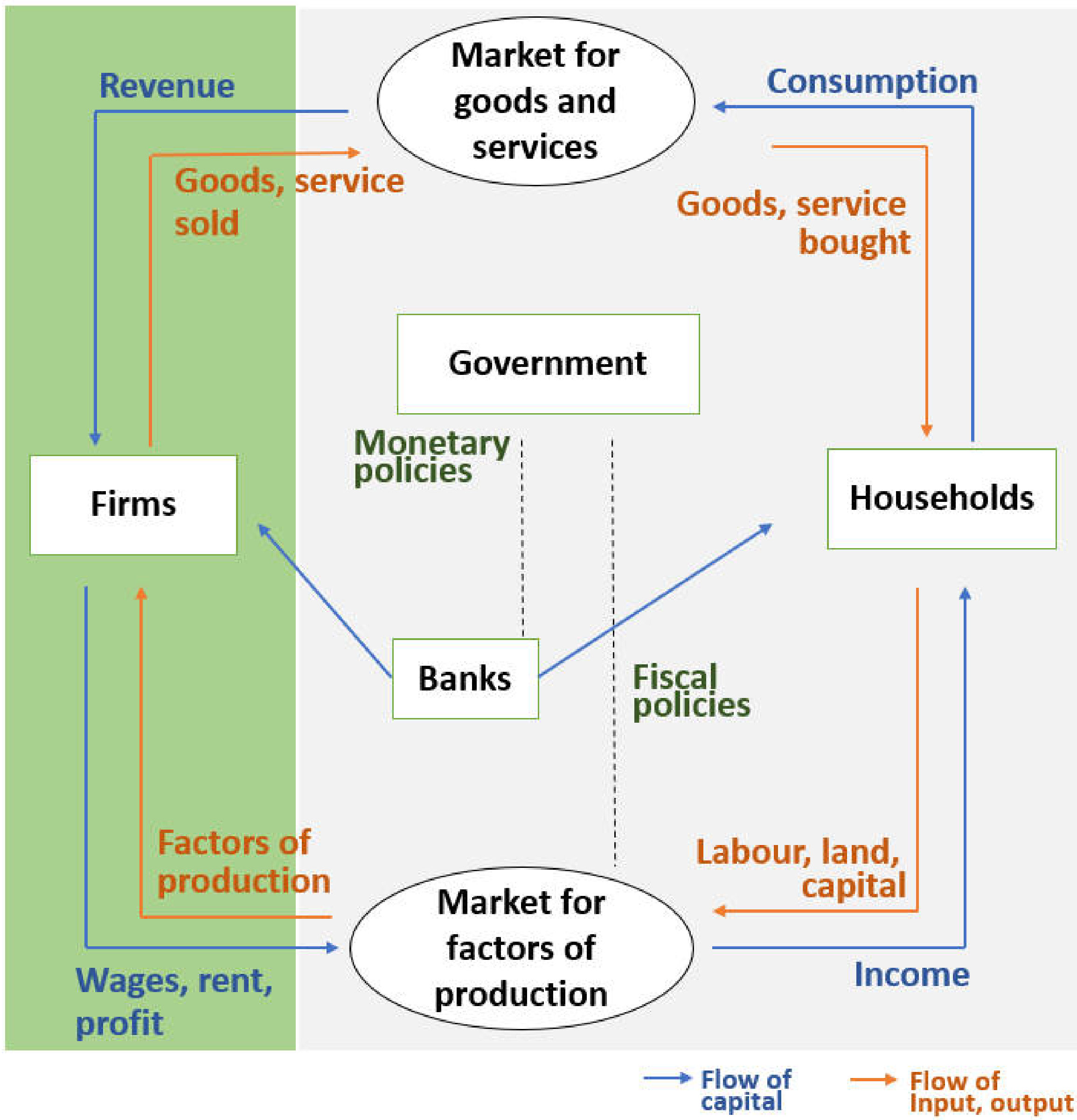
Neoclassic investment theory, production function and estimation

Modern investment theory development is inextricably linked with the application of general equilibrium models in macroeconomics. In the general equilibrium model framework, all economic actors - households, firms, and the government - are assumed to optimise their decisions based on their individual objectives and the information available to them. This thesis focuses on a major branch of investment theory, which underscores the optimal distribution of capital resources to maximise profitability. Guided by potential returns and risks, investment theory shapes decisions on asset acquisition, capital budgeting, and portfolio management, incorporating key concepts like the time value of money, risk-return tradeoff, and diversification.

This section revisits the relationship between the investment framework and the foundational studies of this thesis, demonstrating how the research questions posed in this thesis address existing gaps within this academic field. Furthermore, it positions this work within the broader context of financial and economic research.

2.1 Investment theory

Figure 2.1: A diagram of general equilibrium framework



The macroeconomic study is primarily concerned with addressing inquiries pertaining to a nation's wealth and production. These inquiries can be categorised into four main areas. (1) Determining the factors influencing a country's national income and the maximum output that domestic firms can generate. (2) Examining the distribution of profits derived from this output, particularly the division between wages for workers and retained earnings for companies. (3) Analysing the entities responsible for purchasing the output products, including the extent of household consumption, corporate investment, and government procurement. (4) Investigating the circumstances under which investments and consumption will reach equilibrium. Mankiw (2020) utilised a schematic flow chart to illustrate economic activities from firm to firm. This section expands upon this representation by adopting a more general equilibrium perspective, which incorporates the roles of government and banks. From this equilibrium standpoint, households receive income from various sources, allocate it towards taxes to the government, consumption of goods and services, and saving in banks or capital markets. The firm is the core agent that connects household activities and the output of the domestic economy. As depicted in the green region in Figure 2.1, a firm generates revenue by producing products or selling services and uses this revenue to pay for factors of production. Both households and firms may borrow from banks to make investments. Governments can use monetary and fiscal policies to influence the investment behaviour of market participants.

2.1.1 Neoclassical investment theory

This thesis concentrates on the firm's perspective within the general equilibrium framework. The primary aim is to construct investment models that illustrate the relationship between optimal capital levels and maximised output.

Effective allocation of capital investment resources is crucial for the survival and success of firms. On the one hand, excessive investment can lead to a waste of capital. Overproduction of products that exceed market demand poses a risk to a company's cash flow. Conversely, inadequate investment in materials and machinery can result in shortages and undersupply, which negatively impact a company's profitability (Jeanne and Michael 2000). The definition and measurement of optimal capital stock from a theoretical standpoint is essential for evaluating the ineffective investment in the empirical research presented in the subsequent chapters.

The Solow-Swan model, named after Robert Solow and Trevor Swan, has had a significant impact on the study of economic growth and has shaped the way economists approach macroeconomics as a whole (Solow 1956; Swan 1956)[1]. The Solow-Swan model uses a simple and abstract representation to show how the combination of capital and labour investment leads to production output, and how changes in consumption and population affect economic output over time. It is a dynamic general equilibrium model that can be formulated under either discrete or continuous time assumptions.

The Solow-Swan model has been influential in setting the direction for research in economic growth[2] and has served as the foundation for the neoclassical investment model, which provides a framework for studying a wide range of macroeconomic issues such as labour, income, taxes, and monetary policies through the Real Business Cycle approach. The neoclassical investment model is seen as a refined framework that incorporates the assumptions of consumer and corporate production function maximisation. The model includes a general equilibrium among representative firms, representative households, and the government[3].

This section reviews the model based on the discrete-time assumption and briefly discusses how it can be transformed into a continuous time representation and connected to other famous modern asset pricing frameworks. In terms of representative firms, the neoclassical model assumes that participants coordinate in a decentralised economy, and all the factors of the economic structure of labour, assets, and capital are

[1] Bob Solow was awarded the Nobel prize in 1987 for his contributions to this field.

[2] There are other works that study investment theories, such as the Harrod-Domar model. However, the Harrod-Domar model does not aggregate production measurements and is considered less attractive compared to the Solow-Swan model (Sato 1964). Another example is the Robinson Crusoe model, which is a central economy model named after the famous fictional character. It assumes the existence of representative agents, or central planners, who make consumption, production, and saving decisions for individuals. In this model, there is no economic structure or market, and all individuals automatically collaborate and coordinate (Grapard 1995). This model is also considered less comprehensive compared to the Solow-Swan or neoclassical model.

[3] The model that relates to household consumption and government budget planning can be read from (Acemoglu 2012; Gali 2015).

necessary. The representative firm will optimise its profitability dynamically based on budget constraints. More specifically, a firm operating in a competitive economy may have a Cobb-Douglas production function that

$$Y_t = K_t^{\alpha} \left(A_t L_t\right)^{1-\alpha} \qquad \text{with } 0 < \alpha < 1 \tag{2.1}$$

The Y_t denotes the output, K_t denotes the capital stock, A_t denotes the production constant and L_t is the labour stock. It is also assumed that the capital increases according to the following form that

$$K_{t+1} = (1-\delta)K_t + I_t \qquad \text{with } 0 < \delta < 1 \tag{2.2}$$

The I_t denotes the real assets investment in each period, and the δ represents the rate of depreciation. This means that the difference between the levels of capital in two periods is determined by the investment and depreciation that occurred between those periods.

The profit of a firm's production is the difference between aggregate output, labour cost, and capital expenditure that

$$\begin{aligned} P_t &= Y_t - w_t L_t - I_t \\ &= K_t^{\alpha} \left(A_t L_t\right)^{1-\alpha} - w_t L_t - I_t \end{aligned} \tag{2.3}$$

The P_t stands for output[4], and the w_t is the real wage rate. Therefore, the value of the firm can be derived from the discounted net present value form that

$$\begin{aligned} V_t &= \sum_{s=t}^{\infty} \left(\prod_{s'=t+1}^{s} \frac{1}{1+r'_s} \right) P_s \\ &= P_t + \frac{1}{1+r_{t+1}} P_{t+1} + \frac{1}{1+r_{r+1}} \frac{1}{1+r_{r+2}} P_{t+2} \cdots \end{aligned} \tag{2.4}$$

[4]In corporate finance studies, they can represent profit or value-added.

As we are interested in how a firm should plan its capital resources, the goal is to maximise the value function subject to the value of the real asset level. Using equations (2.1) and (2.3) the target function is derived as

$$
\begin{aligned}
V(K_t) &= \max_{L_t, I_t} \left(P_t + \frac{1}{1+r} V(K_{t+1}) \right) \\
&= \max_{L_t, I_t} \left(K_t^{\alpha} (A_t L_t)^{1-\alpha} - w_t L_t - I_t + \frac{1}{1+r} V(K_{t+1}) \right)
\end{aligned}
\tag{2.5}
$$

The Bellman equation is set up with the L_t, I_t as control variables, and equations (2.1) and (2.2) as the first-order condition. This results in

$$
\begin{aligned}
(1-\alpha) K_t^{\alpha} A_t^{1-\alpha} L_t^{-\alpha} - w_t &= 0 \\
\text{and} \\
\frac{1}{1+r_{t+1}} \frac{\partial V(K_{t+1})}{\partial K_{t+1}} &= 1
\end{aligned}
\tag{2.6}
$$

It can be derived[5]

$$
\begin{aligned}
\frac{\partial V(K_t)}{\partial K_t} &= \alpha K_t^{\alpha-1} (A_t L_t)^{1-\alpha} + \frac{1}{1+r_{t+1}} \frac{\partial V(K_{t+1})}{\partial K_{t+1}} \frac{\partial K_{t+1}}{\partial K_t} \\
&= \alpha K_t^{\alpha-1} (A_t L_t)^{1-\alpha} + \frac{1}{1+r_{t+1}} V'(K_{t+1})(1-\delta)
\end{aligned}
\tag{2.7}
$$

Hence the derivative form of K_{t+1} can be derived from equation (2.6). Substituting it into equation (2.7) results in

$$
\begin{aligned}
V'(K_t) &= \alpha K_t^{\alpha-1} (A_t L_t)^{1-\alpha} + \frac{1}{1+r_{t+1}} V'(K_{t+1})(1-\delta) \\
&= \alpha K_t^{\alpha-1} (A_t L_t)^{1-\alpha} + \frac{1}{1+r_{t+1}} 1 + r_{t+1}(1-\delta) \\
&= \alpha K_t^{\alpha-1} (A_t L_t)^{1-\alpha} + (1-\delta)
\end{aligned}
\tag{2.8}
$$

[5]This is derived based on Benveniste-Scheinkman envelope theorem that $V'(x_t) = F_x(x_t, y_t) + \beta V'(G(x_t, y_t)) G_x(x_t, y_t)$.

Equation (2.8) applies to both the t and $t+1$ periods. So using the first-order condition derived for I_t produces

$$\begin{aligned} -1+\frac{1}{1+r_{t+1}}\left[\alpha K_{t+1}^{\alpha-1}\left(A_{t+1}L_{t+1}\right)^{1-\alpha}+(1-\delta)\right]=0 \\ \alpha K_{t+1}^{\alpha-1}\left(A_{t+1}L_{t+1}\right)^{1-\alpha}+(1-\delta)=1+r_{t+1} \end{aligned} \tag{2.9}$$

Combining this with the first-order condition derived for L_t in equation (2.6), the marginal capital and marginal labour stock can be expressed as

$$\begin{aligned} \alpha\frac{Y_t}{K_t} &= r_t+\delta \\ (1-\alpha)\frac{Y_t}{L_t} &= w_t \end{aligned} \tag{2.10}$$

In the framework of a competitive economic environment, two fundamental conditions hold sway: firstly, the equilibrium condition wherein the marginal product of labour equals the marginal cost of labour; and secondly, the equilibrium condition whereby the marginal product of capital equates to the marginal cost of capital. The cost of labour is the real wage rate, and the costs of capital are the interest rate r and the depreciation rate δ. In the manufacturing industry, this typically refers to machinery rental or purchase with depreciation and other financing costs.

The above expression shows the net output that satisfies the first-order condition

$$\begin{aligned} P_t &= Y_t-w_tL_t-I_t \\ &= Y_t-(1-\alpha)\frac{Y_t}{L_t}L_t-I_t \\ &= Y_t-(1-\alpha)Y_t-I_t \\ &= \alpha Y_t-I_t \\ &= K_t\left(r_t+\delta\right)-\left(K_{t+1}-(1-\delta)K_t\right) \\ &= K_tr_t+K_t\delta-\left(K_{t+1}-K_t+K_t\delta\right) \\ &= K_tr_t+K_t\delta-K_{t+1}+K_t-K_t\delta \\ &= \left(1+r_t\right)K_t-K_{t+1} \end{aligned} \tag{2.11}$$

Substituting back to into equation (2.4) allows us to determine the equilibrium capital level for companies that

$$
\begin{aligned}
V_t &= (1+r_t) K_t - K_{t+1} + \frac{(1+r_{t+1}) K_{t+1} - K_{t+2}}{1+r_{t+1}} + \frac{(1+r_{t+2}) K_{t+2} - K_{t+3}}{(1+r_{t+1})(1+r_{t+2})} + \cdots \\
&= (1+r_t) K_t - K_{t+1} + K_{t+1} - \frac{K_{t+2}}{1+r_{t+1}} + \frac{K_{t+2}}{1+r_{t+1}} - \frac{K_{t+3}}{(1+r_{t+1})(1+r_{t+2})} \cdots \\
&= K (1+r_t)
\end{aligned}
\tag{2.12}
$$

Using the above equation, we have developed a model for optimal capital planning. This model, based on the neoclassical approach, describes the optimal capital level in the equilibrium state. It emphasises two key factors: output and the cost of capital. As the equation shows, a higher output goal generally requires a greater investment in real assets, but a higher cost of capital decreases the demand for capital investment. The cost of capital in the production process can present in two ways: the rental expense associated with machinery, and the opportunity cost of forgone interest earnings from risk-free investments.

The above revision encapsulates the essence of the first phase of theoretical development. This stage of the theory was primarily developed by economists in the early 1960s, as epitomized by the work of Jorgensen (Jorgenson 1963; Jorgenson and Stephenson 1969a,b). The framework has inspired a number of empirical studies to examine its conclusion, where two main criticisms arise. The first is that the model assumes that investments are made in a single period, which is unrealistic in practice, as companies often invest in real assets over multiple periods until they reach the desired level (Eisner 1960). The second criticism pertains to the model's disregard for adjustment costs and irreversible investments, both of which are commonly observed in empirical capital management practices (Doms and Dunne 1998).

2.1.2 The Q theory

The second criticism takes center stage in the discussions, with sunk costs and irreversible investments becoming the primary research focus. It sparks debates that defined the second and third phases of investment theory development. Tobin's leading work (Tobin 1969) marks the beginning of the second phase of investment theory development, proposing a more generalised model that addresses the sunk cost issue. Although rudimentary, Tobin's model, known as the Q theory, laid the groundwork for subsequent research. In the following studies, significant contributions refining the Q model are made by Yoshikawa (1980), Hayashi (1982), and Abel (1983). The improved model introduces a cost function accounting for adjustment costs and also assumes optimal investment decisions are based not on past information, but on expectations of future market conditions. This is achieved by introducing probability distributions with a leading fashion to measure investment uncertainty. This framework for the first time creates a link between theoretical investment models and empirical financial markets. This connection more accurately captures how firm managers base their investment plans on expectations of changes in sales or stock trends.

The third phase of investment theory development focuses on addressing the issues associated with irreversible investments. Irreversible investments refer to capital allocation decisions that, once made, cannot easily be reversed or altered without incurring significant costs. This aspect is particularly relevant in industries requiring investments in large-scale projects or specialised equipment. These investments often involve a significant amount of resources, such as money, time, and effort, and are typically made with a long-term horizon. Examples of irreversible investments include purchasing land or buildings, constructing a factory, or installing expensive machinery. Emphasising the importance of accurate forecasting and prudent decision-making, the notion of irreversibility reflects the potential for substantial sunk costs and financial losses due to misguided decisions.

The study of irreversible investments traces its roots to the work of Arrow and his colleagues in 1970 (Arrow and Kurz 1970). Significant strides in the field are made by McDonald and Siegel (1986; 1985), who develop a comprehensive improved framework that considers investment timing, commodity price uncertainty, and the decision to shut down operations due to long-term uncertainty. The model adopts a Wiener process-based approach, linking macroeconomic investment with micro asset pricing research for the first time. This work marks a turning point in the field's development, establishing the framework as a fundamental concept in investment theory. The model successfully overcomes major obstacles, solidifying its position as a cornerstone in the field that maintains its relevance to this day.

The enhanced model posits that investment is defined as a significant expenditure made for the acquisition of real assets and plant equipment, which are intended for long-term use and are irreversible. The existence of sunk cost makes it impossible for firm managers to complete investments in a single accounting period. However, it is important to note that in the long-term production process, investment opportunities do not expire even if the investment is not made all at once, which is an assumption that is often overlooked when considering one-off investments. Investors may choose to wait during the decision-making period in order to find better timing for their investments. But prolonged waiting and observing can also lead to missed opportunities. As a result, determining when and how to invest becomes a key research question and the focus of efforts to improve models. This includes studying dynamic stochastic equilibrium and optimal adjustment choices for decision-making, which is commonly referred to as the study of convex adjustment cost and lumpy investment. The impact of lumpy investment propositions continues to be a topic of discussion today (Bloom et al. 2018; Doms and Dunne 1998; Gutiérrez and Philippon 2016). During this process, economists identify major factors that can influence the decision to make an irreversible investment. It includes the expected future demand for the product or service being produced, the availability of resources, and the level of competition in the market. In addition, the level of uncertainty about future conditions, such as changes in technology or market demand, can also play a role in the decision to make an irreversible investment.

The improved framework provides strong theoretical support for financial and economic studies (including this thesis) that use corporate finance data to examine whether a firm's investment plan has been optimal under current market conditions. In this section, the second and third phases of investment theory development are reviewed together.

Following the previous notation settings, the production function is denoted as $Y_t = F(K_t, L_t)$ where F is a continuous and differentiable convexity function. The cost function of adjusting real asset investments is denoted as $C_t(I_t, K_t)$ and it satisfies first and second-order conditions:

$$\frac{\partial \mathrm{C}\left(\mathrm{I_t}, \mathrm{k_t}\right)}{\partial \mathrm{I_t}} > 0 \tag{2.13}$$

and

$$\frac{\partial^2 \mathrm{C}\left(\mathrm{I_t}, \mathrm{k_t}\right)}{\partial \mathrm{I_t^2}} > 0 \tag{2.14}$$

The adjustment cost function is a convex, quadratic, continuous, and differentiable function with respect to investment I_t. It is strictly increasing, meaning that the more real capital that is invested, the higher the cost will be, and the marginal cost also increases with the increase in investment[6]. This implies that if a large amount of investment is made all at once, the adjustment cost will also increase significantly, so it is more beneficial to distribute investment over several periods. If denoting the investment as $\mathrm{u_t I_t}$ where $\mathrm{u_t}$ is the marginal price rate of capital investment, the net

[6]The presence of adjustment costs is notable and provides the foundation for the study in Chapter 4. Doms and Dunne (1998) examine investment patterns from over 13,700 manufacturing companies in the US and found that a large number of companies alter their investment in a lumpy manner, which results in a significant amount of adjustment cost. The magnitudes of these costs show high levels of heterogeneity across different types of plants.

output of the firm can be expressed as

$$\mathrm{P_t = F\left(K_t, L_t\right) - w_t L_t - u_t I_t - C\left(I_t, K_t\right)} \tag{2.15}$$

A continuous discount function $\mathrm{D(t,s)} = \exp\left[-\int_t^s \mathrm{r}_\tau \mathrm{d}\tau\right]$ is used to calculate the accumulated net present value, and the firm's optimisation target function at time t is

$$\mathrm{V_t} = \max \int_{\tau=t}^{\tau=\infty} \mathrm{P}_\tau \mathrm{D}(\tau)\mathrm{d}\tau \tag{2.16}$$

The capital constraint is that the marginal change in capital stock corresponds precisely to the disparity between investment and depreciation rates that

$$\frac{\mathrm{dK_t}}{\mathrm{dt}} = \mathrm{I_t} - \delta \mathrm{K_t} \tag{2.17}$$

Based on the above assumptions, the Hamilton function is written as follows

$$\begin{aligned} \mathrm{H_t} &= \mathrm{P_t} + \mathrm{q_t}\frac{\mathrm{dK_t}}{\mathrm{dt}} \\ &= \mathrm{F\left(K_t, L_t\right) - w_t L_t - u_t I_t - C\left(I_t, K_t\right) + q_t\left(I_t - \delta k_t\right)} \end{aligned} \tag{2.18}$$

And the first-order conditions of optimisation are

$$\frac{\partial \mathrm{F\left(K_t, L_t\right)}}{\partial \mathrm{L_t}} = \mathrm{w_t} \tag{2.19}$$

$$\mathrm{u_t} + \frac{\partial \mathrm{C\left(I_t, K_t\right)}}{\partial \mathrm{I_t}} = \mathrm{q_t} \tag{2.20}$$

$$-\frac{\partial \mathrm{H}}{\partial \mathrm{K_t}} = \frac{\mathrm{dq_t}}{\mathrm{dt}} - \mathrm{r_t q_t} \tag{2.21}$$

The equation (2.19) assumes that the optimal marginal level of labour employment equals the real marginal wage rate, and the equation (2.20) assumes that the optimal capital stock equals the shadow price of capital minus the marginal adjustment cost. The shadow price of capital is $\mathrm{q_t}$, which represents the scarcity or real value of a certain type of capital and is often used to measure the value of tangible or intangible assets[7] Taking the derivative of the Hamilton function helps in understanding the shadow function. When we substitute it into equation (2.21), it results in a first-order linear equation that

$$\frac{\mathrm{dq_t}}{\mathrm{dt}} = (\mathrm{r_t} + \delta)\,\mathrm{q_t} - \mathrm{F}'_{\mathrm{K}}(\mathrm{K_t}, \mathrm{L_t}) + \mathrm{C}'_{\mathrm{K}}(\mathrm{I_t}, \mathrm{K_t}) \tag{2.22}$$

The solution of the linear equation is

$$\mathrm{q_t} = \int_{\tau=t}^{\tau=\infty} \left[\mathrm{F'_K}(\mathrm{K}_\tau, \mathrm{L}_\tau) - \mathrm{C}'_{\mathrm{K}}(\mathrm{I}_\tau, \mathrm{K}_\tau)\right] \mathrm{D(t,s)}\mathrm{e}^{-\delta(\tau-\mathrm{t})}\mathrm{d}\tau \tag{2.23}$$

The above result shows that $\mathrm{F'_K}$ is the marginal output of capital, and $\mathrm{C'_K}$ is the marginal adjustment cost of capital investment. The net difference represents the net profit (i.e. net marginal productivity) of a capital investment, and this shadow price is the discounted accumulated net profit of the capital investment. If one further examines the adjustment cost function and assumes it has the following form:

$$\mathrm{C}(\mathrm{I_t}, \mathrm{K_t}) = \mathrm{g}\left(\frac{\mathrm{dK_t}}{\mathrm{dt}}\right) = \mathrm{g}(\mathrm{I_t} - \delta \mathrm{k_t}) \tag{2.24}$$

Assuming that the function $g(0) = 0$ and that its first and second-order derivatives are increasing functions. Substituting this into equation (2.20) will get

[7]For example, consider a company that uses a certain investment to produce a product, and the constraint on capital supply is $I < 10$. If we calculate the maximum output under the constraint $I < 10$ as $P = 100$, and then relax the constraint to $I < 11$, resulting in an output of $P = 110$, the additional 10 units of output represent the shadow price of capital.

$$g'(I_t - \delta K_t) = q_t - u_t \tag{2.25}$$

If denoting $G(\bullet)$ as the inverse function of $g'(\bullet)$. With $G(\bullet) = g'^{-1}(\bullet)$ and $G'(\bullet) > 0, G'(0) = 0$, it produces

$$I_t - \delta K_t = G(q_t - u_t) \tag{2.26}$$

Equation (2.26) is the key conclusion of the Q theory. It shows that the optimal net investment should be a strictly increasing function of the shadow price of capital. The higher the shadow price q_t is, the more capital should be invested.

Understanding how the shadow price changes empirically can significantly help to make more efficient investment decisions. This can be linked to the capital market, where we can observe the additional output brought by the potential relaxation of marginal investment constraints from stock market. The metric of Tobin's Q is developed based on this notion. It is a commonly used index in the financial market, computed as the ratio of a physical asset's market value to its replacement value. A company should invest when Tobin's Q is greater than 1, as this indicates that the market value reflects underestimated value or potential profitability for the firm. On the other hand, if Tobin's Q is less than 1, the stock of a firm may be underestimated. A new equilibrium can be established by attracting more investors to boost its stock price or by the firm gaining more profit by selling its capital stock. This application essentially reflects the nature of Equation (2.26).

Soon after the establishment of the Q model and Tobin's Q, numerous empirical researchers began utilising microeconomic data to study investment behaviour. This included further theoretical extensions regarding adjustment costs, lumpy investments, and other related factors (Doms and Dunne 1998). In practice, Tobin's Q, despite being a compelling index for understanding the asset market, does not completely align with the conclusions drawn from the Q equation. Tobin's Q is calculated using value extracted from financial reports, with the replacement cost being measured by real assets or similar metrics. It is an average Q calculated by $q_t = V_t / (u_t K_t)$ while the shadow price defined in the equation (2.26) measures the marginal productivity brought by a marginal unit of capital investment. In practice, measuring the marginal investment return for newly produced commodities is quite challenging. Therefore, researchers have often resorted to using average Q as an alternative to theoretical Q.

Researchers have also shown that average Q is not a good metric for testing the financial market's investment behaviour (Abel and Blanchard 1986; Blanchard and Wyplosz 1981). Abel and Blanchard (1986) use a representative dataset and a direct measure of marginal Q to test the explanatory ability of the investment model and find that these measurements of Q do not explain investment behaviour very well.

The investment-cash flow sensitivity hypothesis has provided a widely accepted explanation for the poor performance of average Q in empirical studies. According to Fazzari et al. (1987), financial constraints exist for firms at all levels. They often cannot finance as much as they would like due to various reasons, even if they have very promising expected capital returns (i.e. high shadow price). Financing from internal sources is often easier than from external sources due to market frictions such as asymmetric information and agent costs. These factors make it difficult for firms to adjust their capital to the desired level in each operational period. Fazzari et al. (1987) analyse the investment-cash flow coefficients of a broad sample of American manufacturing firms. They categorise firms based on their internal cash flow levels and find that marginal productivity (i.e., Tobin's Q) is not the only explanatory variable guiding investment. Firms tend to invest more when they have greater internal cash flows, even after controlling for marginal costs. Therefore, in addition to Tobin's Q, cash flow can also influence investment. They view this sensitivity as an indicator of the financial constraints faced by firms, and this idea has inspired ongoing discussions to this day. This discovery concerning optimal capital and mismeasured Q inspires subsequent discussions in this thesis.

2.1.3 Measuring marginal productivity - a new method

Marginal productivity is crucial in investment studies, as it also serves as a key explanatory or control variable in investment analysis. While company managers may be able to observe marginal productivity during the production process, it cannot be easily measured using financial report data. This situation presents a substantial challenge for empirical investment studies as they rely on the accurate measurement of marginal Q as a primary or control variable. The possibility of a mismeasured Q has instigated considerable debate and has challenged the conclusions proposed on this basis (Fazzari et al. 1987; Jason and Jenny 2012).

This research proposes that a newly devised production-based markup, intended to assess a company's market power, can function as a reliable indicator to estimate marginal Q. This proposition originates in the field of industrial organisation research, where one of the primary areas of interest is estimating the production function and exploring its relationship with market assumptions, price changes, marginal profitability, and input-output elasticity. The method was proposed by De Loecker et al. (2016). Traditionally, the markup calculation relied heavily on the demand data, which not only required strong assumptions but was also difficult to obtain. This novel method doesn't necessitate presumptions about the market structure or demand curves confronting firms, nor assumptions about how firms distribute their inputs across different products[8]. This enables us to estimate markup from production data, which is readily available in financial reports. This new method offers more flexibility in accurately measuring marginal productivity, proving especially beneficial for research involving unquoted firms[9].

I will provide a brief introduction to the model and its key assumptions, with notations following the work of De Loecker et al. (2020). Suppose there is an economy with

[8]For more theoretical discussions and applications, refer to De Loecker et al. (2016).

[9]While publicly listed firms have Tobin's Q for measuring average productivity - serving as a suboptimal metric - this does not apply to unquoted firms.

N firms, indexed by $i = 1...N$. We assume a common notion of the Cobb-Douglas production function. It is also assumed that firms possess heterogeneous productivity and technology in their production functions, denoted as Ω_{it} and Q_{it}. Furthermore, we postulate that technology is a function of input such that

$$Q_{it} = Q_{it}\left(\Omega_{it}, \boldsymbol{V}_{it}, K_{it}\right) \tag{2.27}$$

The $\boldsymbol{V} = \left(V^1, \ldots, V^J\right)$ is a vector of production input variables (consisting of labour, materials, intermediate inputs, etc.). K_{it} is the capital stock. We assume that input prices are exogenously given, implying that these prices are not influenced by variable factors such as quantity demanded, bargaining power, etc. The goal of the firm's production planning is to minimise the Lagrangian objective cost function that:

$$\mathcal{L}\left(V_{i,t}, K_{i,t}, \lambda_{i,t}\right) = P_{i,t}^V V_{i,t} + r_{i,t}K_{i,t} + F_{i,t} - \lambda_{i,t}\left(Q(\cdot) - \bar{Q}_{i,t}\right), \tag{2.28}$$

P^V is the vector of the input prices. r denotes the capital cost of user, and F denotes the fixed capital costs. The λ is the Lagrange multiplier, which also represents the marginal input-output elasticity in optimal capital structure studies. It is assumed that this function dynamically adjusts each year. All other variables can be adjusted without incurring additional costs, but capital investment is associated with adjustment costs and other frictions. The above model setting is consistent with the key assumption of our research in other sections. Taking the first-order condition with respect to the input variable V as:

$$\frac{\partial \mathcal{L}_{i,t}}{\partial V_{i,t}} = P_{i,t}^V - \lambda_{i,t}\frac{\partial Q(.)}{\partial V_{i,t}} = 0 \tag{2.29}$$

Rearranging the the above function with $\frac{\partial Q(.)}{\partial V_{i,t}}$ on the left hand side and multiplying by $\frac{V_{i,t}}{Q_{i,t}}$ produces:

$$\frac{\partial Q(.)}{\partial V_{i,t}} \frac{V_{i,t}}{Q_{i,t}} = \frac{1}{\lambda_{i,t}} \frac{P^V_{i,t} V_{i,t}}{Q_{i,t}} \tag{2.30}$$

Now the left-hand side of the function $\frac{\partial Q(.)}{\partial Q_{i,t}} \frac{\partial V_{i,t}}{V_{i,t}}$ is the expression of the elasticity of bundle input, which can be denoted as $\theta^v_{i,t}$. According to the definition, the markup of a firm is $\mu \equiv \frac{P_{i,t}}{\lambda_{i,t}}$, where the $P_{i,t}$ is the price of the output. Substituting the expression of $\lambda_{i,t}$ in the equation (2.30) lead to the expression for markup:

$$\mu_{i,t} = \theta^v_{i,t} \frac{P_{i,t} Q_{i,t}}{P^V_{i,t} V_{i,t}} \tag{2.31}$$

The production quantity-based method for calculating markup does not necessitate the same assumptions as the accounting approach (for further details, refer to De Loecker et al. (2016)). However, it still assumes a first-order constraint on at least one of the input bundles. Understanding this difference is crucial for interpreting the results presented later at the firm level. The trend in markup does not necessarily synchronise with changes at the accounting level.

The function 2.31 indicates that markup is computed by calculating two components: the share of aggregate input in relation to revenue $\frac{P_{i,t} Q_{i,t}}{P^V_{i,t} V_{i,t}}$, and the output elasticity of variable input $\theta^v_{i,t}$. Obtaining the output elasticity $\theta^v_{i,t}$ requires estimating the production function, a task acknowledged to be challenging (Van Beveren 2012; Van Biesebroeck 2007). I introduce three influential methods used in estimating the production function: the Olley and Pakes (1992) (OP hereafter) method, the Levinsohn and Petrin (2003) (LP hereafter) method, and the Ackerberg et al. (2006; 2015) (ACF hereafter) method. The estimated markup, obtained through these methods, will be applied in the subsequent chapters of this thesis, hence I also briefly introduce the specific metrics employed for each variable.

Consider the log-linear form of the Cobb-Douglass production function,

$$y_{i,t} = a_0 + a_k k_{i,t} + a_l l_{i,t} + \omega_{i,t} + \epsilon_{i,t}, \tag{2.32}$$

where $y_{i,t}$ denotes the natural logarithm of the value-added output of firm i at time t, $k_{i,t}$ denotes the natural logarithm of invested capital, and $l_{i,t}$ denotes the natural logarithm of the company's labour input. The technical efficiency effect is captured by the items $a_0 + \omega_{i,t} + \epsilon_{i,t}$. It is commonly assumed that $\omega_{i,t}$ represents an unobserved productivity dynamic known to the firm but not observable to us. This term is interchangeably referred to as TFP or unobservable technical efficiency. a_0 represents the mean efficiency across all firms, and $\epsilon_{i,t}$ represents a random error or productivity shock that is not observable by firms before investment decisions are made.

The basic assumption regarding the input variables is that the firm chooses the levels of $k_{i,t}$ and $l_{i,t}$ to maximise its profitability, with capital and labour inputs positively influenced by the firm's internal technical efficiency $\omega_{i,t}$. However, estimating equation (2.32) with the least square estimator leads to biased results due to endogeneity. Previous studies attempted to address the endogeneity issue by using a fixed effect model, but this approach requires the strong assumption of a constant $\omega_{i,t}$, which is often considered inconsistent with actual production processes where productivity changes heterogeneously between firms and dynamically over time (Kim et al. 2007).

The first method for estimating production function is proposed by Olley and Pakes (1992). The OP estimation assumes that the firm can observe the TFP during production and adjusts its investment in capital accordingly. The inverse investment function can then be expressed as an explicit function of investment, capital stock, and other control variables. Labour is assumed to be invested in the previous period $t-1$, while the level of the free variable $\omega_{i,t}$ is determined after the shock $u_{i,t}$ occurs. The unobservable technical efficiency parameter $\omega_{i,t}$ is assumed to be a first-order Markov process that

$$\mathbf{E}(\omega_{i,t}|\omega_{i,t-1}) + u_{i,t} = g(\omega_{i,t-1}) + u_{i,t}, \tag{2.33}$$

In this model, capital invested serves as a state variable, while other lagged free variables are represented by $\omega_{i,t-1}$. The random shock $u_{i,t}$ is assumed to be independent of all other terms. The non-labour TFP is calculated from the residual by substituting (2.33) in (2.32), which produces that

$$y_{i,t} - \hat{a}_l l_{i,t} = a_k k_{i,t} + g(\hat{\phi}_{i,t-1}(i_{i,t-1}, k_{i,t-1}) - a_0 - a_k k_{i,t-1}) + u_{i,t} + \epsilon_{i,t}, \tag{2.34}$$

The $\phi(.)$ function is utilised to regulate sample selection bias in coefficient estimation. The coefficients are estimated in a two-step process: in the first step, consistent labour estimates are produced by controlling other terms with a polynomial expansion of the explicit function. In the second step, equation (2.34) is estimated with the $g(.)$ function typically left without a specific economic explanation and approximated by an n^{th} order polynomial. The combination of these two steps results in consistent estimates of the parameters.

The second method is an improved estimator developed by Levinsohn and Petrin (2003). The estimation of OP is criticised for being potentially biased due to the presence of a non-monotonic linear relationship between capital investment and productivity. This is a cause for concern, particularly when analysing developing countries where a significant portion of the sample for the capital investment proxy has negative values. Levinsohn and Petrin (2003) propose that, under certain conditions, intermediate inputs measured by other metrics such as fuel, water, electricity or materials can serve as better proxies for productivity. There are three advantages to using these metrics: first, most of the inputs will be positive numbers; second, adjustment of these intermediate inputs is more nimble than capital investment and is, therefore, more responsive to productivity shocks; and third, these proxies are not state variables, making them more congruent with economic interpretation. Therefore, we can substitute $k_{i,t}$ with $m_{i,t}$ in equation (2.32) and estimate based on equation (2.35).

$$
\begin{aligned}
y_{i,t} - \hat{a}_l l_{i,t} = {} & a_k k_{i,t} + a_m m_{i,t} + g(\hat{\phi}_{i,t-1}(m_{i,t-1}, k_{i,t-1}) - a_0 - a_k k_{i,t-1} - a_m m_{i,t-1}) \\
& + u_{i,t} + \epsilon_{i,t},
\end{aligned}
\tag{2.35}
$$

The rest estimation details are the same as the OP method.

The third method for estimating production function is proposed by Ackerberg et al. (2006; 2015). They review the OP and LP methods and suggest that such estimations assume that labour or intermediate input investment operates as a non-dynamic investment and must be independent of productivity, which is considered too strong an assumption in some empirical contexts. The variables can be expressed as functions of capital investment and productivity shock in these circumstances. However, this may lead to collinearity and identification issues when plugged into the log-production function. ACF propose that this issue can be addressed by assuming that the company chooses labour at the end of the $t-1$ period (i.e., before capital investment) and then makes intermediate inputs at time t. This means that the intermediate input function can be expressed as $m_{i,t} = m(\omega_{i,t}, k_{i,t}, l_{i,t})$. With the strict assumption of monotonicity for both m and $\omega_{i,t}$, the intermediate input function is invertible and can be solved in the first stage as:

$$
y_{i,t} = a_0 + a_k k_{i,t} + a_l l_{i,t} + \omega(k_{i,t}, l_{i,t}, m_{i,t}) + \epsilon_{i,t}, \tag{2.36}
$$

In the first stage, equation (2.36) is estimated using a non-parametric polynomial form to obtain an estimate of productivity $\omega_{i,t}$. In the second stage, the Markovian nature of the production function is estimated by estimating the productivity residual. A more accurate estimate for capital, labour, and intermediate inputs can be achieved by utilising orthogonal assumptions as moment conditions.

In using specific metrics for each variable, this thesis follows some of the choices from the existing work of Bournakis and Mallick (2018), which estimates production functions using the same database as this research. The y is value-added, measured by the natural logarithm of turnover minus the cost of sales. The capital stock level, k, is measured by taking the natural logarithm of the book value of fixed tangible assets. Labour, l, is measured by taking the natural logarithm of the number of employees. In estimating TFP_{OP}, the natural logarithm of the change in fixed tangible assets is used to measure capital investment. Studies have used extrapolation or imputation to address missing data, but this study chooses to sacrifice a year of information for the accuracy of original records as of Bournakis and Mallick (2018). To estimate TFP_{LP}, the natural logarithm of the cost of sales is used as state variables, as this is the fundamental difference between the two methods. To estimate TFP_{ACF}, the variables used by De Loecker et al. (2020) are adopted. In the study, the state variable is measured by the cost of sales as marginal cost, and the proxy variable is measured by administrative expenditure, which is overhead cost and includes expenditures that are not directly related to marginal cost but still change in short- and medium-term demand shocks. All financial variables are appropriately deflated using suitable deflators.

2.1.4 Theoretical model for Chapter 4

This section provides a brief introduction to an implication extended from the Q theory, which serves as the theoretical foundation for Chapter 4, where the impact of policy on a firm's profitability is measured. The theory outlined below shows that an increase in productivity can lead to an increase in the firm's revenue. Therefore, when measuring the impact of a policy, it's important to take into account its effect on productivity, or the supply side boost. A firm's value is determined by demand shifts and heterogeneous productivity.

Based on a stochastic based framework proposed by Foster et al. (2008), this study measures the policy impact on supply-side revenue effects. This study adopts a simplified version of the revenue function that: assumes P_t represents output, as before, but P_t now follows a random walk process with equal probabilities of going up or down:

$$\mathrm{P_{t+1}} = \begin{cases} \mathrm{P_t}(1+\eta) \\ \mathrm{P_t}(1-\eta) \end{cases} \tag{2.37}$$

The output random variable follows a marginal process, and the expected output is equal to the output of the previous term: $\mathrm{E}\left[\mathrm{P_{t+k}} \mid \mathrm{P_t}\right] = \mathrm{P_t}$ for $\mathrm{k} = 1, 2, 3....$ If denoting the discount factor as $\frac{1}{1+\rho}$, the discounted expected output can be expressed as

$$\sum_{\mathrm{k}=1}^{\infty} \frac{1}{(1+\rho)^{\mathrm{k}}} \mathrm{E}\left[\mathrm{P_{t+k}} \mid \mathrm{P_t}\right] = \mathrm{P_t} \sum_{\mathrm{k}=1}^{\infty} \frac{1}{(1+\rho)^{\mathrm{k}}} = \frac{\mathrm{P_t}}{\rho} \tag{2.38}$$

The optimal investment derived in the previous section states that managers should make an investment when the result above exceeds the capital cost K that $\mathrm{P_t}/\rho > \mathrm{K}$. The new setting allows for the assumption of a probability distribution that takes into account gains and losses in the waiting and observing process such that: if the investment return rate is positive (negative), we invest (do not invest). The net increase is therefore $\frac{1}{2}\eta \mathrm{P}_t + \frac{1}{2} \cdot 0 = \frac{1}{2}\eta \mathrm{P}_t$ so the net discounted profit from waiting is positive $\frac{1}{1+\rho} \cdot \frac{\eta \mathrm{P_f}}{2} > 0$ but only for a small magnitude. If P_t is significantly greater than $\rho\mathrm{K}$, then making an investment is still the optimal solution as derived in the Q theory model, because immediate investment is always the optimal solution in such circumstances. To further measure the uncertainty, the Bellman function is introduced that

$$\mathrm{V_0(P)} = \max \left\{ \mathrm{V_1(P)} - \mathrm{K}, \frac{1}{1+\rho} \mathrm{E}\left[\mathrm{V_0}\left(\mathrm{P'}\right) \mid \mathrm{P}\right] \right\} \tag{2.39}$$

To maximise the function, the firm needs to compare $\mathrm{V_0}$ the output of waiting and observing, with $\mathrm{V_1}$, the output of making an immediate investment in every period.

The solution to the model depends on the assumptions made for each period and can be found in (Pindyck 1990). This dynamic estimation model is the foundation of the error correction model and a general baseline model for estimating a company's investment.

This section advances upon the foundation, constructing a theoretical model for Chapter 4. Specifically, if assuming that the function G in equation (2.26) takes the form

$$\mathrm{G}\left(\mathrm{I}_t, \mathrm{K}_t\right) = \frac{\mathrm{g}}{2}\left[\frac{\mathrm{I}_t^2}{\mathrm{K}_t} - \mathrm{a}\right] \tag{2.40}$$

The g represents the adjustment cost, which is assumed to be convex as before, and increasing in $\frac{I}{K}$. The a is a constant parameter. Then the net output function can be written as:

$$\Pi_t\left(\mathrm{K}_t, \mathrm{I}_t\right) = \mathrm{p}_t\left[\mathrm{F}\left(\mathrm{K}_t\right) - \mathrm{G}\left(\mathrm{K}_t, \mathrm{I}_t\right)\right] - \mathrm{p}_t^k \mathrm{I}_t \tag{2.41}$$

where the p_t is the price of output and p_t^k is the price of capital investment. In a fully competitive market where all companies are assumed to be price takers, and the return to scale is constant, the optimal investment can be derived from equations (2.41) and equation (2.16) as

$$\left(\frac{\mathrm{I}}{\mathrm{K}}\right)_t = \mathrm{a} + \frac{1}{\mathrm{g}}\frac{\mathrm{p}_t^{\mathrm{k}}}{\mathrm{p}_t}\left[\frac{\mathrm{V}_t}{\mathrm{p}^{\mathrm{k}}(1-\delta)\mathrm{K}_{t-1}} - 1\right] = \mathrm{a} + \frac{1}{\mathrm{g}}\frac{\mathrm{p}_t^{\mathrm{k}}}{\mathrm{p}_t}\mathrm{q}_t \tag{2.42}$$

As defined previously, the q_t represents marginal Q. The result indicates that marginal Q (as a function of firm value) is the key determinant of investment. However, the challenge of measuring Q has led researchers to seek a better representation of this equation. If following the work of Foster et al. (2008) and defining the net output function as

$$\Pi_t = \frac{1}{4\gamma}\left(\phi_t - \phi_t^*\right)^2 \tag{2.43}$$

The γ represents the substitutability of the varieties function, which is assumed to be non-negative. The ϕ_t and ϕ_t^* denote the the profitability index and its threshold respectively, and the profitability index has the form of

$$\phi_t = \theta_t - \frac{\mathrm{w}_t}{\omega_t} \tag{2.44}$$

The θ_t denotes a demand shifter, and a firm's growth in profitability is positively determined by the demand shifter, i.e.

$$\frac{\partial \Pi_t}{\partial \theta_t} = \left(\frac{\partial \Pi_t}{\partial \phi_t}\right)\left(\frac{\partial \phi_t}{\partial \theta_t}\right) = \frac{1}{2\gamma}\left(\phi_t - \phi_t^*\right) > 0 \tag{2.45}$$

The ω denotes the company's productivity function and w denotes the company's input price for production. Therefore the quotient of w to ω measures the marginal cost of output. The company's profitability is positively determined by the productivity function and negatively determined by the input price function

$$\begin{aligned} \tfrac{\partial \Pi_t}{\partial \omega_t} &= \left(\tfrac{\partial \Pi_t}{\partial \phi_t}\right)\left(\tfrac{\partial \phi_t}{\partial \omega_t}\right) = \tfrac{1}{2\gamma}\left(\phi_t - \phi_t^*\right)\tfrac{w_t}{\omega_t^2} > 0 \\ \tfrac{\partial \Pi_t}{\partial w_t} &= \left(\tfrac{\partial \Pi_t}{\partial \phi_t}\right)\left(\tfrac{\partial \phi_t}{\partial w_t}\right) = -\tfrac{1}{2\gamma}\left(\phi_t - \phi_t^*\right)\tfrac{1}{\omega_t} < 0 \end{aligned} \tag{2.46}$$

And the equation 2.16 can be written as

$$\mathrm{V_t} = \max \int_{\tau=t}^{\tau=\infty} \tfrac{\beta^s}{4\gamma}\left(\phi_{\tau+s} - \phi_{\tau+s}^*\right)^2 \mathrm{D(t,s)d}\tau \tag{2.47}$$

By taking the partial derivative of the target function, we can see that the profit of a firm is positively determined by demand-shifter.

$$\begin{aligned} \tfrac{\partial V_t}{\partial \theta_{t+s}} &= \left(\tfrac{\partial V_t}{\partial \phi_{t+s}}\right)\left(\tfrac{\partial \phi_{t+s}}{\partial \theta_{t+s}}\right) = \tfrac{\beta^s}{2\gamma}\mathbb{E}\left[\phi_{t+s} - \phi_{t+s}^*\right] > 0, \\ \tfrac{\partial V_t}{\partial \omega_{t+s}} &= \left(\tfrac{\partial V_t}{\partial \phi_{t+s}}\right)\left(\tfrac{\partial \phi_{t+s}}{\partial \omega_{t+s}}\right) = \tfrac{\beta^s}{2\gamma}\left[\mathbb{E}\left[\left(\phi_{t+s} - \phi_{t+s}^*\right)\tfrac{w_{t+s}}{\omega_{t+s}^2}\right] > 0. \end{aligned} \tag{2.48}$$

In Chapter 4, the demand-shifter discussed is an external growth shock resulting from the credit expansion policy, Help-to-Buy. Additionally, the second function reveals that productivity has a positive effect on a firm's profitability. The work of Ding et al. (2018) has also investigated how productivity differences impact firm value by influencing its supply-side investment. The main objective of Chapter 4 is to estimate the policy shock's effect on firm value. To accurately capture the value change that results from the demand increase induced by the policy, it is essential to not only consider direct revenue changes but also control for growth brought about by the supply side, as measured by productivity. The theoretical model presented above justifies the need for this approach when evaluating policy effects.

2.2 Estimation and causality inference

This section explores the methodology from an econometric perspective. It reviews the essential econometric methods used for studying dynamic panel data, which are the main types of data used in subsequent chapters. The objective is to substantiate why specific estimation methods are favoured over others in assessing each model. This is particularly crucial because investment regression models often fail to comply with the Gauss-Markov theorem due to issues of data heteroscedasticity and correlated variables. Ordinary linear regression methods could falter under these circumstances. Hence, econometricians have exerted considerable efforts to increase estimation precision amidst these challenges. Notably, the contributions of econometric methods have played an equally significant role in developing investment frameworks. Grasping the links between the Q model and its associated estimation method is vital to fully comprehend their central contribution to the literature.

One of the challenges in conducting financial-economic studies, as well as a broader range of quantitative social science research, lies in achieving rigorous causality inference. In an ideal scenario, causality inference is achieved through model-based analyses involving extensive sets of randomised and repeated experiments. Such studies naturally address or control issues such as endogeneity, heteroscedasticity, and correlated variables (Hernán and Robins 2010). However, this ideal approach is often impractical for most empirical econometric studies, where observational data are the best available option.

In recent years, statisticians have made significant progress in developing modern inference techniques that offer richness and versatility, enabling researchers to draw more robust conclusions under certain empirical assumptions using observational data. The core concept is to create experimental conditions as if treatment had been randomly assigned conditional on our target covariates of research, then conduct statistical calculation with the relevant assumptions prudently scrutinised (Hernán and Robins 2010).

This section departs from the simplest linear model and concludes with the Generalised Method of Moments (GMM hereafter), one of the most frequently used methods in this thesis. We demonstrate how GMM regression is essentially a more generalized regression that encompasses not only prevalent methods such as Ordinary Least Squares (OLS) and Two-Stage Least Squares (2SLS), but also connects to a broader range of estimation methods including Generalised Least Squares (GLS) and Maximum Likelihood Estimation (MLE).

2.2.1 Identification strategies

The general strategy for identifying an economic problem begins with formulating a practical model. This research adopts a baseline model derived from a theoretical framework to mitigate issues of oversimplification in studies. Several standard methods are employed to address omitted variables, endogenous variables, and reverse causality before drawing conclusions.

Quasi-experiments have become increasingly popular recently and are considered an excellent alternative to natural economic experiments. In a quasi-experiment, researchers cannot predict or control the occurrence of the external shock. Hence any external shock that occurs can manifest in the comparison between the control and treatment groups. When observational data are collected from objects that are as homogeneous as possible before and after the shock, we can examine the difference brought about by the external shock on the dependent variable. Using dummy variables for the external shock is equivalent to taking the first-order difference between the control group and the studied group, thereby removing the endogenous factor. This approach allows us to estimate the relationship between a dependent variable and explanatory variables. For instance, in the labour economics study by Nakamura et al. (2022), they investigate the effect of mobility on income to understand wage differentials. Wages and mobility cannot be directly discerned from ordinary regressions as they are endogenous: individuals might relocate in pursuit of better economic opportunities, or they could be trapped in locations that do not optimise their financial benefits. These choices, in turn, affect their wage level. Nakamura et al. (2022) address this concern by leveraging the external shock of a volcano eruption in Iceland that permanently displaced some residents. By comparing the long-term wage disparity between the individuals who relocated and those who didn't in before and after moving homes, they identified a "pure" causal effect of geographical mobility on wages, with movers earning $27,000 more annually than non-movers.

Another commonly used tool for the endogenous variable is instrument variables (IVs). IVs are frequently employed in regression analysis to address endogeneity concerns associated with potential explanatory variables. These variables are chosen for their correlation with the endogenous explanatory variable while maintaining independence from the dependent variable. IVs serve as external factors unaffected by the independent variable, and their introduction into the model aims to mitigate biases stemming from endogeneity. By utilising IVs, researchers could refine the model of interest by introducing variation that impacts the explanatory variables without directly influencing the dependent variable.

When fitting the endogenous explanatory variables using external instrumental variables and subsequently employing the fitted explanatory variables in formal regression, the fitted explanatory variables essentially operate as a linear combination of external independent variables. This approach effectively addresses concerns of endogeneity. Taking one of the most widely studied economic identification papers as an example, Acemoglu et al. (2001) look into the performance of institutions on increasing income per capita. The endogeneity lies in the fact that more developed countries could afford more and tend to establish better institutions with policies that would facilitate the development of the economy. The study uses the mortality rate of first settlers (roughly 400 years ago) as an instrument variable for institutions and argues that settler mortality affected settlements and settlements affected early institutions. The early institutions persisted and formed the basis of current institutions, which makes the early mortality rate serve as a proper instrument variable to differentiate the actual effect of the quality of institutions.

Regression Discontinuity Design (RDD) is a type of quasi-experimental research design that is used to study the effects of an intervention or treatment on a population. In this design, participants are assigned to receive the intervention or treatment based on a threshold or cutoff point. One key feature of regression discontinuity design is that it allows researchers to control for differences between the groups receiving the intervention and those who do not. Using a threshold to assign participants to the treatment or control group, researchers can ensure that the two groups are similar in terms of their characteristics and background, which helps reduce the influence of confounding factors on the results. The rationale for using this technique for causality inference is that the participants do not control the randomness within a small range. Therefore, the effect of such a random incident can be seen as strictly external. The difference between such a method and instrument variable is that Regression Discontinuity Design emphasises the jump effect of a particular variable (i.e. treatment or intervention). In contrast, the instrument variable tracks the continuous change of the variable. Meanwhile, the Regression Discontinuity Design requires fewer assumptions, therefore, can be more flexible. Another advantage of regression discontinuity design is that it allows researchers to estimate the treatment effect with greater precision than other quasi-experimental designs. This is because the threshold used to assign participants to the treatment or control group provides a natural break in the data, which allows researchers to use statistical techniques to estimate the effect of the intervention accurately. One example is the work of Carozzi et al. (2020) that studies the impact of a credit expansion policy (Help-to-Buy) on housing prices. The Help-to-Buy policy offers different subsidy price caps for new homes in different areas in the UK[10]. The houses that they studied on the borders of the Greater London Authority border and the England/Welsh border are homogeneous in property conditions but their prices manifest that they are affected by spatial discontinuities in the scheme's requirements. By looking into the home price differentials on both sides of the borders, they find that this policy increases house prices by 6% in London and by 8% in England.

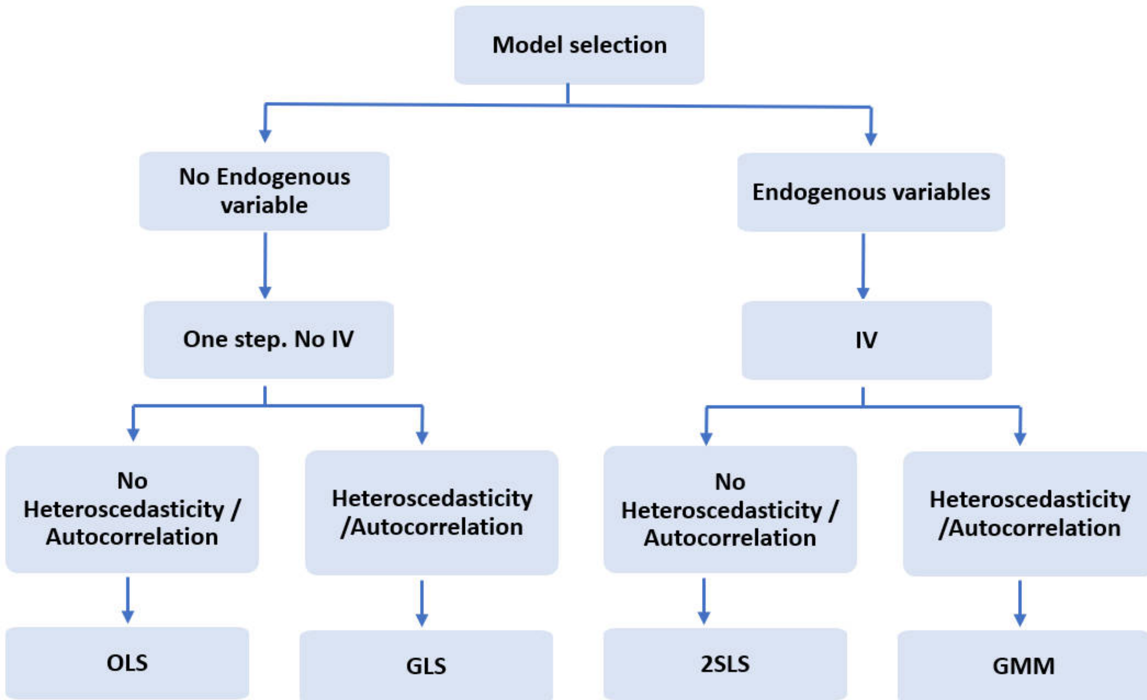
In addition to the most widely adopted identification strategies reviewed above, many other methods are used, such as adding proper control variables and Sargan and Hansen-J over-identification tests. We will use these methods in later chapters with appropriate explanations and justifications. In the next section, these methods are formally reviewed in statistical form and introduce how they are suitable for studying the research questions of this thesis.

2.2.2 Statistical estimation models and links

Regressions of economic structural equations often suffer from issues of violating the Gauss Markov theorems such as endogenous variables or correlated error terms. Using Ordinary Least Square (OLS hereafter) regression will lead to a biased estimator (the coefficients are overestimated). Therefore, the 2SLS is commonly used to solve this problem. The key of 2SLS is using an instrument variable that is correlated to the

[10]The areas are GLA, England, Welsh, and Scotland. The different regions have different mortgage fund caps.

Figure 2.2: Econometric methods classification: comparing different approaches



endogenous variable while being independent of the error term to "filter" the effect of the uncorrelated part from the endogenous variable in the first stage, then conduct a least square estimation based with the fitted variable with remaining variables. More specifically, if writing a linear model in matrix form as

$$\text{y} = X\beta + \epsilon \tag{2.49}$$

where y is a $n*1$ column vector of the dependent variable; X is a $n*p$ matrix containing observed data features with some of the variables being endogenous; β is a $p*1$ vector of correlation coefficients where $p-1$ is the number of variables; ϵ is a $n*1$ vector measuring the un-observable disturbance terms. With instrument variable matrix Z a step by step process to derive first stage coefficients $\widehat{\phi}$ as

$$
\begin{aligned}
&X = Z\widehat{\phi} \\
&Z^\top X = Z^\top Z\widehat{\phi} \\
&\left(Z^\top Z\right)^{-1} Z^\top X = \left(Z^\top Z\right)^{-1} Z^\top Z\widehat{\phi} \\
&\left(Z^\top Z\right)^{-1} Z^\top X = \widehat{\phi}
\end{aligned}
\tag{2.50}
$$

The parameters estimated in the second stage are the ones we are interested in. It is estimated with the fitted value of X produced in the first stage.

$$
\begin{aligned}
&Y = \widehat{X}\beta_{2SLS} \\
&\widehat{X}^\top Y = \widehat{X}^\top \widehat{X}\beta_{2SLS} \\
&\left(\widehat{X}^\top \widehat{X}\right)^{-1} \widehat{X}^\top Y = \left(\widehat{X}^\top \widehat{X}\right)^{-1} \widehat{X}^\top \widehat{X}\beta_{2SLS} \\
&\left(\widehat{X}^\top \widehat{X}\right)^{-1} \widehat{X}^\top Y = \hat{\beta_{2SLS}}
\end{aligned}
\tag{2.51}
$$

Substituting the estimated X from the first stage that

$$
\hat{X} = Z\widehat{\phi} = Z\left(Z^\top Z\right)^{-1} Z^\top X \tag{2.52}
$$

The coefficient estimation of β_{2SLS} is expressed as

$$
\begin{aligned}
\hat{\beta}_{2SLS} &= \left(X^\top Z\left(Z^\top Z\right)^{-1} Z^\top Z\left(Z^\top Z\right)^{-1} Z^\top X\right)^{-1} X^\top Z\left(Z^\top Z\right)^{-1} Z^\top Y \\
&= \left(X^\top Z\left(Z^\top Z\right)^{-1} Z^\top X\right)^{-1} X^\top Z\left(Z^\top Z\right)^{-1} Z^\top Y
\end{aligned}
\tag{2.53}
$$

Arranging the closed form estimator of $\hat{\beta}_{2SLS}$, the function can be written as below where P is projection matrix

$$
\hat{\beta}_{2SLS} = \left(X^\mathrm{T} P_Z X\right)^{-1} X^\mathrm{T} P_Z Y \quad \text{with } P_Z = Z\left(Z^\top Z\right)^{-1} Z^\top \tag{2.54}
$$

This arrangement makes it easy to see how 2SLS is linked to OLS. If substituting the instrument matrix with the identity matrix, the estimator will become the OLS coefficient estimator. Seeing the link to Generalised Least Square estimator is quite similar:

$$
\begin{aligned}
\hat{\beta}_{GLS} &= \left[(PX)^{\top}PX\right]^{-1}(PX)^{\top}Py \\
&= (X^{\top}\underbrace{P^{\top}P}_{\Omega^{\top}}X)^{-1}X^{\top}P^{\top}Py \\
&= \left(X^{\top}\Omega^{-1}X\right)^{-1}X^{\top}\Omega^{-1}y.
\end{aligned}
\tag{2.55}
$$

One issue that could not be addressed by 2SLS estimation is the correlated error term. In empirical research, it is common to find serial correlation or autocorrelation within a sample observation, particularly in the settings of this thesis. For example in the investment model reviewed above, companies tend to make investment in multiple periods based on the cost of each month and their prospect profitability. This makes it possible for the data to exhibit correlated investments, which may affect the reliability and accuracy of the results.

Zellner (1962) addresses this issue by proposing Seemingly Unrelated Regressions (SUR) estimation that uses a covariance matrix (or sometimes unknown non-identity covariance matrix) to estimate coefficients. It is commonly referred to as estimating M different dynamic panel data models that

$$
y_{ti} = \sum_{j=1}^{k_i} x_{tij}\beta_{ij} + \varepsilon_{ti}, t = 1, 2, \ldots, T; i = 1, 2, \ldots, M; j = 1, 2, \ldots, k_i \tag{2.56}
$$

where t works as time index, i works individual observation index, and j works as covariant index. In matrix form, the data are stored as

$$
\underset{(MT\times 1)}{\mathbf{y}} = \begin{pmatrix} \mathbf{y}_1 \\ \mathbf{y}_2 \\ \cdots \\ \mathbf{y}_M \end{pmatrix}, \quad \underset{(MK\times 1)}{\boldsymbol{\beta}} = \begin{pmatrix} \boldsymbol{\beta}_1 \\ \boldsymbol{\beta}_2 \\ \cdots \\ \boldsymbol{\beta}_K \end{pmatrix}, \quad \underset{(MT\times 1)}{\varepsilon} = \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \cdots \\ \varepsilon_M \end{pmatrix} \tag{2.57}
$$

In the setting of this thesis, each y and ϵ are $T * 1$ vectors that store data or unobserved error of n company in a specific year; the β is a $K * 1$ vector that holds explanatory variables that we are interested in. The model allows observations to be correlated in a way that

$$\underset{(MT\times MT)}{\mathbf{V}(\mathbf{y})} = \begin{pmatrix} \sigma_{11}\mathbf{I}_T & \sigma_{12}\mathbf{I}_T & \dots & \sigma_{1M}\mathbf{I}_T \\ \sigma_{21}\mathbf{I}_T & \sigma_{22}\mathbf{I}_T & \dots & \dots \\ \dots & \dots & \dots & \dots \\ \sigma_{M1}\mathbf{I}_T & \dots & \dots & \sigma_{MM}\mathbf{I}_T \end{pmatrix} = \Sigma \otimes I_T = \psi \tag{2.58}$$

The $\otimes$ denotes the Kronecker product operator, which means σ is $M * M$ dimensional and positive definite, consisting of covariance between the disturbances of i^{th} and j^{th} term for each company. The assumption assumes that the variance of ϵ_{ti} is constant for all t; the contemporaneous covariance between error term ϵ_{ti} and ϵ_{tj} is constant for all t. For different year, the inter-temporal covariance between ϵ_{ti} and $\epsilon_{\text{t'j}}$ $(t \neq t^*)$ when are zero for all i and j. Under this setting, the coefficient estimator is derived as

$$\begin{aligned} \hat{\beta}_{SUR} &= \left(X'\psi^{-1}X\right)^{-1} X'\psi^{-1}y \\ &= \left[X'\left(\Sigma^{-1} \otimes I_T\right) X\right]^{-1} X'\left(\Sigma^{-1} \otimes I_T\right) y \end{aligned} \tag{2.59}$$

As in matrix X the data are none zero only at the diagonal position, and the serial correlation only exists within the same year. We can observe the $\hat{\beta}_{SUR}$ is just a special case of $\hat{\beta}_{GLS}$

$$\begin{aligned} \hat{\boldsymbol{\beta}}_{GLS} &= \begin{pmatrix} \frac{1}{\sigma_{11}}\left(\mathbf{X}_1'\mathbf{X}_1\right) & \mathbf{0} & \dots & \mathbf{0} \\ \mathbf{0} & \frac{1}{\sigma_{22}}\left(\mathbf{X}_2'\mathbf{X}_2\right) & \dots & \dots \\ \dots & \dots & \dots & 0 \\ \mathbf{0} & \dots & \mathbf{0} & \frac{1}{\sigma_{MM}}\left(\mathbf{X}_M'\mathbf{X}_M\right) \end{pmatrix}^{-1} \begin{pmatrix} \frac{1}{\sigma_{\sigma_1}}\mathbf{X}_1'\mathbf{y}_1 \\ \frac{1}{\sigma_{22}}\mathbf{X}_2'\mathbf{y}_2 \\ \dots \\ \frac{1}{\sigma_{MM}}\mathbf{X}_M'\mathbf{y}_M \end{pmatrix} \\ &= \begin{pmatrix} \left(\mathbf{X}_1'\mathbf{X}_1\right)^{-1}\mathbf{X}_1'\mathbf{y}_1 \\ \left(\mathbf{X}_2'\mathbf{X}_2\right)^{-1}\mathbf{X}_2'\mathbf{y}_2 \\ \dots \\ \left(\mathbf{X}_M'\mathbf{X}_M\right)^{-1}\mathbf{X}_M'\mathbf{y}_M \end{pmatrix} \end{aligned} \tag{2.60}$$

The model estimated in the above method does a good job of regressing models with heteroscedasticity and serial correlation issues. But it does not provide consistent estimation for models with lagged dependent terms regressed as explanatory variables. Models with lagged lag term regressed as explanatory variables are commonly seen in econometric studies, especially in macroeconomic studies where the metrics are collected not only in a cross-section way but also in a time-wise way (where they are often termed panel data or longitudinal data). We denote the panel data model with the lagged term as an explanatory variable as

$$y_{ti} = \phi y_{t-1,i} + \beta_i + \varepsilon_{ti} \tag{2.61}$$

where the $\phi y_{t-1,i}$ represents the first-order lagged term of the dependent variable (this can expand to multi-term lag), and the model is named as dynamic panel data regression model. The lagged term is correlated to the dependent term $y_{t,i}$, so it can not be estimated with any fixed effect model reviewed above. Theoretically, taking the first-order difference of the equation (2.61) would eliminate the individual fixed effect as

$$y_{ti} - y_{t-1,i} = \alpha \left(y_{t-1,i} - y_{t-2,i} \right) + \left(\epsilon_{t,i} - \epsilon_{t-1,i} \right) \quad (t = 2, 3, ...T) \tag{2.62}$$

As $\Delta y_{ti} = y_{ti} - y_{t-1,i}$ is correlated to $\Delta \epsilon_{ti} = \epsilon_{t,i} - \epsilon_{t-1,i}$, hence $\Delta y_{t-1,i}$ is correlated to $\Delta \epsilon_{t,i}$, and using OLS estimation will lead to a biased estimator. But $y_{t-2,i}$ is not correlated to $\Delta \epsilon_{t,i}$, hence $y_{t-2,i}$ or $\Delta y_{t-2,i}$ can work as instrument variable for $\Delta y_{t-1,i}$. So in estimating the first difference model there are two ways to choose instrument variable: 1) from $t = 3$ using $y_{t-2,i}$ as instrument variable for $\Delta y_{t-1,i}$; 2) from $t = 4$ using $\Delta y_{t-1,i}$ as instrument variable for $\Delta y_{t-2,i}$. And it can be proven that the estimator of both instrument variables is consistent for coefficient ϕ. But in practice when the coefficient ϕ is close to 1 or a large value, the estimation becomes unstable and the instrument is ineffective.

In order to deal with weak instrument issues Lars Hanson (1982) proposes the Generalised Method of Moment to estimate dynamic panel data model. Recall the OLS estimation for equation (2.49) is $\hat{\beta} = (\mathbf{X}'\mathbf{X})^{-1}(\mathbf{X}'\mathbf{y})$. This is equivalent to using the moment of method estimation that $E[x_i(y_i - x_i'\beta)] = 0$ as we assume that the explanatory variable is independent to the random error. This is referred to as the population moment condition and the true value of parameter $\hat{\beta}$ is the only solution under the population moment condition. If we denote the sample moment condition as

$$\frac{1}{N}\sum_{i=1}^{N} x_i\left(y_i - x_i'\hat{\beta}\right) = 0 \tag{2.63}$$

and use this sample moment condition to estimate the population moment condition. In OLS model settings, the number of moment conditions equals the number of parameters to be estimated, so we are able to estimate population moment by sample moment. In a dynamic panel data model where more moment conditions can be found through lagged variables (i.e. the condition quantity exceeds the parameter quantity), we could not get a unique estimation for parameters. Lars Hanson (1982) improves the estimation method by introducing a positive definite weight matrix to make the weighted average moment conditions a target function to minimise. Hanson proved that the estimator $\hat{\beta}$ asymptotically follows normal distribution whose variance is a function of the weight matrix. Hence different weight matrices would lead to different variance-covariance matrices, therefore different estimations of $\hat{\beta}$. Hanson proved that using the identity matrix as a weight matrix in the first step could lead to a temporary but consistent estimation of the $\tilde{\theta}$ by minimising the weighted sample moment condition that

$$\min_{\theta}\left[\frac{1}{N}\sum_{i=1}^{N} g(x_i;\theta)\right]'\left[\frac{1}{N}\sum_{i=1}^{N} g(x_i;\theta)\right] \tag{2.64}$$

where $g(x_i;\theta)$ denotes to moment condition function.

With $\tilde{\theta}$ we could estimate the variance-covariance matrix of coefficient, hence estimate $\hat{\beta}$ as

$$\hat{\boldsymbol{\beta}}_{\mathrm{GMM}} = \left(\boldsymbol{X}^{\top}\boldsymbol{W}\left(\boldsymbol{W}^{\top}\boldsymbol{\Omega}\boldsymbol{W}\right)^{-1}\boldsymbol{W}^{\top}\boldsymbol{X}\right)^{-1}\boldsymbol{X}^{\top}\boldsymbol{W}\left(\boldsymbol{W}^{\top}\boldsymbol{\Omega}\boldsymbol{W}\right)^{-1}\boldsymbol{W}^{\top}\boldsymbol{y} \tag{2.65}$$

By deducing the expression of the GMM estimator, the chapter is concluded.

Chapter 3

Fading investment-cash flow sensitivity puzzle and assets tangibility - Evidence from the UK

3.1 Introduction

The Neoclassical investment Q theory posits that under perfect market conditions, a company's capital investment should be solely determined by its marginal capital productivity, as measured by Tobin's Q. Nonetheless, empirical studies, such as Fazzari et al. (1987), have demonstrated that a firm's investment positively correlates with its cash flow level, even after accounting for Tobin's Q. This positive correlation is referred to as the investment-cash flow sensitivity (ICFS hereafter). Subsequent research has found that the ICFS is prevalent across both developing and developed nations (Baker et al. 2003; Guariglia 2008; Hadlock and Pierce 2010; Hoshi et al. 1991; Jason and Jenny 2012; Kaplan and Zingales 1997; Whited 1992). Soon after, the existence of ICFS became accepted as a stylised fact, prompting ongoing academic debates and policy studies. This study aims to uncover the dynamics of the changes behind ICFS, providing an explanation for its fading trend.

The ICFS describes the responsiveness of capital investments to internal cash flow fluctuations, and it is computed by regressing changes in a firm's investment in productive capital[1] against changes in its internal cash flow[2]. A high ICFS signifies that a company's investments are heavily reliant on the availability of its internal cash flow[3]. The ICFS typically rises when a company requires capital funding but has limited access to public financing channels. In such scenarios, external financing proves more costly than utilising the internal cash flow, hence the company is compelled to use its internal funds for capital investments (Riddick and Whited 2009). This leads to a higher correlation between investment and cash flow, i.e., a higher degree of ICFS.

The ICFS is viewed as a critical metric for gauging financial constraints or capital investment intensity, and is widely used in studies for assessing borrowing conditions, investment costs, efficiency, or evaluating policy impact (Almeida et al. 2004; Gulen and Ion 2016; Khurana et al. 2006; Lian and Ma 2021; Y. Wang et al. 2014). The debate regarding ICFS became more vigorous following the Great Recession, which sparked the need for macro-finance models (Lian and Ma 2021). These models, with their focus on various specific types of financial constraints, have the potential to offer differing insights into broader issues, such as credit efficiency and allocation, monetary policy, economic recovery, among others. (Dávila and Korinek 2018; Diamond et al. 2020; Lorenzoni 2008).

However, recent studies have found that the ICFS has been fading or vanishing in the last two decades in developed economies, and this finding is robust across different nations (Ağca and Mozumdar 2017; Jason and Jenny 2012; Zhen and Chu 2021). This phenomenon soon becomes a new puzzle, and pioneering research has sought

[1] The productive capital is primarily measured by tangible assets. However, some research examines other types of capital, such as working capital and intangible assets.

[2] The cash flow is the net amount of cash generated or used by a company's operations, investments, and financing activities, referring to the movement of cash within the organisation.

[3] It is also referred to as internal funds. These two terms are interchangeably used in studies.

explanations in terms of asset tangibility (Moshirian et al. 2017; Zhen and Chu 2021), financial development (Larkin et al. 2018), and financial liberalisation (X. Wang 2022). These explanations posit positive economic implications, suggesting that the declining ICFS is a result of the financial and economic growth nexus, where companies have more sources to create sales growth or financing with far fewer constraints. The enhanced wealth at both the company and national levels has liberated firms from constraints related to internal cash flow, leading to the fading ICFS.

Nevertheless, the aforementioned studies primarily focus on a narrow subset of publicly listed companies. Their explanations are far from being a stylised fact due to the heterogeneity of firms. This presents a limited perspective of the overall financing landscape, considering the majority of firms in any given country are typically small and medium-sized enterprises (SMEs hereafter). Publicly listed firms have better access to financing markets due to their extensive operating histories, financial transparency, and visibility to potential investors. In contrast, private firms can grapple with more challenges such as information asymmetry, adverse selection, and moral hazard. These issues impede their capacity to obtain external financing, even in the face of promising investment opportunities (Beck et al. 2008). To the best of my knowledge, no study has explored the evolution of ICFS in unquoted firms since the decline was identified in 2012. A significant research gap emerges, as the prevailing conclusion primarily applies to wealthier, privileged companies with substantial market power. This stance potentially contradicts the financing reality of most ordinary firms in every country.

This study fills the gap by investigating the evolution and dynamics of ICFS across an extensive sample of British firms in various sectors, comprising 781,314 firm-year observations, with almost 99% of the firms being SMEs[4]. The UK data presents a unique setting for ICFS research, as the country has relatively smaller corporate bond and commercial paper markets, highly regulated banking and equity markets, and a lower volume of venture capital funding (Guariglia 2008). This makes it representative

[4]As of the end of 2022, SMEs constitute 99% of firms in the UK. More information on this can be read from: Business population estimates for the UK and regions 2022.

of the European financial landscape for non-public firms in developed countries, or larger firms in developing nations.

This study identifies, for the first time, that the ICFS also has declined among unquoted firms from 1984 to 2019 over six subperiods. I propose a hypothesis that the ICFS is significantly influenced by asset tangibility (defined as the ratio of tangible assets to total assets) and that the decrease in a company's asset tangibility contributes to the decline in ICFS over time. The hypothesis is supported by three sets of arguments. Firstly, descriptive statistics display synchronised declines in average asset tangibility and capital investments, indicating a natural decline in the ICFS. Secondly, the main regression test reveals that the ICFS is very low after introducing the cross-product term of asset tangibility, confirming the impact of asset tangibility on investment. It in fact suggests that the investment-cash flow sensitivity is, in fact, an investment-cash flow-tangible capital sensitivity. The third set of results stems from the heterogeneity analysis that divides firms into two groups based on asset tangibility. I find that high asset tangibility firms exhibit a more pronounced decline in ICFS, while the low asset tangibility group shows a much smaller ICFS with a minor decline. This implies that the overall decline of ICFS in the full sample is primarily driven by the ICFS decline in high asset tangibility firms. Importantly, the declining trend of ICFS and the impact of tangibility remain robust after considering alternative explanations, including (1) mismeasurement of Q, (2) the financial and economic growth nexus, and (3) estimation bias.

To further explore the dynamics of declining asset tangibility, I identify two channels through which asset tangibility can influence the ICFS, based on the existing literature. The first channel operates through the return of sales on tangible capital investments. The second channel involves the persistence of cash flow. Historically, higher asset tangibility has been associated with increased sales returns and more persistent cash flow, causing companies to rely heavily on tangible asset investments to forecast future sales and cash flows (Riddick and Whited 2009; Zhen and Chu 2021). My study shows that in recent years, the sales return on tangible assets declines more rapidly among high asset tangibility firms, supporting the validity of the first channel. In testing the second channel, my results indicate that cash flow persistence has not decreased over time in either high or low asset tangibility firms. This finding challenges the conclusions drawn from previous studies on publicly listed firms. The data indicates that productivity within companies, especially those heavily reliant on fixed capital for production, has remained stable, albeit slow. In this scenario, companies opt to reduce capital investment intensity when expectations are low. This finding is consistent with the extant literature on American firms, which suggests that in contrast to superstar firms, the majority of ordinary firms have increasingly limited market power and fewer avenues for growth (De Loecker et al. 2020; Goodridge et al. 2018).

To further verify the robustness of the first channel, I examine its reversed implication. If the decreasing return on capital investment is driving the decrease in ICFS, we can infer that the ICFS exhibits a more significant drop in firms heavily reliant on tangible assets and simultaneously experiencing a higher decline in return on tangible capital investment. A significant determinant of a firm's investment return is its market power. According to the assumption, firms are divided into four distinct groups based on their market power and asset tangibility ratio. It is found that the ICFS experiences the steepest decline in the group with low market power and a high asset tangibility ratio. Companies that can maintain high productivity would not exhibit a declining ICFS. This major implication is illustrated by the fact that a more prominent decline in ICFS is observed in companies experiencing a faster decrease in return on tangible investment. As a result, the contrasting patterns are particularly evident between low TR and high TR firms.

A major contribution of this study is to reveal a different portrait of the vanishing ICFS for SMEs in developed countries. Contrary to the positive conclusions from previous studies, this research shows that the fading ICFS does not stem from improved financing conditions or liberalised markets. The simultaneously declining asset tangibility and return on tangible investment seem to point to the operational struggles faced by non-listed firms. Such results are consistent with the widely discussed sluggish productivity puzzle among non-listed firms in the UK and Europe (Bellocchi et al. 2021; Goodridge et al. 2018). While this study does not probe deeper into the reasons for lower returns on tangible capital investments in non-listed firms, it implies that future research could investigate the low growth and lack of effective market demand in de-industrialised developed countries.

While I am cautious about drawing causal inferences from the analysis, the results are consistent and support the inference of asset tangibility. The similarity in the pace of the disappearance of the ICFS and the declining sales return of tangible capital is robust when tested in samples split from both the industry level and cross-sectional level. This is crucial for ruling out the possibility of omitted variables. As proposed by Larkin et al. (2018), examining time-varying patterns on contrasted groups can help alleviate endogeneity concerns. If an omitted variable still exists, which impacts the ICFS and investment-cash flow-capital sensitivity simultaneously, it must affect firms split based on asset tangibility as well as presenting coordinated trends in terms of sale return in each group. I argue that it is highly unlikely to find such a variable that overcomes the hurdle of explaining the variations in two models with two sets of data simultaneously across six subperiods.

This study also contributes to the existing literature by enhancing the inference of the investment model in two ways. The conclusion is drawn from the classical model proposed by Fazzari et al. (1987), which has two potential issues. Firstly, the classical model controls marginal productivity Q with a mismeasured metric which has been suspected to cause the fading ICFS (Jason and Jenny 2012), and this study proposes a novel metric to control for marginal Q. Another limitation is that the classical model does not adequately account for the potential autoregression of investment and Q measurement (Guariglia 2008). To address this issue, this study re-examines ICFS through an error-correction model (ECM), which does not impose assumptions about short-term investment and its replacement cost. This model offers more flexibility in describing investment behaviours and is considered to be more suitable for studying ICFS among unquoted firms (Guariglia 2008). The two improved tests of ICFS show results similar to the main results in terms of both trend and absolute value.

The remainder of this chapter is organised as follows: In Section 3.2, a review of the literature pertaining to the discovery of ICFS and recent explanations for the fading ICFS is presented. Utilising the theoretical literature, I outline two channels through which asset tangibility can affect ICFS. In Section 3.3, the hypotheses and the model used to study the effect of asset tangibility on a firm's ICFS are introduced. The descriptive analysis of the data is presented in Section 3.4. Section 3.5 systematically presents evidence supporting the following claims: (i) the ICFS in the UK is diminishing; (ii) asset tangibility has a strong and dominant effect in enhancing firms' ICFS; (iii) the declined return of tangible investment is the main cause of the decreased asset tangibility, leading to declining ICFS; (iv) the analysis is immune to the criticism of mismeasured Q, alternative economic impact, and estimation bias. Finally, Section 3.6 concludes the study.

3.2 Literature review

3.2.1 The development of investment cash flow sensitivity

Chapter 2.1 reviews that, from an investment theory perspective, a firm's capital investment should depend solely on the marginal return and cost of the capital, also referred to as marginal capital productivity or marginal Q in a perfect market. A well-known extension is the Modigliani-Miller theorem, which states that in a perfect market, the value of a firm is independent of its capital structure[5] (Miller and Modigliani 1966; Modigliani and Miller 1958). According to the theorem, the value of a firm is deter-

[5] The capital structure refers to the mix of debt and equity used to finance its operations.

mined by its expected future cash flows and the required rate of return of its investors, regardless of how those cash flows are financed under perfect market assumptions.

In the real-world capital market, the optimal financing structure that maximises profitability remains elusive due to various market imperfections such as limited access to credit, asymmetric information, agency problems, limited rationality, and conflicts of interest (Hyytinen and Väänänen 2006). These traditional imperfections lead to prevalent financial constraints for the majority of firms globally. A large-scale survey conducted by Campello et al. (2010) interviews 1,050 CFOs around the world and reveals that most companies experienced significantly reduced capital expenditure during financial distress. During the financial crisis, 81% of the interviewed CFOs report credit constraints, 55% experience difficulties with credit lines, and 59% express concerns about higher borrowing costs. This implies that most firms are exposed to uncertainty and financial constraints on investment, especially during economic downturns. Firm leaders often find themselves being concerned with whether their current financing plan is 'good enough'. Decision makers often wonder whether they would have gained a stronger competitive advantage if they had invested more money in the past, or if an aggressive spending plan could lead to unexpected waste or loss. In such imperfect markets, a one-size-fits-all answer for optimal capital investment is challenging to provide.

In line with CFOs' experiences, researchers find evidence of Q theory not aligning with the market and performing inadequately in guiding investments. One of the most noteworthy pieces of research is by Fazzari et al. (1987), which finds the firm's investment also positively related to cash flow, even after controlling for the marginal Q. They explain that the failure of the Q model can be attributed to the widespread presence of financial constraints. To prove the proposition, they classify firms into low/high financial constraint groups based on a financial standard - dividend payout ratio. They propose that in the stock market, it is widely accepted that a high dividend payout indicates abundant profit hence fewer financial constraints for a firm. In testing firms' investment with their cash flow through[6] function

$$\mathrm{INV}_{i,t} = \beta_0 + \beta_1 \mathrm{Q}_{i,t-1} + \beta_2 \mathrm{CF}_{i,t} + \varepsilon_{i,t} \tag{3.1}$$

they find that β_2 (i.e. ICFS) is higher in low-dividend-payout-ratio firm groups and lower in high-dividend-payout-ratio firm groups. This is consistent with the reality that companies in financial distress tend to use non-public financing channels to invest, such as internal cash flow or cash reserves. Therefore, Fazzari et al. (1987) conclude that ICFS is an indicator of financial constraints.

However, Kaplan and Zingales (1997) contend that some firms may opt for less dividend distribution as part of a long-term strategy, and such firms are not necessarily financially constrained. They propose that no single criterion such as firm size or age can accurately predict whether a firm is financially constrained. As a result, they introduce a novel metric for assessing financial constraints, incorporating both qualitative and quantitative information. Upon re-evaluating ICFS using this more comprehensive metric, they find that the sensitivity moves in the opposite direction compared to the findings of Fazzari et al. (1987). Therefore, Kaplan and Zingales (1997) conclude that ICFS should not be interpreted as a severity of financial constraints. Instead, it is better understood as reflecting the firm's preference for using internal funds or capital intensity.

should not be interpreted as a measure of financial constraints, but rather as a reflection of the firm's preference for using internal funds or capital intensity. While in subsequent research Fazzari et al. (1987) challenge Kaplan and Zingales (1997) from both theoretical perspectives and financial constraint classification standards, other studies also question whether ICFS accurately represents the severity of financial constraints (Alti 2003; Cleary 1999; Cleary et al. 2007; Gatchev et al. 2010; Gomes 2001;

[6] INV is investment, measured by the change of fixed assets. CF is cash flow. Both terms are scaled by total assets. Q is the control variable of marginal Q, measured by the market-to-book ratio. β_2 is ICFS.

Kadapakkam et al. 1998; Moyen 2004).

Chen and Chen (2012) outline several possible explanations for the inconsistent results observed in previous studies. One reason is that earlier researchers did not consider the role of cash reserves in financing investments, leading to an overestimation of the sensitivity of investment to Q. However, recently this argument has diminished in relevance due to a general trend of decreased reliance on cash reserves for investments. A more prominent explanation is the mismeasurement of Q (a list of benchmark discussions can be found from Alti (2003), Erickson and Whited (2000, 2002), Jason and Jenny (2012), and J. Lewellen and K. Lewellen (2016)). When regressing investment on other variables, it is crucial to account for growth opportunities measured by marginal Q. Nevertheless, accurately measuring this metric using financial report data aggregated annually proves challenging (as discussed in Chapter 2.1.2), where studies had to resort to using average Q as a sub-optimal proxy. This proxy tends to exhibit time-series correlation, and earlier research did not adequately control for lagged Q or address the bias introduced by regressing on a correlated lag term. This can potentially result in a mis-estimation of ICFS.

The debate surrounding ICFS has persisted since 1988 and still generate rich discussions in the recent decade (a partial list is Almeida et al. (2004), Erickson and Whited (2000), Guariglia (2008), Jason and Jenny (2012), Larkin et al. (2018), Moshirian et al. (2017), and Zhen and Chu (2021)). The connection between investment and cash flow has been widely acknowledged as significant in empirical studies (Hadlock and Pierce 2010; Hoshi et al. 1991; J. Lewellen and K. Lewellen 2016; McLean et al. 2012). Meanwhile, researchers have employed the ICFS as an indicator of financial constraints or market frictions, extended to further purposes such as measuring external financial costs in their analyses (Almeida and Campello 2007; Beatty et al. 2010; Biddle and Hilary 2006; Bond et al. 2003; Fazzari and Petersen 1993; Hoshi et al. 1991; Love 2003).

3.2.2 Recent research on the fading ICFS

Recently, researchers have observed a notable pattern of decline in the ICFS. Early studies have found that the sensitivity falls within the range of 0.2 to 0.7 (Fazzari et al. 1987; Kaplan and Zingales 1997). However, more recent empirical results indicate a significant drop to 0.15 in the late 1990s in developed economies (Baker et al. 2003), which further decreases to 0.01 to 0.09 in the 2000s (Erickson and Whited 2012), and even vanishes in some cases (Jason and Jenny 2012; Larkin et al. 2018; Moshirian et al. 2017). Primary research has begun to uncover the declining ICFS among special samples, such as constrained firms (Allayannis and Mozumdar 2004), or firms operating in imperfect markets (Ağca and Mozumdar 2008; Ascioglu et al. 2008; Islam and Mozumdar 2007), and traditional high-asset-based firms (Brown and Petersen 2009). Chen and Chen (2012) comprehensively examine the declining trend and confirm that the fading ICFS could not be explained by alternative factors such as changes in sample composition, physical asset structure, government practice, or market power. This study is seen as a benchmark for confirming the ICFS declining puzzle, calling for explanations of its dynamics.

Pioneering studies attempt to attribute the cause of the vanishing ICFS to global development. Larkin et al. (2018) propose that swift economic growth and well-developed financial environments in developed countries have alleviated financial distress for companies. As national wealth increases, companies gain access to a broader range of economic resources, which leads to more efficient capital allocation within the country. In this instance, companies are not reliant on cash flow for financing, which in turn leads to a reduction in sensitivity. Their observations reveal that the ICFS has significantly declined in wealthier countries but remains unchanged in developing countries. The key driver is the relaxation of financial constraints at the firm level. This study provides a valid perspective, as numerous studies have demonstrated that financial constraints tend to arise in markets with more imperfections and fewer financial resources, leading to high external financing costs at the country level (Fazzari et al. 1987; Hoshi et al.

1991; McLean et al. 2012).

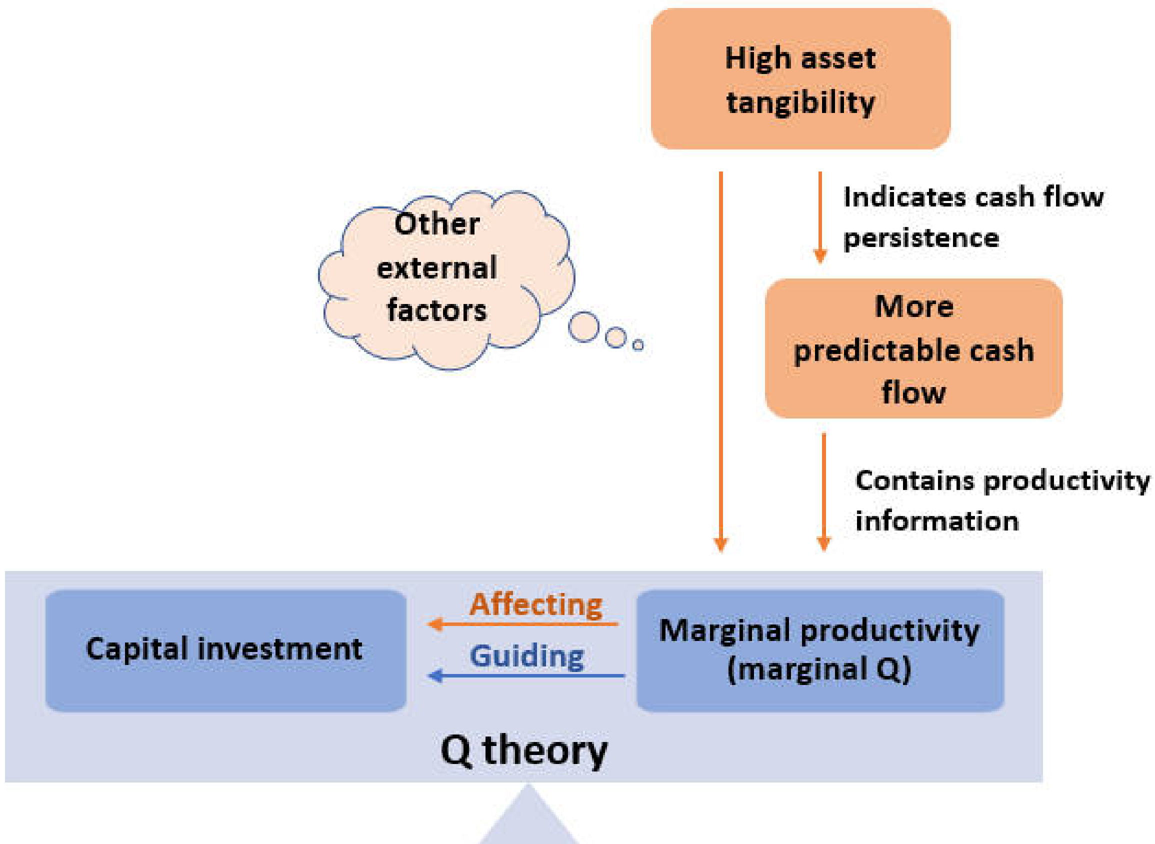
X. Wang (2022) also examines the influence of broader economic conditions on the vanishing sensitivity puzzle. They argue that financial liberalisation can help alleviate financial risks induced by economic fluctuations and foster greater risk-sharing among firms. The analysis demonstrates that countries with a higher level of financial liberalisation witness a more substantial decline in the ICFS. Moreover, financial integration at the global level facilitates a reduction in financing constraints for non-high-income countries, contributing to a major decline in the ICFS among these nations. Despite taking into consideration distortions in the financial sector, a potent correlation between the level of liberalisation and investment sensitivity in developed economies still emerges. Consequently, the author concludes that the financial liberalisation and deregulation could potentially explain the diminishing ICFS.

This thesis aims to address the puzzle from a third perspective: asset tangibility. I identify two channels through which asset tangibility can impact a firm's investment from existing literature. The first channel originates from neoclassical investment theory, which posits that the ratio of tangible assets to total capital provides information about marginal productivity (Moshirian et al. 2017)[7]. Companies, when working with physical assets for production, have an advantage in observing the productivity of tangible assets from an internal perspective throughout the production process. This allows them to make informed decisions regarding tangible investments when they identify growth opportunities. Therefore, capital investment, and by extension the reliance on cash flow, is closely linked to the expected rate of capital return. This suggests that if the profitability of tangible assets diminishes, the investment intensity of tangible assets will also decrease in rather a reactive way.

The second channel by which asset tangibility affects ICFS is through its impact on cash flow persistence. Riddick and Whited (2009) find that with other factors controlled,

[7] This is also the theoretical foundation for using the intermediate investment of capital, water, electricity, and labour to estimate production functions, as discussed in Chapter 2.1.3.

Figure 3.1: The mechanism of assets tangibility in affecting ICFS



Note: The figure illustrates the impact of asset tangibility on firms' investment. Empirically, asset tangibility plays an important role in predicting marginal productivity and the persistence of future cash flow, influencing capital investment and ICFS. Additionally, external factors such as financial development and financial liberalisation can also influence a company's capital investment. These factors collectively contribute to shaping the investment behaviour and outcomes of firms.

when a firm's future cash flow is more predictable, it is more inclined to invest in productive assets rather than saving, as this is expected to generate higher future cash flows and potentially increase profits. Tangible capital assets, such as real estate, production equipment, and logistics facilities, are typically long-term assets closely related to a company's core business, providing a reliable and stable source of cash flow. In contrast, intangible assets, intangible assets such as brands, patents, and technology, often have higher uncertainty and shorter-term revenue streams, making it challenging to provide a stable source of cash flow. In recent years, the production of intangible assets has become increasingly important in advanced economies (Hansen et al. 2005). Meanwhile, quoted firms possess more investment channels to secure financial returns. The cash flow generated from technology or an advanced economy is less predictable. It's postulated that as the proportion of tangible capital decreases, the stability and predictability of a company's cash flow are compromised, thereby reducing cash flow persistence and contributing to the decline in the ICFS. Research has indicated that cash flow persistence and the impact of asset tangibility on this persistence have been on a downward trend in publicly listed companies in developed countries (Moshirian et al. 2017; Zhen and Chu 2021).

Zhen and Chu (2021) develop a theoretical model to explain how the decreasing dependency on fixed tangible assets leads to a decrease in ICFS. They extend the production function by adding the productive capital structure (measured by the portion of tangible versus intangible assets) as a variable to represent different productivity sources. The classical theoretical models only confirmed that cash flow plays an informational role in guiding investment decision-making (Alti 2003; Moyen 2004). Zhen and Chu (2021) extend the theory by showing that the information contained in cash flow varies according to the portion between tangible and intangible capital. The analytical solution implies that firms capable of generating higher productivity from tangible assets will accumulate more tangible capital. Hence the ratio can reflect the relative productivity of each type of asset. This lends formal theoretical support to the first aforementioned channel, suggesting that a decrease in the productivity of tangible assets will lead to a lower ICFS.

Secondly, their model introduces cash flow volatility as a variable to measure the relationship between tangible capital investment, cash flow, and asset tangibility. The analytical test shows that the ICFS increases as the persistence of the long-run component of cash flow increases and decreases if the variance of the temporary component of cash flow increases. This validates the second channel that if the volatility of cash flow increases and it loses persistence in long-term components, the firm's dependence on investment in cash flow and on tangible assets becomes insignificant. To sum up, the mechanism of assets tangibility in affecting ICFS is presented in Figure 3.1.

3.2.3 Divergence of large and small firms

What is missing from existing studies is the divergence between publicly listed firms and private firms. Smaller firms have been possessing less market power in competitive environments, which has damaged their ability and motivation to invest. De Loecker et al. (2020) demonstrate that the increase in marginal profitability in the US over the last 50 years has primarily been driven by a small portion of superstar firms, while the profitability of the remaining companies remained unchanged[8]. This leads to a significant reallocation of market share, with smaller firms taking a smaller portion of the market. They attribute this to incomplete competition, which creates imbalanced growth and market power between large firms and SMEs. This, in turn, caused comprehensive under-investment in smaller firms.

Superstar firms appear to possess a high amount of tangible assets, but they also employ more effective methods for generating profit than smaller firms. One of the trending approaches in recent years is stock buybacks. Yallapragada et al. (2014) document that aggressive stock repurchases have become a significant value management strategy for firm managers in recent years. Companies can continue issuing corporate bonds to finance capital for stock repurchases, and the repurchased stock is returned to the equity on the firm's balance sheet. The decreased quantity of outstanding shares can significantly increase the firm's dividend payout ratio and earnings per share, thereby leading to a further increase in stock prices (Yallapragada et al. 2014). Friedman et al. (2011) show that Standard & Poor's 500 Index (S&P 500) companies repurchased about $200 billion of their own stock. Baldwin (2012) documents that after the recession, the an-

[8]They find that the aggregated markup has increased from 21% to 61%, and only upper percentile firms contribute to this increase. The median markup has not changed in the last five decades.

nual rate of stock repurchases by S&P 500 companies has risen to $500 billion, which is almost twice as much as traditional cash dividends. Similar balance sheet management strategies have been documented in other large firms, according to Yallapragada et al. (2014). Excess profits can not only support stable capital investment but also maintain high productivity of capital investment. Smaller firms lack access to such channels and are constrained by the traditional production paradigm. A study of full sample firms demonstrates that the total factor productivity of firms in Europe has experienced a slowdown since 1983 (Bellocchi et al. 2021). Additionally, since the financial crisis, the productivity of British firms from all sampled studies has hardly grown at all, a phenomenon famously known as the UK productivity puzzle (Goodridge et al. 2018).

The existing literature indicates that, although research on quoted firms has identified two channels through which asset tangibility can impact the ICFS, these channels may manifest differently in my sample. Specifically, private firms, particularly SMEs, may demonstrate lower returns on capital investment compared to publicly listed firms. Additionally, smaller firms often exhibit higher cash flow persistence, as they are typically limited in their channels to generate cash flow beyond traditional production avenues.

3.3 Methodology and research design

3.3.1 Baseline models and ICFS trend

The first objective of this research is to explore the time varying trend of ICFS for private companies. I test the trend using data split into six subperiods from 1984 to 2019 on three models that

$$\mathrm{INV}_{i,t} = \alpha_{c,t} + \beta_0 + \beta_1 \mathrm{Q}_{i,t-1} + \beta_2 \mathrm{CF}_{i,t} + \beta_3 X_{i,t} + \varepsilon_{i,t} \tag{3.2}$$

$$
\begin{aligned}
\mathrm{INV}_{i,t} =& \alpha_{c,t} + \beta_0 + \beta_1 \mathrm{Q}_{i,t-1} + \beta_2 \mathrm{CF}_{i,t} + \beta_3 \mathrm{CF}_{i,t} * \mathrm{TR}_{i,t} \\
& + \beta_4 \mathrm{TR}_{i,t} + \beta_5 INV_{i,t-1} + \beta_6 X_{i,t} + \varepsilon_{i,t}
\end{aligned} \tag{3.3}
$$

$$
\begin{aligned}
\mathrm{INV}_{i,t} =& \alpha_{c,t} + \beta_0 + \beta_1 \mathrm{Q}_{i,t-1} + \beta_2 \mathrm{Q}_{i,t-1} * \mathrm{TR}_{i,t} + \beta_3 \mathrm{CF}_{i,t} \\
& + \beta_4 \mathrm{CF}_{i,t} * \mathrm{TR}_{i,t} + \beta_5 \mathrm{INV}_{i,t-1} + \beta_6 \mathrm{INV}_{i,t-1} * \mathrm{TR}_{i,t} \\
& + \beta_7 \mathrm{TR}_{i,t} + \beta_8 X_{i,t} + \varepsilon_{i,t}
\end{aligned} \tag{3.4}
$$

The subscript i indexes companies; c indexes industries; and t indexes year. The dependent variable $\mathrm{INV}_{i,t}$ represents the firm's investment, measured by the investment in tangible assets scaled by the beginning-of-period total assets[9]. The fundamental growth opportunity, marginal Q, is controlled by $\mathrm{Q}_{i,t}$, which is measured by the change in the logarithm of sales. The $\mathrm{CF}_{i,t}$ represents cash flow, which is measured by the sum of the firm's after-tax profits and depreciation, scaled by the beginning-of-period total assets. $\mathrm{TR}_{i,t}$ represents the tangible capital ratio, which is the share of tangible assets in total assets at year t. $\mathrm{X_{i,t}}$ is a control vector consisting of commonly used firm characteristic variables, such as firm size and firm age. The industry and time-fixed effects are controlled through $\alpha_{c,t}$. The $\varepsilon_{i,t}$ captures the measurement and other idiosyncratic errors.

It is worth noting that it is acceptable to study the above models without firm fixed effects, which can be more supportive of the impact of asset tangibility, as the variation in asset tangibility mostly stems from cross sections (Zhen and Chu 2021)[10]. This study seeks to manage both firm and industry fixed effects[11], but it could impose collinearity

[9]Previous research has used different scale factors to eliminate the effect of firm size on investment. For example, Fazzari et al. (1987), Moshirian et al. (2017), Larkin et al. (2018) and Zhen and Chu (2021) use total assets, while Ding et al. (2018) use fixed tangible assets. Guariglia (2008) uses recalculated replacement cost of capital as the denominator. To make a comparable study, this research follows the most widely adopted metrics.

[10]As such, the influence of asset tangibility on a firm's investment potentially tends to be consistent within a year but varies from year to year. Therefore, controlling for firm fixed effects in regression might not make much sense, as it could risk generating a sparse model.

[11]The differences in industries can affect ICFS and may introduce biases to our study of asset tangibility. Previous studies address this issue by examining ICFS in a single industry as a robust

with firm fixed effects. To mitigate this concern, this study controls for firm-fixed effects by using firm characteristic variables and controls for industry-fixed effects by UK 2007 SIC codes.

The baseline Model 3.2 is proposed by Fazzari et al. (1987) to measure the presence of ICFS and is the most widely adopted model. Models 3.3 and 3.4 aim to assess the effect of asset tangibility on ICFS through the interaction between the tangible capital ratio and cash flow. Model 3.4 accounts for additional explanatory variables identified as relevant in prior research (Larkin et al. 2018; Moshirian et al. 2017; Zhen and Chu 2021)[12]. These three baseline models are estimated using OLS regression.

The key coefficients of interest are $\frac{\partial \mathrm{INV}_{i,t}}{\partial \mathrm{CF}_{i,t}}$, which measures ICFS, and the coefficient $\frac{\partial \mathrm{INV}_{i,t}}{\partial \mathrm{CF}_{i,t}\mathrm{TR}_{i,t}}$, which measures investment–cash flow–tangible capital sensitivity. Statistically significant coefficients would indicate a significant relationship between asset tangibility, cash flow, and capital investment. The coefficients are estimated within each subperiod to observe how the ICFS changes over time. As suggested by the existing literature, productivity in unquoted firms has been lacklustre since 2000s. Therefore, a decline in the ICFS is expected to be observed across all three models over each sub-period, and the sum of ICFS and investment–cash flow–tangible capital sensitivity should also demonstrate a decrease over time.

To confirm the trend of ICFS and the investment–cash flow–tangible capital sensitivity, I further categorise firms into high asset tangibility ratio (high TR) and low asset tangibility ratio groups (low TR). I test following hypotheses by comparing the changes in ICFS:

Hypothesis 1A: *Companies possessing high asset tangibility may encounter a more substantial reduction in their tangibility ratio, thereby exhibiting a more pronounced decrease in the ICFS.*

test (Guariglia 2008; Larkin et al. 2018).

[12] Models 3.3 and 3.4 diverge from the previous literature in not including equity issued and cash reserves, as these are accounting items pertinent to publicly listed companies only.

Hypothesis 1B: *Companies with low asset tangibility may experience a lesser decline in their tangibility ratio, hence indicating a less marked decrease in the ICFS.*

In line with Hypotheses 1A and 1B, there is expected to be a higher ICFS in magnitude and a larger decrease in ICFS in the high TR group over time.

To ensure the robustness of the analysis, this study adopts two sets of criteria for dividing firms based on asset tangibility. The first criterion is a cross-sectional level separation, where firms are ranked annually according to their tangible asset ratio. The top 50% of firms are assigned to the high TR group based on this ranking. The second criterion involves splitting firms at the industry level. Under the second rule, the average stock of tangible assets and the tangible asset ratios are calculated annually at the industry level over a twenty-year period, from 2000 to 2020. If an industry ranks in the upper percentile in terms of both values during this period, it is classified as a high TR (industry) group. Conversely, if an industry does not meet these criteria, it is classified as a low TR (industry) group.

It is important to note that the two sets of samples are related only in terms of asset tangibility ranking. If asset tangibility is not the driving factor behind the change in ICFS, the two sets of samples could exhibit entirely different ICFS trends. By re-examining the relationship between asset tangibility and ICFS at the industry level, this approach helps address bias estimation concerns related to endogeneity[13].

3.3.2 The mechanism and cross-sectional evidence

In the literature review, two potential channels are identified to explain how asset tangibility influences the ICFS. The first channel proposes that asset tangibility impacts the ICFS by serving as a predictor of marginal productivity. Tangible assets contain valuable information regarding a firm's ability to generate returns. The second chan-

[13] This validation is consistent with similar applications found in recent research, such as the work of Larkin et al. (2018).

nel builds on the idea that high asset intensity is associated with greater cash flow persistence, which, in turn, helps in forecasting future cash flows. In this section, arguments and test propositions are presented from two perspectives: (1) the first channel is applicable to my sample (which primarily consists of unquoted firms); (2) the second channel does not apply to my sample.

The first channel suggest that if the return on tangible capital decreases over time, companies may reduce their investment in tangible assets. This reduced reliance on tangible investment weakens the link between investment and changes in cash flow, leading to a decrease in the sensitivity of investment to cash flow and, consequently, a fading ICFS. To explore this channel, I analyse the sales returns on tangible investment among the high TR and low TR groups using the model that

$$\begin{aligned} \ln(\text{Sales})_{i,t} = &\alpha_{i,c,t} + \theta_0 + \theta_1 \ln(\text{TangbileAssets})_{i,t-1} + \\ &\theta_2 \ln(\text{IntangibleAssets})_{i,t} + \theta_3 \text{X}_{i,t} + \varepsilon_{i,t} \end{aligned} \tag{3.5}$$

The model controls for firm, industry, and time fixed effects, as well as firm characteristics. The θ_1 represents the investment return on tangible assets. If this trend declines in the same way as ICFS declines, an indicative link for the first channel can be established.

To establish a causal understanding of the relationship between investment and tangible asset return, I further conduct tests on the ICFS based on an important implication derived from the first channel. The first channel implies that firms are more likely to reduce investment in tangible assets when they struggle to maintain their productivity. With the literature in Section 3.2.3, I propose that asset tangibility and market power are two significant factors that influence capital investments. Specifically, firms that heavily rely on tangible assets, especially those with lower market power, are more likely to experience investment cuts.

If the first channel holds, we can expect to see a decrease in the ICFS in firms with the least market power and a greater reliance on tangible assets. To test this hypothesis, I classify firms into four distinct groups based on their market power (proxied by total assets, i.e., firm size) and the ratio of tangible assets to total assets (TR). The grouping is performed annually, with firms classified as either large and high TR (top 25% in size and TR), large and low TR, SMEs with high TR, or SMEs with low TR. Based on this categorisation, I propose the following hypothesis:

Hypothesis 2: *The ICFS will exhibit a significant decline primarily in SMEs firms with high TR, while remaining relatively stable in the other groups.*

According to Hypothesis 2, it is expected that the ICFS in large and high TR firms will not exhibit a noticeable decline, as they have the ability to maintain returns on capital due to their high market power. Similarly, the ICFS in large and low TR firms is not expected to decrease significantly, as their cash flow is not primarily generated from tangible assets. On the other hand, the ICFS in SMEs and low TR firms is anticipated to be lower in magnitude and may potentially experience a decline, as their growth relies more on non-tangible assets or alternative sources. Thus, we expect a significant decline in the ICFS to be primarily observed in SMEs firms with high TR.

The second channel suggests that asset tangibility affects the ICFS through cash flow persistence. I argue that this channel does not apply to my sample. The previous literature suggests that high cash flow volatility is typically associated with new production paradigms characterised by higher market power, such as intangible asset-based production, technology-driven operations, stock buybacks, and transformed monopolies (De Loecker et al. 2020; Zhen and Chu 2021). In comparison, the firms in my sample are predominantly smaller, with fewer intangible assets (as demonstrated by summary statistics) and limited access to financing channels. Based on these observations, I propose testing this through the following hypotheses:

Hypothesis 3: *There is no significant declining trend in cash flow persistence over* *time.*

Hypothesis 4: *Asset tangibility has no significant impact on the change in cash flow persistence over time.*

To test Hypothesis 3 and 4, I follow a commonly adopted method (used by Jason and Jenny (2012), Moshirian et al. (2017), and Zhen and Chu (2021)), which uses an autoregressive AR(1) model to test cash flow persistence in the full firm sample that

$$\mathrm{CF}_{i,c,t} = \alpha_{c,t} + \theta_0 + \theta_1 \mathrm{CF}_{i,t-1} + \theta_2 \mathrm{X}_{i,t} + \mu_{i,t} \tag{3.6}$$

$$\mathrm{CF}_{i,c,t} * \mathrm{TR}_{i,t-1} = \alpha_{c,t} + \theta_0 + \theta_1 \mathrm{CF}_{i,t-1} * \mathrm{TR}_{i,t-2} + \theta_2 \mathrm{X}_{i,t} + \mu_{i,t} \tag{3.7}$$

The notion is the same with previous sections. The two models are estimated using Weighted Least Squares (WLS) to mitigate the influence of companies with a large amount of cash flow on the results. The WLS method assigns weights to observations based on the residuals of the first step, giving larger weights to observations with smaller residuals and smaller weights to observations with larger residuals. This approach helps ensure that each observation contributes to the estimation process appropriately. The standard errors are robust and clustered at the firm level, accounting for potential heteroscedasticity and correlation within firms.

3.4 Data and summary statistics

3.4.1 Data

The data utilised in this study is obtained from the Bureau Van Dijk Electronic Publishing's Financial Analysis Made Easy (FAME) database. FAME collects information on companies in the UK from various sources[14]. The information includes financial and accounting data from balance sheets, cash flow statements, profit and loss statements. It also collects legal entity details, merger and acquisition activity, news, corporate structures, and ownership. FAME provides data on active companies by default. To avoid survivorship bias, I collect data from both active and inactive companies for my sample.

99% of the firms in the sample are non-publicly listed companies. There are thirty major industries classified by FAME according to the SIC code. Following previous literature, industries that have little to do with fixed tangible asset production are excluded from this sample[15]. As mentioned, in the robust test firms are classified into the high asset tangibility industry group (high TR) and the low asset tangibility industry group (low TR). The high TR group contains a broad classified industry of construction, civil engineering, real estate, and manufacturing industries. The low TR group contains a broad classified industry of telecommunications, computer engineering, information service, and banking industries.

Firms with less than five consecutive years of data and those without complete records on net tangible assets, sales, and PAIT (earnings after interest and tax) are excluded from the sample. This research aims to study the patterns of the majority of British firms and to avoid interference from unexpected shocks or mergers. Consequently, 1% of firms from the overall distribution with either extremely large or small values are excluded. This approach is in line with previous research in this field, as it has been shown that these firms can have an outsized impact on the results (Bond et al. 2003; Guariglia 2008).

[14] There is also information on companies in Germany and Ireland in FAME, but they are not within the scope of this research.

[15] They are agriculture, forestry and fishing; mining; education service; public administration; art; research services.

3.4.2 Summary statistics

Table 3.1 presents a descriptive summary of the primary variables in the baseline models for each subperiod, comprising investment (INV), Tobin Q (Q), cash flow (CF), and the tangibility ratio (TR). The total number of firm-year observations amounts to 781,314. This sample size significantly surpasses that of existing studies investigating ICFS with global firm data[16]. In contrast to existing literature, my sample offers a more comprehensive perspective by incorporating all extant companies, encompassing both active and inactive firms each year. The number of observations in each subperiod is substantially larger compared to the current literature, with the peak number of observations observed during the 2005-2009 subperiod.

The investment, adjusted by the beginning-of-period total assets, is a key variable of interest. It moderately fluctuates from 5.1% in the first subperiod, to around 4.1% in the subsequent three subperiods before sharply declining to 2.7% in the last two periods. This decline aligns with the global trend observed in publicly listed firms, where investment has significantly decreased over the past six decades, from approximately 7% to 4% (Moshirian et al. 2017; Y. Wang et al. 2014). The standard deviation of the investment ratio, as reported in previous literature, has also decreased over time, from 0.06 in 1976 to 0.04 in 2016. My statistics reveal a similar trend, with the standard deviation declining from around 0.2 in the first four periods to 0.13 in the last period. This suggests that firms are becoming more consistent in reducing their investment in tangible capital, which may contribute to a more significant decline in the ICFS.

Similarly to the investment ratio, the other control variables, namely Tobin Q, cash flow, and tangibility ratio, also display a trend of fluctuation followed by a sharp decrease in my sample's investment. However, the change in Tobin Q differs from previous literature. While publicly listed firms in most countries have exhibited a

[16] For instance, Moshirian et al. (2017) examine data from 41 countries with 118,616 firm-year observations. Larkin et al. (2018) analyse data from 43 countries with 419,318 firm-year observations. Zhen and Chu (2021) investigate publicly listed manufacturing firms in the US, with approximately 2,000 firm observations in each ten-year subperiod.

Table 3.1: Descriptive statistics of key variables over time

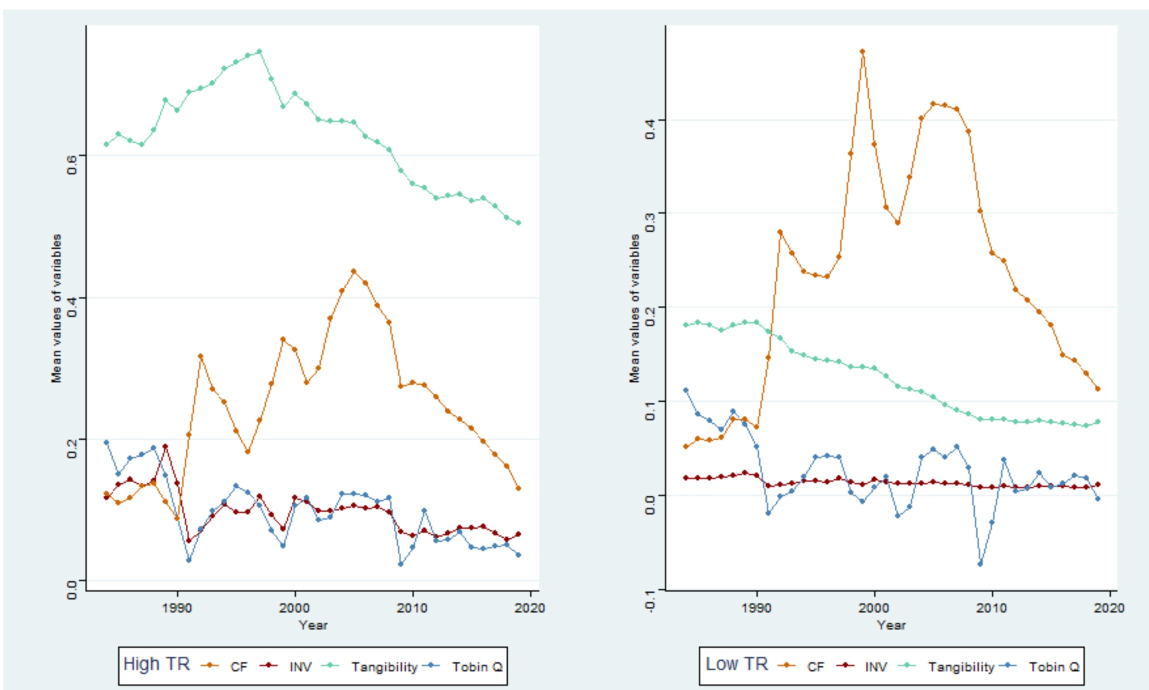
	All	1984-1994	1995-1999	2000-2004	2005-2009	2010-2014	2015-2019
INV Mean	0.036	0.051	0.041	0.044	0.042	0.029	0.027
St. Dev.	(0.172)	(0.178)	(0.201)	(0.199)	(0.192)	(0.151)	(0.13)
Tobin Q Mean	0.031	0.091	0.038	0.036	0.048	0.015	0.024
St. Dev.	(0.58)	(0.385)	(0.492)	(0.579)	(0.629)	(0.588)	(0.515)
CF Mean	0.308	0.081	0.242	0.344	0.406	0.303	0.180
St. Dev.	(1.78)	(0.188)	(1.237)	(1.736)	(2.037)	(1.923)	(1.419)
Tangibility Ratio Mean	0.236	0.296	0.303	0.282	0.247	0.207	0.194
St. Dev.	(0.306)	(0.28)	(0.337)	(0.335)	(0.326)	(0.284)	(0.258)
Total N	781314	7815	36972	149323	232995	192829	127622

Note: The table presents the means and standard deviation of the variables used in baseline models. The sample period is from 1984 to 2019. The variable INV represents an investment, measured by the change in fixed assets scaled by the beginning-of-period total assets. The variable Tobin Q measures marginal capital productivity and is proxied by the sales growth rate. The variable CF represents cash flow, measured by the sum of PAIT and depreciation, scaled by the beginning-of-period total assets. The variable tangibility ratio is also referred to as TR, which is the ratio of tangible assets to total assets. N is the total number of firm-year observations.

persistent increase or a U-shaped trend, rising from the period of 1996-2006 until today, my findings suggest that the growth prospects for firms within our sample are not as optimistic. This provides an indicative sign for the declining ICFS, as it suggests the growth information is diminishing in general. When neither tangible assets nor Tobin's Q serve as indicators of profitability, firms are inclined to reduce their capital investment further among private firms. In contrast, publicly listed companies have alternative mechanisms for profitability and growth, enabling them to anticipate sustainable growth even with less investment in tangible capital.

The mean of cash flow also follows a U-shaped trend, peaking at 0.406 during the 2005-2009 subperiod. The decline observed in the last two periods is anticipated, aligning with the global trend across both developed and developing economies. The magnitude of cash flow in our sample is akin to that of publicly listed companies in developing countries, while in developed countries, the figure has decreased to zero or even turned negative, as observed in Sweden, Canada, Australia, and the US, as demonstrated by Larkin et al. (2018). Another notable difference from previous research is that the standard deviation in publicly listed firms has significantly increased (from 0.07 in 1976 to 0.26 in 2016 as documented by Zhen and Chu (2021)), while it decreases in my sample (from 2.037 in the fourth period to 1.419 in the last period). This provides evidence that the ICFS decrease in their sample is due to less cash flow predictability, whereas this channel does not apply to our sample. In this sample, the cash flow decreases with a considerable degree of certainty. The tangibility ratio has seen a decline with a smaller standard deviation, with further details discussed in the section on cross-sectional statistics.

Figure 3.2: The mean plot of variables in two asset tangibility groups



Note: This figure illustrates the change in the mean value of the main variables over time. The sample period ranges from 1984 to 2019. High TR groups (left figure) consist of firms from high asset tangibility group, while low TR groups (right figure) consist of firms from low asset tangibility group.

Figure 3.2 depicts the annual time-varying mean values of the primary variables for both the high asset tangibility group (left figure) and the low asset tangibility group (right figure). The monotonic declining trend of Tobin's Q in both plots is similar to the trend in the full sample. The investment ratio shows a much steeper decline in high-asset tangibility groups.

The key observation is the trend of the average tangible asset ratio, which shows a steeper decline in the left figure, which is the high TR firm group. It decreases from its highest point of 0.7 to its lowest point of 0.5. In contrast, the ratio in the right figure experiences a less pronounced decline, decreasing from approximately 0.18 to 0.08. Thus, the decline in the overall sample mean, as displayed in Table 3.1, is primarily driven by the decline in the high TR firm group.

Comparatively, the cash flow in both plots exhibits a very similar trend over time, with a steady decline post-2008. This lends credence to my contention that the second channel is not applicable in my case. Companies in the high tangibility group do not reduce their tangible investment more as cash flow experiences a more considerable decrease. Meanwhile, the group with low tangible assets displays a higher average level of cash flow unpredictability. If the reduction in cash flow persistence were the primary catalyst behind the decline in ICFS, we would expect to witness a steeper decline of investment ratio within the low asset tangibility group.

3.5 Results

3.5.1 Baseline result and ICFS trend

Table 3.2 presents the main coefficients of Model 3.2, 3.3, and 3.4. Model 3.2 investigates the relationship between a firm's investment, Tobin's Q, and cash flow while controlling for main firm characteristics variables and fixed effects. The focus is on the trend of the coefficient of cash flow (i.e., the coefficient of CF, representing the ICFS). Models 3.3 and 3.4 examine the interaction effects of asset tangibility and cash flow while incorporating additional investment-relevant control variables. The key interest in Models 3.3 and 3.4 is the coefficient of cash flow interacted with asset tangibility ($CF * TR$).

In the result panel of Model 3.2, the coefficients of cash flow are statistically significant at the 0.1 percent level. The ICFS is 0.088 in the first period and declines to approximately 0.011 in the 2000s. These estimations are consistent with the findings of Guariglia (2008), who examines the ICFS with UK data from 1993 to 2003. In the research, the ICFS fluctuates around 0.038 in the manufacturing industry and 0.055 in the full sample during that period.

The first panel of Table 3.2 indicates that the ICFS shows a decreasing pattern over time, ranging from 0.088 in the first period to 0.008 and 0.012 in the fifth and sixth periods, respectively. The point estimates of 0.088 and 0.012 are frequently employed to compute the elasticity of investment relative to cash flow. When evaluated at the mean level of cash flow and the investment ratio, this elasticity declines from 0.139 in the first subperiod to 0.080 in the final subperiod[17]. This implies that a 10 percent increase in cash flow would have previously resulted in a 1.39 percent increase in investment during the first subperiod, but this has decreased to a 0.8 percent increase in the final subperiod[18]. The decreasing ICFS trend confirms that the ICFS also decreases in non-publicly listed British firms, and the decreasing magnitude is similar to that of publicly listed firms (Larkin et al. 2018; Moshirian et al. 2017).

The second and third panels of Table 3.2 differ from the first panel by including terms for the asset tangibility ratio (TR) and other potentially relevant control factors. The consistent estimations across CF, TR, and $CF * TR$ terms in the second and third panels indicate that the interaction models are robust in explaining firms' investment. In the subsequent discussion, we focus on the results presented in the second panel.

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[17]The elasticity of investment with respect to cash flow can be calculated as follows: $\frac{\frac{ICFS}{\mu_I}}{\frac{1}{\mu_{CF}}}$.

[18]As this study primarily focuses on analysing the ICFS, further elasticity calculations will not be conducted in the following section.

The coefficient of CF is negative after controlling for asset tangibility, and the interaction term coefficient is statistically significant and high in magnitude. These findings imply that the ICFS is largely driven by asset tangibility, and the investment-cash flow sensitivity is essentially an investment-cash flow-tangible capital sensitivity. The interaction coefficient of CF and TR shows a significant downward trend, decreasing from 0.328 in the first period to 0.074 by 2013, with a slight rebound to 0.095 in the final period. This steep decline suggests that the information contained in tangible assets for predicting investment growth has decreased over time in UK firms. After taking into account the interaction term, the sum of the coefficients of CF and $CF * TR$ is 0.251 in the first period and 0.084 in the last period, which is still a decreasing trend. This collectively indicates that firms with higher tangible assets in total capital tend to prioritise tangible investment when they have surplus cash, resulting in a higher ICFS.

In the first two panels of Table 3.2, the coefficient of the marginal capital productivity term (represented by Q) remains statistically significant but diminishes across the six periods. This coefficient deviates from previous literature employing the same models, where tangible capital investment is found to increase or remain stable with the increase in Tobin's Q among quoted firms (Larkin et al. 2018; Zhen and Chu 2021). This implies a divergence between quoted and unquoted firms: unquoted companies have become less responsive in their tangible investments when encountering fluctuations in growth opportunities. Considering the substantial decrease in Tobin's Q over the past four decades in both the high TR and low TR firm groups, this observation is anticipated, as seen in summary plot 3.2.

Table 3.2: The change of ICFS over time - Baseline models

	3.2: $\text{INV}_{i,t} = \alpha_{c,t} + \beta_0 + \beta_1 \text{Q}_{i,t-1} + \beta_2 \text{CF}_{i,t} + \beta_3 X_{i,t} + \varepsilon_{i,t}$					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
Tobin Q	0.019 (0.004)***	0.011 (0.002)***	0.011 (0.001)***	0.004 (0.000)***	0.003 (0.000)***	0.003 (0.000)***
CF	0.088 (0.008)***	0.021 (0.001)***	0.011 (0.000)***	0.010 (0.000)***	0.008 (0.000)***	0.012 (0.000)***
Company fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.066	0.032	0.018	0.017	0.016	0.020
Adj. R^2	0.056	0.030	0.017	0.017	0.015	0.019
Num. obs.	7026	29940	135648	223725	183325	119017

	3.3: $\text{INV}_{i,t} = \alpha_{c,t} + \beta_0 + \beta_1 \text{Q}_{i,t-1} + \beta_2 \text{CF}_{i,t} + \beta_3 \text{CF}_{i,t} * \text{TR}_{i,t} + \beta_4 \text{TR}_{i,t} + \beta_5 INV_{i,t-1} + \beta_6 X_{i,t} + \varepsilon_{i,t}$					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
Tobin Q	0.014 (0.003)***	0.008 (0.001)***	0.010 (0.001)***	0.006 (0.000)***	0.003 (0.000)***	0.003 (0.000)***
CF	−0.077 (0.008)***	−0.013 (0.001)***	−0.011 (0.000)***	−0.011 (0.000)***	−0.010 (0.000)***	−0.011 (0.000)***
TR	0.296 (0.005)***	0.167 (0.002)***	0.201 (0.001)***	0.205 (0.001)***	0.159 (0.001)***	0.160 (0.001)***
CF*TR	0.328 (0.020)***	0.100 (0.003)***	0.071 (0.001)***	0.067 (0.001)***	0.074 (0.001)***	0.095 (0.001)***
Company characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.487	0.295	0.315	0.341	0.279	0.292
Adj. R^2	0.481	0.293	0.315	0.340	0.278	0.292
Num. obs.	7026	29940	135648	223725	183325	119017

Table 3.2 (Continued)

	3.4: $\text{INV}_{i,t} = \alpha_{c,t} + \beta_0 + \beta_1 \text{Q}_{i,t-1} + \beta_2 \text{Q}_{i,t-1} * \text{TR}_{i,t} + \beta_3 \text{CF}_{i,t} + \beta_4 \text{CF}_{i,t} * \text{TR}_{i,t} + \beta_5 \text{INV}_{i,t-1} + \beta_6 \text{INV}_{i,t-1} * \text{TR}_{i,t} + \beta_7 \text{TR}_{i,t} + ..$					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
Tobin Q	-0.001 (0.004)	-0.002 (0.002)	-0.003 (0.001)***	0.001 (0.000)**	0.000 (0.000)	-0.000 (0.000)
CF	-0.076 (0.008)***	-0.013 (0.001)***	-0.011 (0.000)***	-0.011 (0.000)***	-0.010 (0.000)***	-0.011 (0.001)***
TR	0.292 (0.006)***	0.166 (0.002)***	0.192 (0.001)***	0.203 (0.001)***	0.157 (0.001)***	0.159 (0.001)***
CF*TR	0.321 (0.020)***	0.100 (0.003)***	0.072 (0.001)***	0.067 (0.001)***	0.074 (0.001)***	0.095 (0.001)***
Company characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.491	0.299	0.313	0.341	0.280	0.295
Adj. R^2	0.486	0.297	0.313	0.340	0.279	0.294
Num. obs.	7010	29731	124154	220396	180610	117765

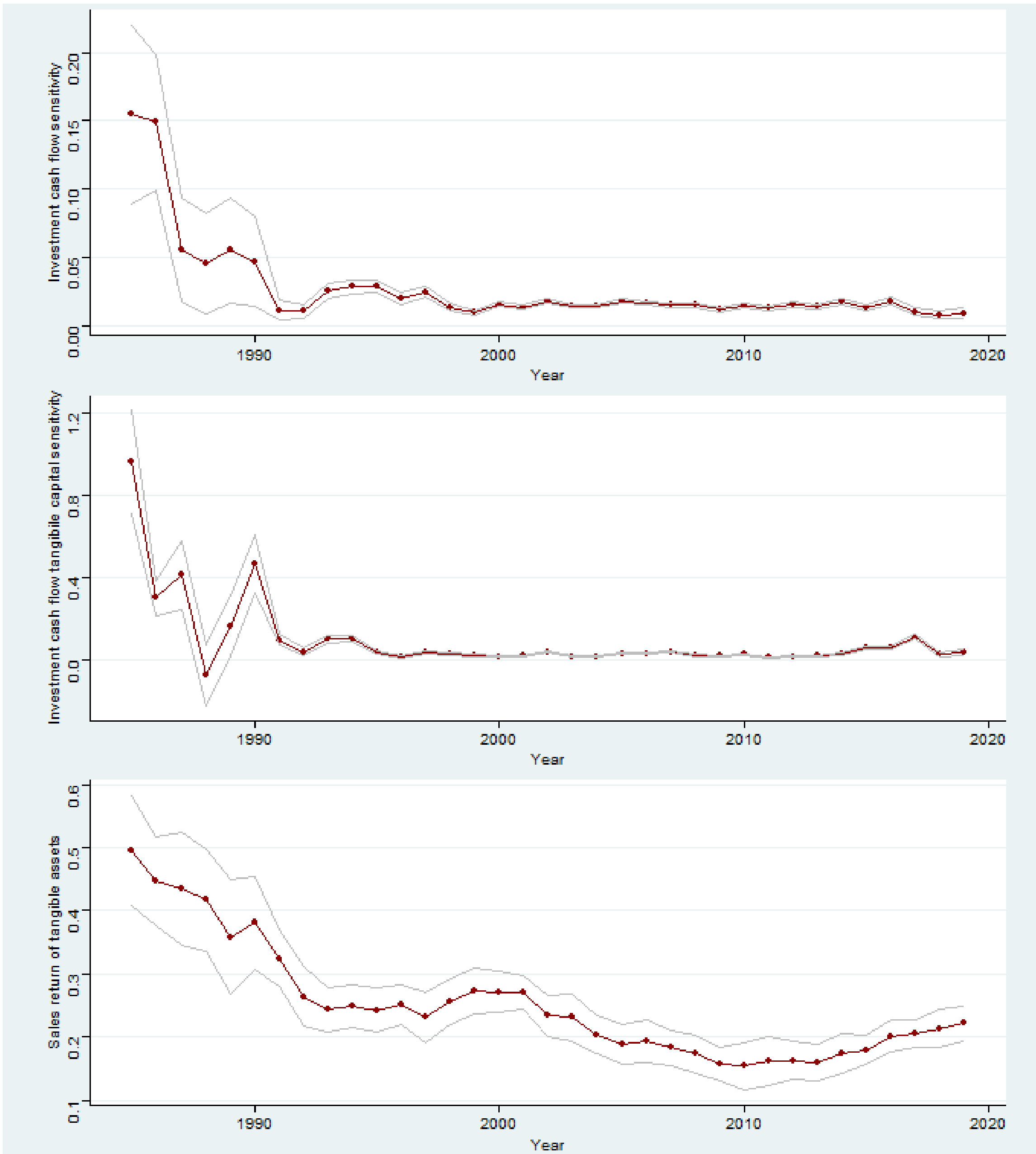
Note: The table presents the main coefficients of Model 3.2, 3.3, and 3.4. Model 3.2 examines the relationship between a firm's investment, Tobin's Q, and cash flow. Model 3.3 and 3.4 examine the interaction effects of asset tangibility and cash flow while incorporating more relevant control variables. Only essential variables are reported. The models are estimated within each subperiod to investigate the time-evolving trend of the coefficients. The variable INV represents investment, measured by the change in fixed assets scaled by the beginning-of-period total assets. Tobin's Q measures marginal capital productivity and is proxied by the sales growth rate. The variable CF represents cash flow, measured by the sum of PAIT and depreciation scaled by the beginning-of-period total assets. X is a control vector consisting of commonly used firm characteristics. The industry and time-fixed effects are controlled through $\alpha_{c,t}$. The coefficient of Q is investment-Q sensitivity; The coefficient of CF is the ICFS. Num. obs is the total number of firm-year observations. The sample period spans from 1984 to 2019. The standard errors of estimated coefficients are reported in parentheses. The R-squared and adjusted R-squared values are reported as measurements of goodness-of-fit, and the significance level is denoted as $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

The ICFS estimations presented earlier are calculated for six subperiods spanning a period of thirty-six years. However, these average trends may not fully capture the time variations of the ICFS. To provide a more detailed analysis, I calculate the cross-sectional ICFS for each year and present it in Figure 3.3. In this analysis, all variables are demeaned by year to eliminate the fixed effect of firms. Additionally, industry fixed effects and firm characteristics are controlled for, similar to previous models. Figure 3.3 displays the yearly ICFS estimations along with the sensitivity between investment, cash flow, and tangible capital. The coefficients shown in the upper plot are derived using Model 3.2, while the middle plot illustrates the interaction coefficients of cash flow and asset tangibility ratio, calculated using Model 3.4.

Figure 3.3 yields findings highly comparable to the baseline models shown in Table 3.2. The confidence interval indicates that all the coefficients are statistically significant. A significant decrease in the ICFS (illustrated in the upper plot) is observed from the beginning to the 2000s, and it remains at a low level from 2000 to 2019. The investment-cash flow-tangible capital sensitivity ($CF * TR$), as shown in the middle plot, consistently exceeds the ICFS coefficients throughout the entire observation period, demonstrating a similar decreasing trend. This continues to support my argument that the change in ICFS is primarily driven by the level of tangible assets in companies. Every year, high asset tangibility companies are relatively more reactive to cash flow when making capital investments. They make more investments when they have more internal cash flow, displaying higher ICFS. As comparison, the investments of low-tangible asset firms are much less sensitive to changes in cash flow.

To investigate whether the declining ICFS is attributable to decreasing investment returns on capital investments, I present the yearly estimation of sales return on tangible assets in the lower plot of Figure 3.3. It demonstrates a noticeable decline at a similar rate over time, particularly from 1984 to 2000, coinciding with the period of decreasing ICFS. This finding, coupled with the decrease in investment-Q sensitivity, provides further evidence to support the hypothesis that the decline in investment returns may

Figure 3.3: Annual Trends in ICFS and investment-cash flow-tangible capital sensitivity



Note: This figure presents the changes in the ICFS estimated by Model 3.2 (upper plot) and the investment-cash flow-tangible capital sensitivity estimated by Model 3.4 (middle plot), as well as the sales return of tangible assets estimated by Model 3.5 (lower plot). The coefficients are estimated annually with demeaned values to remove the firm fixed effect. It can be observed that the ICFS decreases significantly until the 2000s, with particularly lower coefficients from 2000 to 2019. The investment-cash flow-tangible capital sensitivity is higher in magnitude and exhibits a more severe decline. The sales return of tangible assets has also decreased sharply over time.

contribute to the insufficient capital investment in recent years, ultimately leading to the diminished ICFS.

3.5.2 The mechanism and cross-sectional evidence

Table 3.3: The change of ICFS over time - High TR and Low TR groups

	High TR group: $\text{INV}_{i,t} = \alpha_{c,t} + \beta_0 + \beta_1 \text{Q}_{i,t-1} + \beta_2 \text{CF}_{i,t} + \beta_3 X_{i,t} + \varepsilon_{i,t}$					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
Tobin Q	0.053 (0.014)***	0.026 (0.006)***	0.031 (0.002)***	0.016 (0.001)***	0.012 (0.001)***	0.012 (0.002)***
CF	0.168 (0.028)***	0.064 (0.004)***	0.029 (0.001)***	0.023 (0.001)***	0.021 (0.001)***	0.030 (0.002)***
Company characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.134	0.080	0.051	0.033	0.036	0.037
Adj. R^2	0.100	0.069	0.049	0.031	0.035	0.034
Num. obs.	1748	7178	33174	55646	45606	29586

	Low TR group: $\text{INV}_{i,t} = \alpha_{c,t} + \beta_0 + \beta_1 \text{Q}_{i,t-1} + \beta_2 \text{CF}_{i,t} + \beta_3 X_{i,t} + \varepsilon_{i,t}$					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
Tobin Q	0.005 (0.002)***	0.004 (0.001)***	0.004 (0.000)***	0.002 (0.000)***	0.001 (0.000)***	0.001 (0.000)***
CF	0.018 (0.003)***	0.005 (0.000)***	0.003 (0.000)***	0.003 (0.000)***	0.002 (0.000)***	0.002 (0.000)***
Company characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.043	0.028	0.019	0.027	0.028	0.019
Adj. R^2	0.030	0.024	0.018	0.026	0.027	0.018
Num. obs.	5278	22762	102474	168079	137719	89431

Note: The table presents the main coefficients of Model 3.2, which examines the relationship between a firm's investment, Tobin's Q, and cash flow. The first and second panels are estimated on firms from high and low asset tangibility groups, which are ranked by tangible asset ratio every year; firms with asset tangibility ratio ranking in the top quarter percentile are in the high TR group. Only essential variables are reported. The models are estimated within each subperiod to investigate the time-evolving trend of the coefficients. The variable INV represents investment, measured by the change in fixed assets scaled by the beginning-of-period total assets. Tobin's Q measures marginal capital productivity and is proxied by the sales growth rate. The variable CF represents cash flow, measured by the sum of PAIT and depreciation scaled by the beginning-of-period total assets. X is a control vector consisting of commonly used firm characteristics. The industry and time-fixed effects are controlled through $\alpha_{c,t}$. β_1 is investment-Q sensitivity; β_2 is the ICFS. Num. obs is the total number of firm-year observations. The sample period spans from 1984 to 2019. The standard errors of estimated coefficients are reported in parentheses. The R-squared and adjusted R-squared values are reported as measurements of goodness-of-fit, and the significance level is denoted as $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

To verify that the ICFS is indeed the investment-cash flow-tangible capital sensitivity, I conducted a heterogeneity analysis that examines the trend of ICFS in high and low tangible ratio (TR) firm groups. Firms are ranked annually based on their tangible asset ratio, with those in the top half classified as the high TR group. Table 3.3 displays the results estimated by Model 3.2. In the high TR group (upper panel), the coefficients of cash flow (CF, i.e., ICFS), have decreased from 0.168 in the first subperiod to 0.030 in the last subperiod. In contrast, the ICFS in the low TR group (lower panel) has fallen from 0.018 in the first subperiod to 0.002 in the last subperiod. The absolute value decrease is 0.138 in the high TR group and 0.016 in the low TR group. These findings support Hypotheses 1A and 1B, which posit that higher asset tangibility is associated with higher ICFS and experiences a larger decline in ICFS, while a smaller magnitude decline in ICFS is observed in low asset tangibility groups. The difference in the magnitude of the decline supports our theory that the decrease of ICFS in the full sample is primarily driven by firms with high asset tangibility.

Interestingly, investment-Q sensitivity has declined in both high and low TR groups, but remains higher in the high TR group, consistent with the ICFS. This suggests that capital investment-return pattern is generally linked to tangible capital's role in production. In contrast, the investment-Q sensitivity in low TR groups is near zero, similar to most publicly listed firms (Moshirian et al. 2017). This indicates that the investment behaviour of low TR firms has significantly deviated from the traditional production paradigm. Their tangible capital investment has relied less on cash flow nor on marginal productivity over time.

Table 3.4: Changes in tangible asset returns over time - High TR and Low TR groups

	High TR: $\ln(\text{Sales})_{i,t} = \alpha_{i,c,t} + \theta_0 + \theta_1 \ln(\text{TangbileAssets})_{i,t-1} + \theta_2 \ln(\text{IntangibleAssets})_{i,t} + \theta_3 \text{X}_{i,t} + \varepsilon_{i,t}$					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
ln(Tangible assets)	0.585 (0.084)***	0.654 (0.059)***	0.574 (0.027)***	0.414 (0.016)***	0.421 (0.021)***	0.359 (0.028)***
ln(Intangible assets)	0.027 (0.012)*	0.045 (0.011)***	0.018 (0.006)**	0.017 (0.002)***	0.013 (0.002)***	0.009 (0.002)***
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Num. obs.	1835	7770	35080	57199	47581	31263
R^2	0.953	0.972	0.983	0.982	0.986	0.989
Adj. R^2	0.926	0.949	0.968	0.971	0.979	0.984

	Low TR: $\ln(\text{Sales})_{i,t} = \alpha_{i,c,t} + \theta_0 + \theta_1 \ln(\text{TangbileAssets})_{i,t-1} + \theta_2 \ln(\text{IntangibleAssets})_{i,t} + \theta_3 \text{X}_{i,t} + \varepsilon_{i,t}$					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
ln(Tangible assets)	0.334 (0.056)***	0.196 (0.011)***	0.194 (0.006)***	0.160 (0.004)***	0.132 (0.004)***	0.125 (0.005)***
ln(Intangible assets)	0.010 (0.011)	0.018 (0.005)***	0.032 (0.004)***	0.024 (0.002)***	0.026 (0.002)***	0.021 (0.002)***
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Num. obs.	5540	24033	107032	172725	143208	94394
R^2	0.942	0.965	0.967	0.970	0.976	0.974
Adj. R^2	0.921	0.946	0.945	0.958	0.967	0.965

Note: The table presents the results of Model 3.5, which examines the relationship between a firm's tangible investment and sales. The first and second panels are estimated on firms from high and low asset tangibility groups, which are ranked by tangible asset ratio every year; firms with asset tangibility ratio ranking in the top quarter percentile are in the high TR group. Only essential variables are reported. The models are estimated within each subperiod to investigate the time-evolving trend of the coefficients. X is a control vector consisting of commonly used firm characteristics. The firm, industry, and time-fixed effects are controlled through $\alpha_{i,c,t}$. The sample period spans from 1984 to 2019. The standard errors of estimated coefficients are clustered at the firm level and are reported in parentheses. The R-squared and adjusted R-squared values are reported as measurements of goodness-of-fit, and the significance level is denoted as $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

It has been observed that the decline of ICFS is primarily driven by the decrease of ICFS in high asset tangible ratio firms. I put forth the first channel through which asset tangibility impacts ICFS: the decline in ICFS arises from a reduction in the productivity information contained in tangible assets. To test this hypothesis, I measure the productivity information using the sales return of tangible assets and examine whether it demonstrates a correlated trend with ICFS. It is estimated by Model 3.5. Table 3.4 reports the time-varying sales return on the accumulation in tangible and intangible assets. In the first panel, the coefficient is 0.585 in the first subperiod, indicating that a 1 percent increase in tangible assets leads to a 5.85 percent increase in sales[19]. This figure declines to 0.359 percent in the final subperiod. In the second panel, the coefficient is much lower (0.334) in the first subperiod, with a smaller decline to 0.125 in the final subperiod.

As expected, high TR firms heavily depend on tangible assets to propel their growth, despite their declining productivity. It's worth noting that even the return on intangible assets within the high TR group has experienced a decrease over time. Conversely, firms with a low tangibility ratio are less reliant on fixed assets for income generation, but they have managed to attain higher returns on their intangible assets. Nevertheless, their overall investment return has been sluggish and less substantial compared to high TR firms. This could suggest that the productivity of UK firms is dominated by the productivity decline in high TR firms. The decreasing return trends in both groups align significantly with the changes observed in the ICFS in the respective groups. This provides additional support for, and elucidation of, Hypotheses 1A and 1B.

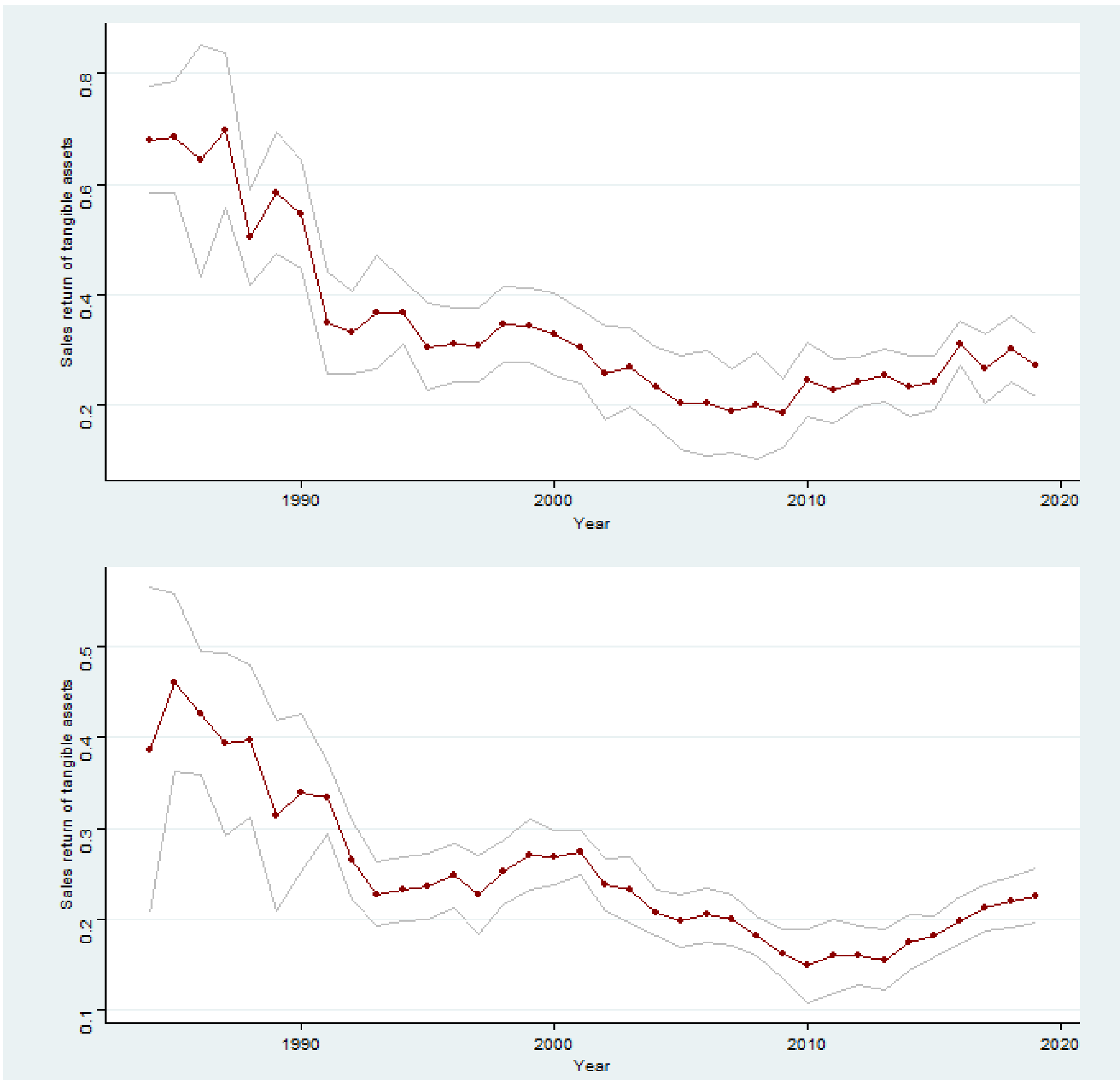
For robustness, I re-examine the trend of ICFS and sales return on tangible assets by subdividing the sample at the industry level, as shown in Table 3.11 and 3.12. An industry is classified as a high TR (industry) group if it ranks in the upper percentile by both values from 2000-2020; otherwise, it is categorised as a low TR (industry) group. Table 3.11 demonstrates that the trend of ICFS closely resembles the results separated

[19]As the variables are measured in logarithms, the coefficient of the tangible asset is interpreted as elasticity.

in a cross-sectional manner in Table 3.3. Table 3.12 reveals that the sales return of tangible capital is highly similar to the results separated in a cross-sectional fashion in Table 3.4. As discussed in the methodology section, the samples divided by the two methods relate only to asset tangibility. The consistent trend observed in both samples strengthens the argument for the impact of asset tangibility on ICFS. Moreover, this robust test helps mitigate concerns about endogeneity. This is because, if there were an omitted variable affecting ICFS, it would have to account for the observed industrial variation and present a highly consistent estimations in both samples, which is highly unlikely.

Figure 3.4 displays the sales return on tangible assets estimated cross-sectionally for each year. All variables are demeaned to remove the firm fixed effect, and all coefficients are statistically significant. A noteworthy observation is that the coefficients in high TR groups are consistently much higher – nearly twice as high – as those in low TR groups in many years. Meanwhile, it can be seen that the coefficients of tangible assets in the high TR group decrease from 0.7 to above 0.2, while in the low TR group, they drop from 0.45 to above 0.15. The declining trends in both high and low TR groups are also in line with the findings in Table 3.4, which supports the conjecture that the decline in ICFS results from a reduction in productivity information contained in tangible assets. This finding further suggests that a larger drop in sales return could lead to a more significant decline in ICFS in high TR firms.

Figure 3.4: The annual sale return of tangible assets - high TR and low TR firms



Note: The figure portrays the sales return of tangible assets estimated for high TR and low TR firms. The TR refers to the tangible to total assets ratio, which is ranked every year; firms with asset tangibility ratio ranking in the top half are in the high TR group. The data is estimated annually using Model 3.5. All variables are demeaned to eliminate the firm fixed effect. The sales return on tangible capital is higher in the high TR group, exhibiting a larger decline. The return has been decreasing in both groups.

Table 3.5: The change of ICFS over time - comparison in four groups

	Large firms with high TR					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
CF	0.988 (0.115)***	0.513 (0.053)***	−0.059 (0.004)***	0.027 (0.005)***	0.009 (0.002)***	0.053 (0.010)***
Company characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.270	0.090	0.083	0.027	0.032	0.040
Adj. R^2	0.181	0.058	0.075	0.023	0.026	0.030
Num. obs.	434	2036	10018	17061	12714	7341

	Large firms with low TR					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
CF	0.016 (0.006)**	0.005 (0.002)*	0.000 (0.001)	0.001 (0.000)**	0.000 (0.000)	0.001 (0.000)**
Company characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.110	0.044	0.024	0.013	0.023	0.030
Adj. R^2	0.070	0.030	0.021	0.011	0.020	0.026
Num. obs.	1207	5320	24231	39638	34049	23845

	SMEs firms with high TR					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
CF	0.263 (0.046)***	0.064 (0.003)***	0.011 (0.001)***	0.009 (0.001)***	0.008 (0.000)***	0.011 (0.001)***
Company characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.120	0.100	0.037	0.021	0.033	0.037
Adj. R^2	0.069	0.087	0.033	0.019	0.030	0.034
Num. obs.	1073	5169	23378	39048	33080	22262

Table 3.5 (Continued)

	SMEs firms with low TR					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
CF	0.018 (0.004)***	0.005 (0.000)***	0.002 (0.000)***	0.002 (0.000)***	0.002 (0.000)***	0.000 (0.000)***
Company characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.057	0.033	0.017	0.021	0.033	0.015
Adj. R^2	0.039	0.028	0.016	0.021	0.033	0.014
Num. obs.	3345	17547	78956	129480	104300	65824

Note: The table presents the main coefficients of Model 3.2, which examines the relationship between a firm's investment, Tobin's Q, and cash flow. The first and second panels are estimated on firms from high and low asset tangibility groups, which are ranked by tangible asset to total assets ratio every year; firms with asset tangibility ratio ranking in the top quarter percentile are in the high TR group. Only essential variables are reported. The variable INV represents investment, measured by the change in fixed assets scaled by the beginning-of-period total assets. Tobin's Q measures marginal capital productivity and is proxied by the sales growth rate. The variable CF represents cash flow, measured by the sum of PAIT and depreciation scaled by the beginning-of-period total assets. X is a control vector consisting of commonly used firm characteristics. The industry and time-fixed effects are controlled through $\alpha_{c,t}$. β_2 is the ICFS. Num. obs is the total number of firm-year observations. The sample period spans from 1984 to 2019. The standard errors of estimated coefficients are reported in parentheses. The R-squared and adjusted R-squared values are reported as measurements of goodness-of-fit, and the significance level is denoted as $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

I further examine an implication of the above results to test the robustness of the first channel. The aforementioned findings suggest that companies reduce their investment in tangible assets as the return on such capital investment decreases, leading to a decline in capital intensity and a fading ICFS. This contains a major implication that a more prominent decline in ICFS should be observed in companies experiencing a faster decrease in return on tangible investment. Conversely, companies that can maintain high productivity should not exhibit a declining ICFS. These contrasting patterns will be particularly evident between low TR and high TR firms. To evaluate this theory, companies are divided into four groups based on asset tangibility and market power (proxied by total assets), with a split at the first percentile level: (1) large firms with high TR, (2) large firms with low TR, (3) SMEs with high TR, and (4) SMEs with low TR. I propose as Hypothesis 2 that the ICFS will exhibit a significant decline mainly in the group (3). Firms in the group (3), characterised by lower market power, are expected to face greater challenges in maintaining sales return (De Loecker et al. 2020). Meanwhile, these firms also heavily rely on tangible assets for production, making them the group that experiences the fastest decline in tangible asset return.

Table 3.5 demonstrates the time-varying trend of ICFS in four different groups. In the third group, it can be seen that the ICFS is steadily decreasing, from 0.263 in the first subperiod, to 0.011 in the final subperiod. In the second and fourth groups (i.e. low TR groups), the ICFS is much smaller in magnitude (0.016 in the second group and 0.018 in the fourth group), with a very minor decline to almost zero over the subsequent four subperiods. In the first group with large market power and high tangible assets, there appears to be no significant trend of ICFS. The four sets of evidence jointly support our Hypothesis 2. According to Hypothesis 2, ICFS in large and high TR firms will not significantly decrease as they are capable of maintaining investment returns on tangible capital with the highest market power; ICFS in large and low TR firms will not significantly decrease as their cash flow are predominantly not generated by tangible assets; ICFS in SMEs and low TR firms will be low in magnitude and may possibly witness a decrease as their growth also comes more from non-tangible assets or alternative financial channels. By this result, additional confidence is established that the decline in ICFS is primarily driven by the reduced return on tangible assets.

In addition, a key premise for the above inference is that the market power separation indeed represents the different abilities to maintain tangible capital productivity. Therefore, I examine the sales return on tangible capital using Model 3.5 for the four groups, and the results are presented in Table 3.13. This analysis confirms that, in both high or low TR splits, the sales return of tangible capital for large firms is generally greater than that of SMEs.

Lastly, an investigation is conducted to examine the second channel through which asset tangibility can impact the decline in the ICFS. The second channel is based on the notion that firm's capital investment varies with cash flow because cash flow provides information about marginal productivity. High cash flow predictability incentivises firms to invest more in tangible capital to generate future cash flow (Riddick and Whited 2009). If cash flow loses its predictive power over time, there will be a decline in ICFS.

Although documented by Chen and Chen (2012) and Moshirian et al. (2017), the information contained in cash flow has dramatically decreased in firms in the US and in large firms of developed economies, which partly explains the fading ICFS. I argue that this is not the case in our sample, which mainly consists of SMEs. Large publicly listed firms typically have more sources to generate cash and are less financially constrained. However, firms in our sample rely largely on tangible capital or intangibles to produce, as presented in Table 3.4. Meanwhile, as per the summary plot in Figure 3.2, there hasn't been any significant difference in the variation of cash flow between high TR and low TR firm groups. This suggests that the channel regarding cash flow persistence may not be applicable in the context of this study.

Table 3.7 shows the estimation results of the autoregression of cash flow, which is a proxy for cash flow persistence. From the first panel, it is observed that the persistence of cash flow does not decrease. Instead, it rises from 0.251 in the initial sub-period to 0.559 in the final period, with significant increases observed from the second to the sixth sub-period. A similar trend is present in the low TR group, with an even higher increase in magnitude, which suggests an increasing trend in the predictability of tangible assets in predicting growth opportunities. This contradicts the pattern with ICFS and cannot be the channel to explain the relationship between the declining ICFS and asset tangibility. This supports my Hypothesis 3. Furthermore, I examine the cash flow-tangible capital autoregression and report the result in Table 3.15. There also appears to be no decreasing trend of the impact of asset tangibility on cash flow persistence over time, which further supports Hypothesis 4.

This finding challenges the previous results derived from publicly listed firms. The observed increase in cash flow persistence, along with the non-decreasing trend in the impact of asset tangibility on cash flow persistence over time, opposes the fading trend of ICFS in previous results. Consequently, I conclude that the second channel cannot be considered a valid explanation for the relationship between the declining ICFS and asset tangibility in this study.

Table 3.7: The change of cash flow persistence over time - High TR and Low TR groups

	High TR: $\text{CF}_{i,t} = \alpha_{i,c,t} + \theta_0 + \theta_1 \text{CF}_{i,t-1} + \theta_2 \text{X}_{i,t} + \mu_{i,t}$					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
CF_{Lag1}	0.251 (0.025)***	0.059 (0.016)***	0.152 (0.046)***	0.404 (0.016)***	0.402 (0.020)***	0.559 (0.017)***
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.783	0.952	0.865	0.815	0.727	0.933
Adj. R^2	0.774	0.952	0.865	0.815	0.726	0.933
Num. obs.	1527	5965	27480	50723	42526	29899

	Low TR: $\text{CF}_{i,t} = \alpha_{i,c,t} + \theta_0 + \theta_1 \text{CF}_{i,t-1} + \theta_2 \text{X}_{i,t} + \mu_{i,t}$					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
CF_{Lag1}	0.123 (0.010)***	0.126 (0.021)***	0.335 (0.014)***	0.738 (0.014)***	0.552 (0.011)***	1.087 (0.025)***
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.965	0.896	0.924	0.766	0.977	0.436
Adj. R^2	0.964	0.896	0.923	0.766	0.977	0.435
Num. obs.	4339	18198	83133	154423	131287	90482

Note: The table presents the results of the WLS estimation of autoregressive Model 3.6, and the coefficient of CF_{Lag1} represents the AR(1) autoregression of the cash flow, representing cash flow persistence. The variable CF represents cash flow, which is measured by the sum of PAIT and depreciation scaled by the beginning-of-period total assets. X is a control vector consisting of commonly used firm characteristic variables such as firm size and firm age. The firm, industry and time-fixed effects are controlled through $\alpha_{i,c,t}$. The $\varepsilon_{i,t}$ captures the measurement or other unobservable errors. Num. obs is the total number of firm-year observations. The sample period is from 1984 to 2019. The standard errors of estimated coefficients are reported in parentheses. The R-squared values are reported as measurements of goodness-of-fit, and the significance level is denoted as: $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

3.5.3 Robustness

Measurement error in marginal Q

Studies have argued that the presence of ICFS could be a result of mismeasured Q. As discussed in the literature section of Section 3.2 and of Chapter 2.1.3, in empirical studies, the Q is proxied by an averaged suboptimal metric, sales growth (average Q), instead of the true measurement of marginal Q as the shadow cost of capital (Erickson and Whited 2000, 2002; Jason and Jenny 2012). The more market friction there is, the more average Q will deviate from the true marginal Q in guiding capital investment. Imperfect market conditions make average Q insufficient to capture all productivity information, which leads to some productivity information being captured by cash flow, hence producing ICFS. Under this explanation, if market imperfections have improved over the last several decades, making average Q a better metric for guiding capital investment, there will be a weakening link between cash flow, Q, and investment, resulting in a declining ICFS. This challenges my conclusion regarding the effect of asset tangibility.

I propose two approaches to address this concern. The first is to use the new estimation - production function based markup proposed by De Loecker et al. (2016) to measure marginal Q. As discussed in Chapter 2.1.3, this markup captures the product-level marginal return on invested capital and serves as a better metric than the increase in sales to capture marginal productivity. This improved metric is regarded as having fewer biases compared to the average Q and offers theoretical advantages. If the declining ICFS is primarily driven by mismeasured Q instead of asset tangibility, the use of an improved metric should not show decreasing trends in ICFS, and there should not be a distinguishable trend between the decline among low or high asset tangibility groups.

Table 3.8 shows the ICFS trend estimated with markup as a proxy for marginal Q.

The markup estimation requires estimating production function for elasticity. I use the ACF method for estimation (see detailed discussion in Chapter 2.1.3). A caveat is that this estimation requires administration cost data, but such data is incomplete in the first subperiod of 1984-1989. However, from the remaining five subperiods, it can be observed that the ICFS has a very similar pattern to the main results in Table 3.3, in terms of both magnitude and decreasing patterns in the two groups. In the main result, the ICFS decreases from 0.064 in the second period to 0.030 in the last period in the high TR group. In this robustness test, it decreases from 0.075 in the 1990-1995 period to 0.044 by 2019. Similarly, the ICFS is much lower in magnitude with a minor continuous decrease in the low TR group. These results still support Hypothesis 1A and 1B.

Secondly, following the method of Moshirian et al. (2017) and Larkin et al. (2018), I re-test Model 3.2 in two groups by dropping Q. If the declining ICFS is caused by the improvement in the information contained in the Q instead of asset tangibility, I should observe a non-decreasing ICFS estimated without Q. The result is presented in Table 3.16, and it can be seen that the ICFS is almost identical to the main result in Table 3.3. These two tests make the conclusion of asset tangibility and its relation with the declining ICFS significantly immune to the mismeasured Q criticism.

Table 3.8: The change of ICFS over time in two groups - estimated by markup measured Q

	High TR group: $\text{INV}_{i,t} = \alpha_{c,t} + \beta_0 + \beta_1 \text{Q}_{i,t-1} + \beta_2 \text{CF}_{i,t} + \beta_3 X_{i,t} + \varepsilon_{i,t}$				
	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
CF	0.075 (0.006)***	0.052 (0.003)***	0.036 (0.002)***	0.030 (0.001)***	0.044 (0.002)***
Company characteristics	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes
R^2	0.085	0.057	0.045	0.045	0.043
Adj. R^2	0.067	0.050	0.042	0.043	0.040
Num. obs.	3961	11718	26937	30750	23173
	Low TR group: $\text{INV}_{i,t} = \alpha_{c,t} + \beta_0 + \beta_1 \text{Q}_{i,t-1} + \beta_2 \text{CF}_{i,t} + \beta_3 X_{i,t} + \varepsilon_{i,t}$				
	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
CF	0.007 (0.001)***	0.004 (0.000)***	0.003 (0.000)***	0.003 (0.000)***	0.002 (0.000)***
Company characteristics	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes
R^2	0.029	0.013	0.021	0.021	0.013
Adj. R^2	0.022	0.010	0.020	0.020	0.012
Num. obs.	12079	38220	80286	89457	67811

Note: The table displays the key coefficients of Model 3.2, acting as a robustness check for Table 3.3. Only the essential coefficient is reported. The difference lies in the measure of Tobin's Q. In this test, Tobin's Q, which gauges the marginal productivity of capital, is proxied by the markup proposed by De Loecker et al. (2016). The rest specifications are identical to Table 3.3. The first and second panels are estimated on firms from high and low asset tangibility firms, which are ranked by tangible asset ratio every year; firms with asset tangibility ratio ranking in the top quarter percentile are in the high TR group. Only essential variables are reported. The subperiod does not contain 1984-1989 due to a lack of data. The industry and time-fixed effects are controlled through $\alpha_{c,t}$. β_2 is the ICFS. Num. obs is the total number of firm-year observations. The sample period spans from 1990 to 2019. The standard errors of estimated coefficients are reported in parentheses. The R-squared and adjusted R-squared values are reported as measurements of goodness-of-fit, and the significance level is denoted as $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

Alternative explanation

Another explanation that could potentially challenge the asset tangibility theory involves improvements in economic and financial conditions. This poses a major threat to my conclusion among others. The ICFS exists because there is financial friction in the market. The prevalent financial constraint and high financing costs lead to difficulties in obtaining external financing, forcing companies to use internal cash for investment when available, leading to a high ICFS. Financial liberalisation and growing economic wealth in recent decades could significantly ease the financial constraints for firms. More financial resources and efficient economic resource allocation can attenuate the cost differences between internal and external channels, making firms less dependent on cash flow for investment, leading to a decline in ICFS (Larkin et al. 2018; X. Wang 2022).

I argue that two primary points suggest this might not be the explanation for the fading ICFS in my sample. Firstly, as demonstrated in summary statistics Table 3.1 and Figure 3.2, the average capital investment has not increased over the last three decades. If the ICFS is decreasing because more financial resources are being provided to them, we should observe an increase in average capital investment. Secondly, the UK financing market has not been dramatically liberalised as those in the US. Compared to other developed economies, the UK has not been considered a perfectly free market due to its relatively scarce venture capital and stringent supervision in the equity market (Guariglia 2008).

To support my argument, I test the effect of financial improvement on ICFS by splitting firms based on their external financial constraint levels to test the interacting effect of financial constraints with ICFS by

$$\begin{aligned} \mathrm{INV}_{i,t} =& \alpha_{c,t} + \beta_0 + \beta_1 \mathrm{Q}_{i,t-1} + \beta_2 \mathrm{FC\_Dummy}_{i,t} + \beta_3 \mathrm{CF}_{i,t} \\ &+ \beta_4 \mathrm{CF}_{i,t} * \mathrm{FC\_Dummy}_{i,t} + \beta_5 \mathrm{TR} + \beta_6 \mathrm{X}_{i,t} + \varepsilon_{i,t} \end{aligned} \tag{3.8}$$

The FC_Dummy$_{i,t}$ is a categorical variable for financial constraint levels. All other model settings are the same as in the baseline Model 3.3. The categorical variable takes values for three levels, from low, medium to high. If financial improvement, rather than asset tangibility, is the reason causing the vanishing ICFS, we would observe the ICFS declining at different rates in firms with different levels of financial constraints. The category with the most financial constraints would present the most pronounced decline as the economic environment improves.

Firstly, firm size is used as the criterion to measure financial constraints. Under the assumption of asymmetric information, smaller firms are less well-known, relatively younger, and more vulnerable to the effects of market imperfections. This makes smaller firms finance at higher costs from external channels. Secondly, smaller firms have less market power and lower productivity, which results in generating less internal cash flow, making them more internally financially constrained (Beck et al. 2005; Schiantarelli 1996). This makes firm size one of the most widely adopted metrics for measuring internal and external financial constraints (Acharya et al. 2007; Guariglia 2008). Following the criteria of Guariglia (2008), firm size is measured by the total assets and is divided into three groups based on the three quartiles of the distribution each year.:

i: $SIZE_{SML}$ is represented by a value of 1 when the firm's total assets fall below the lower quartile;
ii: $SIZE_{MED}$ is represented by a value of 2 when the firm's total assets fall below the upper quartile;
iii: $SIZE_{LAG}$ is represented by a value of 3 when the firm's total assets fall above the upper quartiles.

The second separation criterion is firm age. The age of a company is computed by the difference between the current year and the year of incorporation. This metric is often used as an alternative method for measuring both external and internal constraints. According to Guariglia (2008), younger firms are more likely to experience financial constraints as they possess limited information and less valuable collateral in the capital market. As they might have fewer records of performance to demonstrate their fair financial value in the market, they tend to have more difficulty in securing favourable financing deals, such as those with venture capitalists. So, firms are divided into three financial constraint groups based on the three quartiles of their age distribution each year as follows:

i: AGE_{YOU}, represented by a value of 1 for firms whose age falls below the lower quartile;
ii: AGE_{MED}, represented by a value of 2 for firms whose age falls below the upper quartile;
iii: AGE_{OLD}, represented by a value of 3 for firms whose age falls above the upper quartile.

Table 3.9: The change of ICFS with the effect of financial constraints

	Financial constraints: measured by firm size					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
$CF * SIZE_{SML}$	0.001 (0.010)	0.012 (0.001)***	0.005 (0.000)***	0.005 (0.000)***	0.006 (0.000)***	0.008 (0.000)***
$CF * SIZE_{MED}$	0.021 (0.013)	0.012 (0.003)***	0.011 (0.001)***	0.008 (0.000)***	0.004 (0.001)***	0.001 (0.001)
$CF * SIZE_{LAG}$	0.063 (0.019)***	0.028 (0.010)**	-0.000 (0.004)	0.001 (0.003)	-0.002 (0.003)	-0.009 (0.003)**
Company fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.468	0.261	0.295	0.319	0.252	0.267
Adj. R^2	0.462	0.259	0.295	0.319	0.252	0.266
Num. obs.	7026	29940	135648	223725	183325	119017
	Financial constraints: measured by firm age					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
$CF * AGE_{YOU}$	0.032 (0.010)***	0.012 (0.001)***	0.007 (0.000)***	0.009 (0.000)***	0.009 (0.000)***	0.009 (0.001)***
$CF * AGE_{MED}$	-0.030 (0.013)*	0.003 (0.001)	0.000 (0.001)	-0.004 (0.000)***	-0.004 (0.000)***	-0.002 (0.001)*
$CF * AGE_{OLD}$	0.012 (0.019)	0.007 (0.005)	0.003 (0.001)	-0.003 (0.001)**	-0.004 (0.001)**	-0.004 (0.002)*
Company fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.468	0.261	0.295	0.319	0.252	0.267
Adj. R^2	0.462	0.259	0.294	0.319	0.252	0.266
Num. obs.	7026	29940	135648	223725	183325	119017

Note: The table presents the main coefficients of Model 3.8 $\text{INV}_{i,t} = \alpha_{c,t} + \beta_0 + \beta_1 \text{Q}_{i,t-1} + \beta_2 \text{FC\_Dummy}_{i,t} + \beta_3 \text{CF}_{i,t} + \beta_4 \text{CF}_{i,t} * \text{FC\_Dummy}_{i,t} + \beta_5 \text{TR} + \beta_6 \text{X}_{i,t} + \varepsilon_{i,t}$. The focus is $\beta 4$, the coefficients of ICFS interacted with financial constraint dummies. Only essential variables are reported, and the remaining variables are identical to those in Table 3.3. The industry and time-fixed effects are controlled through $\alpha_{c,t}$. The total number of firm-year observations is denoted as Num. obs, and the sample period spans from 1984 to 2019. Standard errors of estimated coefficients are reported in parentheses. The R-squared and adjusted R-squared values are reported as measurements of goodness-of-fit, and the significance level is denoted as follows: $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

Table 3.9 presents the ICFS trend interacted with financial constraint dummies. In the first panel, where firms are divided based on size as a measure of financial constraints, the ICFS neither exhibits a noticeably larger coefficient nor a significant declining trend among small firms. Similarly, no discernible decline is observed in medium and large firms.

A similar pattern is noted in the second panel, where financial constraints are distinguished based on age. In the coefficients interacted with the young age dummy, a minor decline is evident in the first three subperiods, but it increases in the subsequent three subperiods where greater financial improvement would have been expected. The remaining two age groups demonstrate no meaningful ICFS or trend. Notably, a declining trend in ICFS is not observed in the medium age group. These findings contradict the hypothesis that financial development eases financial friction, thus leading to a decline in ICFS.

Further, following a common method (such as the one used by Larkin et al. (2018)), I split firms into two non-exhaustive groups: large-old firms versus small-young firms, representing the least and most financially constrained firms, respectively. Table 3.17 shows the ICFS comparison between small-young firms in the first panel and large-old firms in the second panel. A decrease in ICFS is noted in small, young firms, but only within the initial three sub-periods. More pronounced declines should have been evident in the subsequent sub-periods. Similarly, we should expect the large-old firms (the second panel) to also exhibit a decreasing trend in ICFS and have smaller ICFS values, given their lesser financial constraints and likelihood of benefiting from the improved financial environment. However, the estimations do not support the expectations. Thus, these findings further suggest that the improvement in the financial environment is not the cause of the fading ICFS.

Estimation bias

The final robustness test focuses on potential omitted variables and the estimation process. Prior studies suggest that firms may base their investment decisions on lagged growth factors (Erickson and Whited 2000, 2002), which could be overlooked by the baseline model proposed by Fazzari et al. (1987).

The first factor potentially neglected is lagged marginal Q (Jason and Jenny 2012). Beyond Tobin's Q at year $t-1$, Tobin's Q at year $t-2$ is also likely to guide investment. In analyses involving publicly listed firms, Tobin's Q is typically measured using the market-to-book ratio. Given that the financial trading market is considered more efficient than the business environment for SMEs, a firm's response to investment opportunities influenced by capital returns may be slower than that in publicly listed firms. This increases the likelihood of autocorrelated Q being present in this study. If the autoregression of Q is not accounted for, it could lead to an overestimation of its relationship with cash flow, leading to a biased estimation in ICFS.

Additionally, research has shown that current investment is also related to investment in the previous year. And this potential correlation could result in an underestimation of Q and an overestimation of the cash flow coefficient (Guariglia 2008; Moshirian et al. 2017). While the AR(1) lagged investment is included in the baseline Model 3.4, estimating this model could be biased with OLS due to potential endogeneity issues brought by serial correlation[20].

To address these concerns, the ICFS is re-examined through an error correction model (ECM). This model has been further refined in line with investment theory by incorporating additional relevant variables. The primary advantage of such a model is that it permits the dynamic adjustment of variables over multiple periods, which accurately reflects the behaviour of smaller firms that often observe and wait before committing to immediate capital investments. Furthermore, the ECM doesn't impose any ad-

[20]This issue is discussed in detail in Chapter 2.2.

ditional restrictions on short-term behaviour, thus providing the flexibility needed to track long-term investments. This model specification has been shown to have superior characteristics and has been widely adopted in previous works, particularly in studies investigating the ICFS in SMEs (Cummins et al. 2006; Guariglia 2008). The proposed model is set out as

$$\begin{aligned}\mathrm{INV}_{i,t} =& \alpha_{c,t} + \beta_0 + \beta_1 \mathrm{Q}_{i,t-1} + \beta_2 \mathrm{Q}_{i,t-2} + \beta_3 \mathrm{CF}_{i,t} \\ &+ \beta_4 \mathrm{Q\_Correction}_{i,t} + \beta_5 \mathrm{INV}_{i,t-1} + \varepsilon_{i,t}\end{aligned} \tag{3.9}$$

The main setup of this model remains the same as in the previous baseline models. The $\mathrm{Q}_{i,t-2}$ represents the second lag term of Q, which is measured by the change in the logarithm of sales. The $\mathrm{Q\_Correction}_{i,t}$ is an error correction term that captures additional information contained in Q and is measured by the second lag term of the difference between the logarithm of replacement capital cost K and sales. More details about the reasoning behind the model specification can be found in the appendix of the study by Guariglia (2008).

One of the main challenges with including lagged explanatory variables (which could possibly be correlated) is that it could introduce bias in ordinary least squares (OLS) estimation. To address this issue, I used the generalised method of moments (GMM) method. The GMM is used to estimate the Model 3.9. It is developed by Arellano and Bond (1991) to address the potential endogeneity issues arising from simultaneity, unobserved firm-specific heterogeneity, and possible correlation between the error term and lagged dependent variables. The error correction model can provide a more comprehensive alternative for ensuring the robustness of the conclusion. More details about this approach are discussed in Chapter 2.2.

Table 3.10 presents the results of the GMM estimated error correction model, showing the trend of ICFS between firms with high and low TR. The Sargan test reveals no over-identification issues in the key results, and the Wald test statistics show no signs of higher-order serial correlations. This indicates that the instrument variables are suitable for estimation. The magnitude and declining trend of ICFS appear to be very similar to the results in the main Table 3.3. The ICFS in the high TR group falls from around 0.141 to 0.052, dropping by half in the final subperiods. Meanwhile, the ICFS in the low TR group has been low since the initial period (0.039) and dropped to 0.003 in the final period. This suggests that the conclusion of Hypothesis 1A and 1B is robust against potential estimation bias and endogenous variables.

Table 3.10: The change of ICFS over time in two groups - estimated by error correction model

	High TR firms group					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
CF	0.042 (0.029)	0.141 (0.007)***	0.058 (0.001)***	0.106 (0.000)***	0.073 (0.001)***	0.052 (0.001)*
Company fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Num. obs.	2287	9204	37066	57715	47979	31830
Sargan Test: p-value	0.987	0.654	0.000	0.000	0.003	0.000
Wald Test Coefficients: p-value	0.000	0.000	0.000	0.000	0.003	0.000
	Low TR firms group					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
CF	0.039 (0.001)***	0.010 (0.001)***	0.004 (0.000)***	0.005 (0.000)***	0.004 (0.000)***	0.003 (0.000)*
Company fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Num. obs.	6831	27593	111187	173667	143958	95444
Sargan Test: p-value	0.394	0.057	0.000	0.000	0.000	0.000
Wald Test Coefficients: p-value	0.000	0.000	0.000	0.000	0.000	0.000

Note: The table presents the main coefficients of Model $\mathrm{INV}_{i,t} = \alpha_{c,t} + \beta_0 + \beta_1 \mathrm{Q}_{i,t-1} + \beta_2 \mathrm{Q}_{i,t-2} + \beta_3 \mathrm{CF}_{i,t} + \beta_4 \mathrm{Q\_Correction}_{i,t} + \beta_5 \mathrm{INV}_{i,t-1} + \varepsilon_{i,t}$. The model is estimated by GMM regression, which provides a more robust method for testing ICFS in terms of variable composition and estimation technique. The primary variable setting is consistent with Model 3.4. Q_Correction captures the correction factor of investment, measured by the logarithm of replacement capital cost minus the logarithm of sales. β_3 represents the ICFS. Num. obs refers to the total number of firm-year observations. The sample period spans from 1984 to 2019. The standard errors of estimated coefficients are reported in parentheses. The Sargan test, which measures over-identification issues, and the Wald test, which measures the serial correlation of lagged instrument variables, are also reported.

3.6 Conclusion

This chapter addresses the recently identified phenomenon of the vanishing or fading ICFS in developed countries. While recent studies have observed a decline in ICFS, the causes remain under debate. Pioneer research based on international samples of publicly listed firms suggest asset tangibility and economic development as the potential reasons. However, publicly listed firms usually have better productivity and are immersed in a more favourable financing environment, making them unrepresentative of most firms. Hence these explanations may not truly capture the investment trend within a given country. To the best of my knowledge, no study has examined whether ICFS has faded in non-publicly listed firms or how ICFS may have evolved over time for these firms. My research investigates the trend of ICFS using a British firm sample, comprising both listed and non-listed firms, offering insights that diverge from previous research and potentially holder more relevance for the majority of firms or SMEs in an economy.

I discover that ICFS is decreasing in non-listed firms. To explain this phenomenon, this study investigates the impact of asset tangibility and reveals that firms with higher asset tangibility ratios tend to invest more when their cash flow increases. As such, ICFS is more accurately described as investment-cash flow-tangible capital sensitivity. Based on this finding, I propose that the decline in tangible assets as a proportion of total assets is the primary driver behind the decrease in ICFS, with high asset tangibility firms showing a more pronounced decline than low asset tangibility firms. The significant ICFS decline in high asset tangibility firms primarily contributes to the overall decline of ICFS in the full sample.

The mechanism through which asset tangibility impacts investment via cash flow is further clarified in this study. I argue that the asset tangibility ratio conveys information on marginal productivity, and it is the declining productivity of tangible assets that leads to reduced investment in tangible capital. My tests show that the sales return of tangible assets has declined more substantially in high asset tangibility firms. Importantly, while the sales return has decreased for both high and low asset tangibility firm groups, low asset tangibility firms have witnessed higher returns from intangible asset investments. In contrast, high asset tangibility firms have observed sluggish returns on intangible asset investments.

This study also provides differing evidence from Moshirian et al. (2017), who argue that asset tangibility is the cause for vanishing ICFS. They propose that firms have transitioned towards production methods based on technology and intangible assets, which can generate cash flow in a more versatile manner. This transition results in lower asset tangibility and less predictability in cash flow, leading to a pronounced decline in ICFS. I argue that this theory only applies to publicly listed firms. Mostly SMEs, particularly those with high asset tangibility, are heavily reliant on traditional production methods to generate profits with predictable prospects. My autoregression tests of cash flow and the cash flow-tangibility ratio show no sign of decline in either high or low TR firms. In fact, I show that, as the increase in sales has slowed over the last three decades, the autoregression coefficients increase, suggesting a stable decline in cash flow. This confirms that the decreased sales return is the main reason for the reduced tangible capital investment and, subsequently, the declined ICFS.

This research also introduces a novel measurement for the control variable of marginal Q in estimating the ICFS. The presence of the ICFS has long been suspected to be caused by the mismeasurement of the control variable of marginal Q. This new metric can be utilised to improve model estimation or enhance the precision of robust tests. Previous studies have conducted robustness tests by simply excluding the potentially mismeasured Q, which only validates the correctness of the ICFS trend but not the exact magnitude of the ICFS. This study employs the traditional metric in the main test for comparison purposes and utilises markup in robust tests. Both sets of results demonstrate the consistency of my findings regarding the impact of asset tangibility on the ICFS in terms of both the trend and absolute magnitude.

This study contributes to the literature by discovering that economic improvement does not help explain the decline in ICFS for non-publicly listed firms. This finding is alerting and counter-intuitive, as numerous studies have found that ICFS decreases as economic conditions improve or market imperfections are removed by financial liberalisation. The ICFS used to be considered as reflecting the severity of financial constraints, with a declining ICFS suggesting a less financially constrained situation, implying that more funds are being channeled into promising investment projects (X. Wang 2022). But this interpretation is disproved by the results, as we demonstrate that the ICFS of the most financially constrained firms does not display a greater decline than unconstrained firms.

This finding holds two implications. Firstly, it indicates that the benefits of financial and economic advancements have not permeated effectively to unquoted firms. Secondly, it suggests that firms may choose not to make capital investments even when their financial constraints have been alleviated. A significant number of British firms in my sample seem to grapple with deficiencies in effective demand or productivity. This second implication is presumed to be the primary factor. This study also connects to and provides evidence from an investment perspective on the puzzle of the UK's sluggish total factor productivity outlined by Goodridge et al. (2018). The changes in investment behaviour as indicated by ICFS offer insights into the wider issue of stagnant productivity, helping to shed light on the broader economic performance of the country.

A crucial inference drawn from this study is the necessity for policymakers to focus on promoting the growth of SMEs, especially those heavily reliant on tangible assets for production. Firms with high asset tangibility continue to play a crucial role in the UK economy, significantly contributing to the labour market by providing jobs. Continual investment in R&D could significantly enhance productivity in these firms. However, such investment only constitutes up to 1.7% of the UK's GDP, a figure notably low in comparison to other developed countries [21]. Reversing this sluggish productivity may demand an extensive revamp across different facets, encompassing cultural transformation, policy support, technological innovation, and more. For researchers and policymakers, future investigations could be focused on how economic tools can be applied to address the issue of low productivity. These measures could involve strategies to improve operational efficiency, foster innovation, and provide conducive policy support to SMEs, among other actions.

A Appendix

[21] More information can be read from UK Parliament report: Research and development spending.

Table 3.11: Changes in ICFS over time - High TR and Low TR at the industry level

	High TR groups: $\text{INV}_{i,t} = \alpha_{c,t} + \beta_0 + \beta_1 \text{Q}_{i,t-1} + \beta_2 \text{CF}_{i,t} + \beta_3 X_{i,t} + \varepsilon_{i,t}$					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
Tobin Q	0.024 (0.006)***	0.010 (0.003)***	0.008 (0.001)***	0.004 (0.001)***	0.004 (0.001)***	0.003 (0.001)***
CF	0.082 (0.011)***	0.032 (0.003)***	0.027 (0.001)***	0.022 (0.001)***	0.019 (0.001)***	0.023 (0.001)***
Company characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.056	0.032	0.025	0.020	0.021	0.021
Adj. R^2	0.046	0.028	0.024	0.020	0.021	0.021
Num. obs.	3830	9153	45134	92472	90952	68896

	Low TR group: $\text{INV}_{i,t} = \alpha_{c,t} + \beta_0 + \beta_1 \text{Q}_{i,t-1} + \beta_2 \text{CF}_{i,t} + \beta_3 X_{i,t} + \varepsilon_{i,t}$					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
Tobin Q	0.016 (0.006)*	0.011 (0.002)***	0.012 (0.001)***	0.005 (0.000)***	0.002 (0.000)***	0.002 (0.001)***
CF	0.093 (0.011)***	0.020 (0.001)***	0.009 (0.000)***	0.008 (0.000)***	0.006 (0.000)***	0.008 (0.001)***
Company characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.076	0.034	0.017	0.016	0.015	0.021
Adj. R^2	0.062	0.031	0.017	0.015	0.014	0.020
Num. obs.	3196	20787	90514	131253	92373	50121

Note: The table presents the main coefficients of Model 3.2, which serves as a robust test for the results in Table 3.3. The high TR and low TR firms are separated at the industry level. The average tangible assets and tangible asset ratio are calculated annually at the industry level for twenty years, from 2000 to 2020. If an industry is ranked in the upper percentile by both values during these years, it is classified as a high TR (industry) group; otherwise, it is classified as a low TR (industry) group. Only essential variables are reported. The variable INV represents investment, measured by the change in fixed assets scaled by the beginning-of-period total assets. Tobin's Q measures marginal capital productivity and is proxied by the sales growth rate. The variable CF represents cash flow, measured by the sum of PAIT and depreciation scaled by the beginning-of-period total assets. X is a control vector consisting of commonly used firm characteristics. The industry and time-fixed effects are controlled through $\alpha_{c,t}$. β_1 is investment-Q sensitivity; β_2 is the ICFS. Num. obs is the total number of firm-year observations. The sample period spans from 1984 to 2019. The standard errors of estimated coefficients are reported in parentheses. The R-squared and adjusted R-squared values are reported as measurements of goodness-of-fit, and the significance level is denoted as $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

Table 3.12: Changes in tangible asset returns over time - High TR and Low TR at the industry level

	High TR: $\ln(\text{Sales})_{i,t} = \alpha_{i,c,t} + \theta_0 + \theta_1 \ln(\text{TangbileAssets})_{i,t-1} + \theta_2 \ln(\text{IntangibleAssets})_{i,t} + \theta_3 \text{X}_{i,t} + \varepsilon_{i,t}$					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
ln(Tangible assets)	0.210 (0.048)***	0.243 (0.025)***	0.195 (0.013)***	0.133 (0.006)***	0.109 (0.005)***	0.127 (0.008)***
ln(Intangible assets)	0.018 (0.010)	0.023 (0.008)**	0.024 (0.006)***	0.018 (0.002)***	0.022 (0.002)***	0.014 (0.001)***
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Num. obs.	3949	9844	47242	94430	94290	71860
R^2	0.947	0.955	0.974	0.975	0.978	0.976
Adj. R^2	0.932	0.936	0.957	0.968	0.971	0.969

	Low TR: $\ln(\text{Sales})_{i,t} = \alpha_{i,c,t} + \theta_0 + \theta_1 \ln(\text{TangbileAssets})_{i,t-1} + \theta_2 \ln(\text{IntangibleAssets})_{i,t} + \theta_3 \text{X}_{i,t} + \varepsilon_{i,t}$					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
ln(Tangible assets)	0.387 (0.063)***	0.188 (0.011)***	0.187 (0.006)***	0.145 (0.004)***	0.120 (0.005)***	0.119 (0.006)***
ln(Intangible assets)	0.013 (0.013)	0.024 (0.005)***	0.039 (0.004)***	0.032 (0.002)***	0.033 (0.003)***	0.028 (0.003)***
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Num. obs.	3295	21833	94725	135487	96499	53797
R^2	0.934	0.962	0.962	0.964	0.975	0.976
Adj. R^2	0.911	0.943	0.940	0.950	0.964	0.967

Note: The table presents the results of Model 3.5, which serves as a robust test for the results in Table 3.4. The high TR and low TR firms are separated at the industry level. The average tangible assets and tangible asset ratio are calculated annually at the industry level for twenty years, from 2000 to 2020. If an industry is ranked in the upper percentile by both values during these years, it is classified as a high TR (industry) group; otherwise, it is classified as a low TR (industry) group. Only essential variables are reported. The models are estimated within each subperiod to investigate the time-evolving trend of the coefficients. X is a control vector consisting of commonly used firm characteristics. The firm, industry, and time-fixed effects are controlled through $\alpha_{i,c,t}$. The sample period spans from 1984 to 2019. The standard errors of estimated coefficients are clustered at the firm level and are reported in parentheses. The R-squared and adjusted R-squared values are reported as measurements of goodness-of-fit, and the significance level is denoted as $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

Table 3.13: Sales return of tangible investment - comparison in four groups

	Large firms with high TR					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
Tangible Assets	0.644 (0.123)***	0.836 (0.106)***	0.633 (0.041)***	0.482 (0.030)***	0.408 (0.042)***	0.387 (0.035)***
Company characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Num. obs.	458	2178	10444	17414	13025	7439
R^2	0.954	0.965	0.973	0.973	0.965	0.976
Adj. R^2	0.909	0.936	0.949	0.960	0.949	0.965

	Large firms with low TR					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
Tangible Assets	0.345 (0.073)***	0.165 (0.026)***	0.285 (0.019)***	0.214 (0.011)***	0.147 (0.012)***	0.128 (0.013)***
Company characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Num. obs.	1257	5503	24890	40458	34898	24169
R^2	0.921	0.948	0.949	0.941	0.929	0.928
Adj. R^2	0.876	0.918	0.910	0.918	0.903	0.904

	SMEs firms with high TR					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
Tangible Assets	0.339 (0.066)***	0.386 (0.055)***	0.478 (0.027)***	0.341 (0.016)***	0.393 (0.023)***	0.337 (0.030)***
Company characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Num. obs.	1119	5625	24888	40306	34784	23882
R^2	0.954	0.956	0.961	0.955	0.980	0.987
Adj. R^2	0.916	0.913	0.921	0.924	0.967	0.980

Table 3.13 (Continued)

	SMEs firms with low TR					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
Tangible Assets	0.244 (0.049)***	0.176 (0.012)***	0.152 (0.006)***	0.133 (0.004)***	0.111 (0.004)***	0.106 (0.005)***
Company characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Num. obs.	3514	18644	82910	133341	108964	70486
R^2	0.937	0.948	0.938	0.942	0.971	0.974
Adj. R^2	0.905	0.915	0.894	0.915	0.957	0.963

Note: The table presents the results of Model 3.5: $\ln(\text{Sales})_{i,t} = \alpha_{i,c,t} + \theta_0 + \theta_1 \ln(\text{TangbileAssets})_{i,t-1} + \theta_2 \ln(\text{IntangibleAssets})_{i,t} + \varepsilon_{i,t}$, which examines the relationship between a firm's tangible investment and sales. The firms are split into four groups based on size and tangible asset ratio ranked every year, splitting at first percentile level. Only essential variables are reported. The sales and tangible assets are logarithmic values. The models are estimated within each subperiod to investigate the time-evolving trend of the coefficients. The firm, industry, and time-fixed effects are controlled through $\alpha_{i,c,t}$. The sample period spans from 1984 to 2019. The standard errors of estimated coefficients are clustered at the firm level and are reported in parentheses. The R-squared and adjusted R-squared values are reported as measurements of goodness-of-fit, and the significance level is denoted as $^{***}p < 0.001$.

Table 3.15: The change of cash flow persistence and asset tangibility over time - High TR and Low TR groups

	High TR: $\text{CF}_{i,c,t} * \text{TR}_{i,t-1} = \alpha_{c,t} + \theta_0 + \theta_1 \text{CF}_{i,t-1} * \text{TR}_{i,t-2} + \theta_2 \text{X}_{i,t} + \mu_{i,t}$					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
$CF * TR_{lag1}$	0.821 (0.019)***	0.265 (0.015)***	1.494 (0.019)***	0.668 (0.006)***	0.393 (0.014)***	0.366 (0.023)***
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.923	0.699	0.982	0.937	0.495	0.997
Adj. R^2	0.919	0.695	0.982	0.937	0.494	0.997
Num. obs.	1527	5965	27480	50723	42526	29899

	Low TR: $\text{CF}_{i,c,t} * \text{TR}_{i,t-1} = \alpha_{c,t} + \theta_0 + \theta_1 \text{CF}_{i,t-1} * \text{TR}_{i,t-2} + \theta_2 \text{X}_{i,t} + \mu_{i,t}$					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
$CF * TR_{lag1}$	0.273 (0.009)***	0.128 (0.009)***	0.314 (0.006)***	0.122 (0.003)***	0.551 (0.004)***	1.351 (0.045)***
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.204	0.711	0.949	0.611	0.857	0.996
Adj. R^2	0.193	0.710	0.949	0.611	0.857	0.996
Num. obs.	4339	18198	83133	154423	131287	90482

Note: The table presents the results of the WLS estimation of autoregressive Model 3.7, and the coefficient of $CF * TR_{Lag1}$ represents cash flow - tangible capital autoregression. The variable CF represents cash flow, which is measured by the sum of PAIT and depreciation scaled by the beginning-of-period total assets. X is a control vector consisting of commonly used firm characteristic variables such as firm size and firm age. The firm, industry and time-fixed effects are controlled through $\alpha_{i,c,t}$. The $\varepsilon_{i,t}$ captures the measurement or other unobservable errors. Num. obs is the total number of firm-year observations. The sample period is from 1984 to 2019. The standard errors of estimated coefficients are reported in parentheses. The R-squared values are reported as measurements of goodness-of-fit, and the significance level is denoted as: $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

Table 3.16: The change of ICFS over time in two groups - dropping Tobin Q

	High TR group: $\text{INV}_{i,t} = \alpha_{c,t} + \beta_0 + \beta_1\text{CF}_{i,t} + \beta_2 X_{i,t} + \varepsilon_{i,t}$					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
CF	0.123 (0.024)***	0.065 (0.004)***	0.029 (0.001)***	0.022 (0.001)***	0.022 (0.001)***	0.030 (0.002)***
Company characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.120	0.073	0.045	0.030	0.036	0.035
Adj. R^2	0.089	0.064	0.042	0.029	0.035	0.033
Num. obs.	1901	8245	36203	57377	47675	31565

	Low TR group: $\text{INV}_{i,t} = \alpha_{c,t} + \beta_0 + \beta_1\text{CF}_{i,t} + \beta_2 X_{i,t} + \varepsilon_{i,t}$					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
CF	0.017 (0.003)***	0.006 (0.000)***	0.003 (0.000)***	0.003 (0.000)***	0.002 (0.000)***	0.002 (0.000)***
Company characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.040	0.025	0.015	0.025	0.026	0.019
Adj. R^2	0.028	0.022	0.014	0.025	0.026	0.018
Num. obs.	5705	24901	109243	173420	143731	95242

Note: The table presents the main coefficients of Model 3.2 with Q term dropped. The first and second panels are estimated on firms from high and low asset tangibility industries, which are ranked by tangible asset ratio every year; firms with asset tangibility ratio ranking in the top quarter percentile are in the high TR group. Only essential variables are reported. The models are estimated within each subperiod to investigate the time-evolving trend of the coefficients. The variable INV represents investment, measured by the change in fixed assets scaled by the beginning-of-period total assets.The variable CF represents cash flow, measured by the sum of PAIT and depreciation scaled by the beginning-of-period total assets. X is a control vector consisting of commonly used firm characteristics. The industry and time-fixed effects are controlled through $\alpha_{c,t}$. β_1 is the ICFS. Num. obs is the total number of firm-year observations. The sample period spans from 1984 to 2019. The standard errors of estimated coefficients are reported in parentheses. The R-squared and adjusted R-squared values are reported as measurements of goodness-of-fit, and the significance level is denoted as $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

Table 3.17: The change of ICFS with the effect of financial constraints

	ICFS in small and young firms					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
CF	0.032 (0.015)*	0.014 (0.002)***	0.007 (0.001)***	0.007 (0.001)***	0.008 (0.001)***	0.008 (0.001)***
Company fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.578	0.297	0.313	0.377	0.366	0.338
Adj. R^2	0.540	0.280	0.310	0.374	0.364	0.334
Num. obs.	600	3356	15607	21361	19345	11375
	ICFS in large and old firms					
	1984-1989	1990-1995	1996-2001	2002-2007	2008-2013	2014-2019
CF	0.125 (0.031)***	0.016 (0.011)	0.004 (0.003)	0.013 (0.002)***	0.006 (0.003)*	0.002 (0.004)
Company fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.579	0.272	0.295	0.311	0.232	0.280
Adj. R^2	0.537	0.253	0.291	0.308	0.228	0.275
Num. obs.	543	2502	14097	25184	18199	10258

Note: The table presents the main coefficients of Model 3.8 $\mathrm{INV}_{i,t} = \alpha_{c,t} + \beta_0 + \beta_1 \mathrm{Q}_{i,t-1} + \beta_2 \mathrm{CF}_{i,t} + \beta_4 \mathrm{Tangibleratio} + \beta_6 \mathrm{X}_{i,t} + \varepsilon_{i,t}$. The objective is to compare the ICFS between small-young firms in the first panel and big-old firms in the second panel, representing the most and least financially constrained firm types, respectively. Only essential variables are reported, and the remaining variables are identical to those in Table 3.3. The industry and time-fixed effects are controlled through $\alpha_{c,t}$. The total number of firm-year observations is denoted as Num. obs, and the sample period spans from 1984 to 2019. Standard errors of estimated coefficients are reported in parentheses. The R-squared and adjusted R-squared values are reported as measurements of goodness-of-fit, and the significance level is denoted as follows: $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

Chapter 4

A Financial Economic Study of Credit Expansion Policies: Help-to-Buy or Help to build?

4.1 Introduction

Government-supported mortgage programmes have attracted considerable interest worldwide, as they are often utilised to increase housing supply or boost affordability (Carozzi et al. 2020)[1]. These schemes include Shared Equity Mortgages (SEMs), housing partnerships, Shared Appreciation Mortgages (SAMs), and continuous workout mortgages, among others. Such programmes have sparked intense debate due to the benefits and risks they pose to stakeholders and broader markets (Benetton et al. 2019; Greenwald et al. 2018; Miles 2015). Despite their significant potential advantages, many programmes have not become enduringly mainstream. A notable exception is the Help-to-Buy Equity Loan (HtB hereafter) scheme. It was introduced by the UK government in April

[1]Many countries have implemented credit expansion policies in different ways. United States, India, and Sweden introduce mortgage interest deduction policies. The Netherlands has mortgage guarantee scheme. France and the United Kingdom have government loans to support prospective buyers.

2013 to assist first-time buyers and has gained popularity since its inception. This study offers a comprehensive causal framework to explore its impact on developers' finance and socioeconomic outcomes, aiming to address lingering criticisms and provide valuable insights into this widely debated policy.

The HtB is a shared equity mortgage programme, which offers government-backed mortgages[2] for up to 20% of property prices outside the Greater London Authority, or 40% within its boundary. As reported by the National Audit Office, the HtB had facilitated the purchase of more than 369,104 homes by 30 June 2022[3]. Finlay et al. (2016) show that the scheme has effectively increased homeownership rates, with 43% of additional homes created between 2013 and 2016 as a result of HtB. The high sales generated by the HtB make it the most significant new housing policy since the introduction of the Right to Buy in 1980 (Carozzi et al. 2020).

What are the true implications of "Help to Buy" as a government-backed mortgage credit expansion policy? Does it solely offer credit subsidies to enhance homeownership, or does it also generate other economic ramifications? As the policy has evolved, questions have arisen about whether the HtB is actually fostering the construction of new homes or simply bolstering the profitability of developers.

The HtB properties are constructed and sold by registered developers, with the government-backed mortgage payment transferred directly to the developer upon completion of the transaction. As direct beneficiaries, any sales changes driven by HtB can be reflected in the developer's balance sheet. An article in the Financial Times critiques British developers for achieving mega profit rates comparable to oil companies such as BP and Shell. The HtB policy is considered to have further exacerbated the scarcity of housing supply and inflated developer profitability by boosting their margins[4]. Two

[2]Interest is waived for the initial five years, with subsequent charges based on inflation following this period.

[3]For additional information, please refer to the government web-page: Help-to-Buy Equity Loan Scheme data to 30 June 2022.

[4]For more information, please read UK housebuilders' profitability no less remarkable than BP's returns.

studies, despite being based on small sample sizes, also indicate that developers have significantly benefited from the policy. HtB not only increased developers' revenue but also enhanced their net profit, affirming the positive impact of the policy (Archer and Cole 2021; Carozzi et al. 2020).

This research uses a comprehensive sample of 797 developer companies to examine the impact of the HtB policy on suppliers in depth. It aims to answer three fundamental research questions: (1) Does the HtB scheme lead to excess profits for participating developers compared to non-participants? (2) If so, how is this elevated profitability achieved: by selling at higher margins or by selling a larger quantity? (3) How does the HtB policy enable participating developers to achieve their sales targets?

This study employs the Difference-in-Differences (DID hereafter) method to a range of financial metrics to examine the causal effect of the policy. A certain number of new home developers never registered for the scheme and thus did not sell HtB properties[5]. The non-participants form a natural control group that enables us to compare the changes (before and after the policy intervention) in outcomes for the treatment group (i.e., HtB participants) with those for the control group over the same period. By evaluating the difference in these changes, the DID method can measure the impact of the HtB on financial metrics. This approach also helps to mitigate the effects of time-invariant differences between the treatment and control groups that could potentially confound the results[6].

The analysis begins by examining the impact of the HtB programme on developer profitability. The DID results suggest that, on average, participating firms have realised £40,199 thousand more in gross profit than non-participants due to HtB, with relatively

[5]To distinguish participants, I compiled a list of house builders from the Home Builders Federation and supplemented it with additional online sources, including Zoopla, New-Homes, and the government-registered house provider list. Any British new home developer has the option to apply for participation in the HtB scheme, and participating developers are encouraged to advertise and market using the government logo. This allows for a comprehensive search for HtB marketing information to determine whether a developer is a participant.

[6]It is also worth noting that self-selection into treatment and control groups does not invalidate the correct identification in the DID approach, as long as the parallel trends assumption holds.

lower surplus gains in PBIT (£33,662 thousand) and PAIT (£23,584 thousand). In terms of return on capital employed (ROCE), participation in HtB appears to result in a 2.1% increase compared to non-participants. These increases in profitability cause changes in the firms' structure: the total assets, total equity, and liabilities have grown in participant firms, with average increases of £75,129 thousand, £64,743 thousand, and £54,529 thousand, respectively.

Then a cost-benefit analysis is undertaken to identify how the policy shock has been translated into profitability, accounting for both cost and revenue effects from a corporate finance perspective. The HtB is anticipated to have a negative impact on developers' costs from an external channel. An upsurge in demand could result in increased construction expenses, such as land acquisition costs and builders' wages. Revenue is influenced by both internal and external factors. The primary focus of this study is to gauge the external revenue effect purely caused by the policy-induced demand shock, resulting from the easing of buyers' credit constraints. This effect should primarily originate from an increase in price driven by the reduction of down-payment requirements, potentially boosting developers' sales (Duca et al. 2011; Favara and Imbs 2015; Ortalo-Magne and Rady 2006). Moreover, the policy shock may also trigger an internal shock by encouraging firms to enhance their total factor productivity (e.g., logistics, technologies, marketing strategies), thereby further amplifying the revenue effect (Ding et al. 2018). The main challenge resides in isolating and quantifying the increase brought by external policy-induced demand increase. I deconstruct the revenue effect into demand-side (external) and supply-side (internal) components to measure the policy's external effect on revenue.

The DID results show that HtB imposes overall negative cost effects on participants, with an average increase of 23.1% in the cost of sales, a 23.3% rise in administrative expenses, and a 14% growth in wages and salary costs. Meanwhile, the positive revenue effects are also notable, with an average rise of 11.4% in inventory and a 22.3% increase in sales. In terms of growth rates, only the rate of inventory increase has risen (7.6%)

due to participation in HtB. No increase is detected in terms of sales increase rates (measured by sales increase rate, excess sales increase rate, and net demand increase rate). From the supply side, HtB does not result in a significant enhancement in total factor productivity, thus addressing concerns related to controlling for the internal revenue effects.

The second research question investigates the impact of HtB on marginal profitability by examining its effect on the developer's markup (i.e., price over marginal cost)[7]. Selling more properties at the same margin or supplying fewer properties at a higher margin can both lead to increased profitability, as revealed in profitability analysis. This raises the question of whether the developers are endowed with increased market power and thus become the driving force behind the price increase, facilitated by the HtB scheme (Carozzi et al. 2020). Ascertaining the changes in markup is crucial for assessing the impact of this policy. The DID study indicates that the markup has decreased in participant firms following the policy implementation, suggesting that the increased profitability primarily originates from selling more properties. This finding is further corroborated by the decline in the rate of sales increase and the rise in the rate of inventory increase. The evidence suggests that the HtB policy has encouraged participant developers to supply more properties to the market. As a result, although HtB does not significantly amplify participant developers' margin profitability, the policy remains financially beneficial for participating firms.

The third part aims to further elucidate the analysis drawn from the second research question: how does the policy enable developers to construct more properties? I provide an explanation from the perspective of fixed capital investment. It also serves to validate the conclusion from the second research question while offering an additional perspective to counter criticisms asserting that the HtB scheme generates excessive profits for developers. These criticisms have not considered the benefit of increased financial efficiency for tangible capital investment. For developers, the primary costs

[7] A higher markup indicates a firm's capacity to set a higher asking price, which makes markup an indicator of market power (De Loecker et al. 2020).

of capital investment are adjustment costs and financing costs. Adjustment costs, particularly those associated with land acquisition, rise quadratically with invested capital and bear a close link to market uncertainty (Grimes and Aitken 2010). The HtB policy has introduced a sustained, stable increase in demand in the market, which from a developer's perspective, could lead to lower adjustment costs and higher marginal productivity of capital. This creates more favourable conditions for developers in terms of financing and investment, enabling them to invest more in capital, undertake more construction projects, and achieve greater profitability. Moreover, financing costs can also be mitigated due to the HtB scheme. Most non-financial firms face borrowing constraints and rely on cash flow-based lending for financing (Lian and Ma 2021). The cash flow brought by the HtB can significantly alleviate these financial constraints, further promoting participants' marginal capital productivity.

It's challenging to observe increased marginal capital productivity directly from market trends due to its marginal forward-looking nature (Fazzari et al. 1987; Jason and Jenny 2012). This study, however, proposes a novel approach to perceive this increment from three different perspectives: capital stock, investment-cash flow sensitivity (ICFS hereafter), and debt-cash flow sensitivity. In doing so, it fills a research gap as, up until now, there has been a lack of studies that thoroughly investigate the investment efficiency of developers under credit expansion policies such as the HtB scheme. This approach not only provides a fresh perspective on analysing the impacts of such policies, but also contributes to the broader discourse on investment theory and policy impact analysis.

Lastly, I have also gathered all available financial reports published by participant developers from 2013 to 2020. By using Optical Character Recognition (OCR) techniques to extract keywords, I find that 766 reports highlight the positive effect of the HtB scheme. This study aims to establish a network that connects changes in credit, house prices, developer financial reports, and Q models to examine the dynamics of new home supply under credit expansion policies. This qualitative information provides a supplementary understanding of how credit policies can affect the housing market.

This study contributes to the literature by adopting and proposing enhanced methodologies for policy evaluation. Firstly, it presents a more comprehensive cost-benefit analysis from a causality perspective. In contrast to traditional event-based studies (Archer and Cole 2021; G. Meeks and J. G. Meeks 2018), this research quantifies the financial impact of the HtB scheme on developers using a quasi-natural experimental setting, which mitigates the confounding influences of other factors. Small and medium-sized enterprises' sales are more susceptible to business cycle fluctuations (Bernanke et al. 1999). This underscores the necessity of employing causal-based analysis methods to control for irrelevant economic dynamics[8]. Secondly, this study adopts a new method for calculating markups, enabling the assessment of marginal profitability using financial report data. This contribution can significantly improve the quality of information available for future policy evaluation. Thirdly, the framework proposes innovative approaches to account for potential supply-side effects and measure the savings effect of reducing quadratic adjustment costs, which could lead to an alternative conclusion in its absence.

The remainder of this paper is structured as follows: Section 4.2 presents an overview of the HtB scheme. Section 4.3 reviews the literature concerning the policy from three perspectives. Section 4.4 outlines the primary quantitative DID methodology and other empirical strategies employed in this study. Section 4.5 delineates the selection criteria for identifying sample developers and provides a summary of the key financial variables. Section 4.6 delves into the policy impacts through a comprehensive cost-benefit analysis. It then estimates the difference in markup brought about by the HtB scheme. The policy's effect on capital investment is also explored. Section 4.7 offers

[8]The time frame of this study (2005-2013) aligns with the institutional recovery and expansion period for developers post-2008, during which the overall industry experienced significant growth (Archer and Cole 2021). Traditional methodologies such as event study rely solely on pre-treatment data to construct a semi-counterfactual post-treatment forecast (Huntington-Klein 2022). In contrast, the DID method utilises the untreated group to capture all other driving forces unrelated to the policy, thereby underscoring the influence of the HtB scheme through more authentic counterfactual comparisons.

concluding remarks on the analysis.

4.2 The institutional setup

4.2.1 The Help-to-Buy scheme

The HtB is introduced by the Ministry for Housing, Communities and Local Government in 2013 with several different schemes, and this study focuses on the most popular one named HtB Equity Loan Scheme[9]. The HtB Equity Loan Scheme is essentially a shared equity mortgage, where the government acts as a sharing lender and provides a capital investment of up to 20% (or 40% in the Greater London Area) of the house purchase price in exchange for the same percentage of the future premium. The borrower may choose the portion of the received equity loan, but 20% is the most common plan choice (Benetton et al. 2019). To receive an Equity Loan, home buyers need to pay a minimum down payment of 5%. This means that in common cases, 75% of the purchase expenditure is paid through obtaining a mortgage loan and the buyers need to meet affordability requirements to be granted the government Equity Loan. The Equity Loan is restricted to purchasing new build units with a price of £600,000 or less. The scheme is only available to first-time buyers and movers who do not own a second home, a restriction put in place to limit exploitation and speculation by investor landlords. The Equity Loan has also significantly reduced financial constraints for buyers by reducing interest payments on the loan. The Equity Loan is charged with a symbolic interest (£1 per year) for the first five years after buying the property and an annual interest fee of 1.75% with inflation from the sixth year onwards. Un-

[9]The HtB projects consist of schemes: the Equity Loan Scheme, Mortgage Guarantees, Shared Ownership, and Individual Savings Accounts and New Buy. The Mortgage Guarantees Scheme has not been adopted after the end of 2016. The Equity Scheme has been the most widely adopted implementation among others and has been confirmed to be extended for three years until 2023 due to high demand. The extended Equity Loan Scheme after February 2021 is referred to as the phase two plan. As our data only covers until 2020, this work only studies phase one HtB.

less the homeowner wants to sell the property, they can repay the equity loan at any time without additional fees or penalties. The HtB scheme was initiated in 2013 with an initial budget of £3.5 billion, which was subsequently increased to £8.6 billion in November 2015. Owing to its success, the programme was extended until 2021 with an additional budget allocation of approximately £10 billion. By December 2020, there are 313,043 properties, amounting to a total value of £86 billion, purchased under the Equity Loan Scheme, with the combined value of equity loans reaching £18.9 billion.

4.2.2 The participation of homebuilders

All qualified developers are eligible for the scheme with no minimum restrictions on the number of home construction. However, as required by the British government, home providers must register and be examined for participation. The registry and examination aim to guarantee the timely delivery of the property and minimise the risk of potential issues in terms of financing and project quality. Homes England requires all candidate firms to submit company information for estimation, including financial forecasts for applicable years. The financial forecasts of applicants are reviewed, and grants are approved based on national demand and the availability of funding. For further applications of the scheme, providers must submit forecasts for subsequent years in order to obtain permission to market each year. The prediction of sales submitted by companies and the agreed sales work dynamically: companies are encouraged to promote in order to meet their sales forecasts actively. The actual performance of home providers is reviewed on a monthly basis, and failing to meet the predicted sales goal can result in reduced agreed sales from Homes England. On the other hand, acquiring more customers and increasing sales can lead to increased agreed sales. The government also carries out strict due diligence procedures for absolute discretion. Once approved, these developers are authorised to construct, advertise and sell HtB properties with the official HM Government HtB advertising trademark. The equity mortgage payment for these properties will be transferred from the government's account to the developers at legal completion of the purchase[10]. This makes the participating developer both the supplier and beneficiary of this policy, as well as the gate for the flow of funds from buyers into the house-building systems (Archer and Cole 2021).

Finlay et al. (2016) conduct interviews with executives from both participant and non-participant firms. They find that most participants had anticipated the positive impact of HtB on sales and had been involved in the scheme from the outset. The positive prospect shown in the interview is validated by my examination of the participant's financial reports. I find that 148 companies explicitly reported direct or indirect benefits from the HtB scheme in a total of 766 reports. In most of the reports that mentioned the HtB scheme, the scheme is considered a major positive factor for boosting their sales in the year. HtB is ranked as one of the two most influential factors, along with interest rates for construction companies. A more detailed qualitative analysis is summarised in Appendix A.3.

However, the strict HtB application process also implies why some developers chose not to participate. Finlay et al. (2016) show the primary reasons are uncertainty and complexity. These firms had fewer active sites at any given time and were less likely to be suitable for building HtB properties. These developers also perceive the learning cost to be high, as the application process was rigorous, and they are concerned that the restrictions would make selling difficult. The authors infer that larger companies are more willing to participate and have a more positive view of the policy, whereas smaller companies are more likely to encounter obstacles in understanding and participating HtB. However, their report also indicates that there are small developers with fewer than five properties participating in HtB.

[10]More details can be read from: Builder Guidance.

4.3 Literature review

This section reviews the literature on the impact of credit expansion policy, specifically the HtB scheme, from three perspectives: (1) the impact on price and supply of new properties; (2) the impact on social welfare; and (3) the impact on developer's finance.

Firstly, a credit expansion policy (such as HtB) could cause a significant demand shock and fluctuations in house prices. The decrease in down payment or the relaxation of credit constraints is the primary channel through which policy shock is introduced into the housing price model. The theoretical framework can be traced back to Stein (1995), who develops a benchmark model demonstrating that changes in down payment can directly impact house prices, price volatility, trading volume, and the correlations among them. Ortalo-Magne and Rady (2006) present a life-cycle model illustrating the effects of credit constraints on home purchasing decisions. They show that these constraints delay first-time home purchases and lead to smaller homes being bought. Their empirical findings highlight the significant role of buyers' financial conditions in driving housing prices and transactions, particularly in the first home market. Duca et al. (2011) emphasise the significance of first-time buyers' financial conditions on the housing market, addressing the breakdown of previous housing price models during the US financial crisis by including financial constraints of first-time buyers. They demonstrate that using the cyclically adjusted loan-to-value ratio to measure credit constraints significantly enhances the precision of long-term house price model predictions. Although it is theoretically intuitive that credit expansion can cause an increase in housing prices, measuring the policy effect in empirical studies is difficult, as credit provision and price are endogenous due to houses being used as collateral for credit (Favara and Imbs 2015).

Two empirical studies attempt to address the endogenous issue and evaluate related policies. Favara and Imbs (2015) use a partially implemented deregulation policy as an instrumental variable, finding that a 1 percent increase in instrumented credit leads to a 0.2 percent increase in house price growth rate, peaking after two years and decreasing to zero after five to six years. Their key finding reveals that the price increase is significant in areas with inelastic housing supply, while in the most elastic areas, the price change is not observed, and the housing stock experiences an increase instead. Similarly, Carozzi et al. (2020) use Difference-in-Discontinuity design method to study the impact of HtB on housing price and construction. They reveal that price equilibrium is significantly influenced by the elasticity of housing supply constraints. In the Greater London Area, where the mortgage policy is more generous, the policy is estimated to increase prices by 6 percent due to supply constraints, with no significant increase in supply observed. On the contrary, an increase in construction is observed without an apparent rise in price at the Welsh/English border. HtB is estimated to enhance the likelihood of new home sales at the English border by 8 percent compared to the Welsh border. Overall, the HtB scheme is found to incentivise builders to adjust their construction objectives. Developers tend to shift away from constructing larger properties that exceed the HtB limit, instead focusing on building smaller units that fall just below the threshold of the HtB scheme.

The reviewed studies collectively indicate that credit constraints, or in other words, the ability to pay a down payment, have a significant impact on housing prices, particularly for first homes. The easing of financial constraints introduced by credit expansion policies can boost housing prices, but this effect is closely related to supply elasticity. As suppliers of these new homes, developers' finances and investments are directly affected by the demand shock and house price changes resulting from the policy.

Consequently, Q theory serves as the theoretical foundation for measuring new house construction. The Q theory has been tested in the housing market and demonstrated to be effectively applied (Donald Jud and Winkler 2003). In more recent work, Grimes and Aitken (2010) have developed a fully specified Q theory-based model that validates and connects a series of prior studies on housing supply (Glaeser and Gyourko 2006; Glaeser et al. 2008; Mayer and Somerville 2000). As price takers, developers will supply more properties in response to the arbitrage opportunity brought about by demand or policy shocks, until prices, housing and land stock, and costs reach a new spatial equilibrium where the costs and benefits of living are equal. Their work connects to this study through its emphasis on quadratic adjustment land costs[11]. It suggests that if developers are provided with long-term, stable, and predictable growth opportunities, they will react more quickly to demand shocks by investing and constructing, as the risk of incurring sunk costs or adjustment costs is significantly lower when demand is predictable. Minimising quadratic adjustment costs can significantly mitigate the cost impact of construction. This explanation provides a more nuanced perspective compared to the Guardian article in the introduction. Claiming HtB simply generates super-normal profits for developers lacks the consideration of the benefits of HtB for capital investment efficiency.

Secondly, in terms of increasing living welfare and policy evaluation, Hilber and Turner (2014) examine the Mortgage Interest Deduction policy in the U.S. and find that this policy only increases home-ownership attainment for higher-income households in areas with less stringent land-use regulations. In markets where supply is limited and inelastic, the increased demand could result in higher housing prices, preventing potential buyers with affordability constraints from owning homes. Benetton et al. (2019) demonstrate through a DID study that when a special round of the scheme was launched in February 2016 and announced in London, the maximum portion of acquisition for Equity Loans was increased from 20% to 40%, prompting many individuals to purchase more expensive properties rather than sticking to their initial plans. This study highlights how HtB has facilitated and promoted buyer investment motivation, with the additional credit gains not being used to reduce their indebtedness risk. The reviewed research primarily focuses on investigating the impact from the perspectives of financial affordability and investment risks. This study contributes to the policy study literature

[11]Before introducing the Q approach, models could not accurately capture developers' investment and new house construction (Capozza and Helsley 1989; Roback 1982); Mayer and Somerville (2000) demonstrate this is because land prices were not differentiated in development costs, leading to inconsistent equilibrium in urban growth models.

by providing evidence on how HtB enhances financial benefits for developers and how it enables them to supply more homes without increasing buyers' marginal expenditure.

Thirdly, a limited number of studies have examined the direct impact of HtB on developers' finances. Carozzi et al. (2020) use the DID method to investigate the HtB effect on five profitability metrics, concentrating on a small group of developers. Their results show a significant enhancement in the financial performance of developers participating in the HtB scheme, with increased HtB sales intensity leading to higher costs, revenue, and profit. However, their sample consists of 84 companies, a small subset compared to the sample employed in this study. Moreover, they do not account for other firm characteristics, which renders the treatment and control groups less comparable in a DID context. G. Meeks and J. G. Meeks (2018) gather sales and financial data from four major HtB participant companies[12], which enables them to examine the policy's impact on average marginal profitability at the property level. Their study finds that the profit margin increased from 11.9% in 2012 to 21.4% in 2016 in their samples. This conclusion is supported by Archer and Cole (2021), which analyses the financial reports of the nine largest British developers to product level, indicating that the marginal profit doubled from 2015 to 2017. They discover that the profit before tax generated on a single house unit was £21,545 in 2008, but this figure surged to £62,702 in 2017. Nonetheless, the conclusions of G. Meeks and J. G. Meeks (2018) and Archer and Cole (2021) are limited by the small sample size. More importantly, they do not employ a counterfactual method to construct an analysis of the dynamics. Event studies do not sufficiently control for macroeconomic factors when evaluating property-level profitability, leaving a need for a more causality-based investigation.

[12]They are Barratt, Bellway, Persimmon, and Taylor Wimpey.

4.4 Methodology and estimations

4.4.1 The DID baseline model

This study primarily employs the DID method to examine the impact of the HtB policy on developer financial performance. It compares the changes in the outcome variable between the treated group (i.e., developers who participated in the HtB scheme) and the control group (i.e., developers who did not participate in the scheme), before and after the policy intervention in 2013. This method helps address potential concerns regarding endogeneity issues and allows us to differentiate the effects of the HtB from other macroeconomic factors. The model estimated is:

$$\begin{aligned} KeyVariable_{i,t} = \beta_0 + \beta_1 HtB_i + \beta_2 \sum_{t \in T} Year_t \\ + \beta_3 HtBPostPolicy_{i,t} + \beta_4 \boldsymbol{X}_{i,t} + \alpha_i + \epsilon_{i,t}, \end{aligned} \tag{4.1}$$

The $KeyVariable_{i,t}$ represents the financial variables of interest for developer i in year t. The time fixed effect ($Year_t$) ranges from 2005 to 2020. It controls for any temporal macroeconomic trends which might affect both the treatment and control groups in a similar way. The HtB dummy variable (HtB_i) takes the value of 1 if the builder participated in the HtB scheme (the identification rule is detailed in the data section). The post-policy dummy variable for HtB participants ($HtBPostPolicy$) takes the value of 1 for firm-year observations of HtB participants after 2013. This is because: (1) 2013 marks the initiation of the policy; using 2013 as separation is conventional, as the study of Carozzi et al. (2020). (2) Based on my analysis of the financial reports, most companies that mentioned the HtB anticipated a demand shock in 2013 and participated in the programme right from the outset. The control vector ($\boldsymbol{X}_{i,t}$) consists of proxies for firm size and age, which are represented by the natural logarithm of total assets and age, respectively. This study limits control variables to these two proxies to account for the effects of both external and internal characteristics[13]. This study controls for company fixed effects with α_i and clusters the standard errors based on the HtB variable, which reduces residual variance and increases the power of statistical tests. The $\epsilon_{i,t}$ represents an unobserved individual random error.

The key focus is on the coefficient β_3. If β_3 is statistically significant and positive, it implies that the policy has exerted a positive influence on a financial metric of firms participating in the scheme.

The requirement for the DID method to be valid is that the parallel-trend assumption has to hold. This assumption states that the trends of the variable of interest for treatment and control groups are parallel in the pre-treatment period, and these parallel trends would continue during the treatment period if the treatment had not happened in a counterfactual situation. Although the latter cannot be observed, it is still essential to provide evidence to support this assumption. The parallel-trend test is conducted using the following model:

$$\begin{aligned} KeyVariable_{i,t} = &\beta_{-\tau} \sum_{\tau=1}^{\tau=8} HtBBefore_{i,t}^{-\tau} + \\ &+ \beta_{\tau} \sum_{\tau=1}^{\tau=7} HtBAfter_{i,t}^{+\tau} + \alpha_0 \boldsymbol{X}_{i,t} + v_i + \mu_t + \epsilon_{i,t}, \end{aligned} \tag{4.2}$$

Where the pre-treatment variable $HtBBefore_{i,t}^{-\tau}(\tau = 1, 2...8)$ is a dummy variable that takes a value of 1 if the observation is from an HtB participating firm τ years prior to the HtB event. Notice that there's no $HtBBefore_{i,t}^{0}$ for the last period prior to treatment. This is to avoid issues of perfect multicollinearity (Huntington-Klein 2022). The post-treatment variable $HtBAfter_{i,t}^{+\tau}(\tau = 1, 2...7)$ is a dummy variable that takes a value of 1 if the observation is from an HtB participating firm τ years after the HtB event. The v_i and μ_t represents the firm and year fixed effect, and the $\epsilon_{i,t}$ represents

[13]Financial variables tend to be inherently correlated, and incorporating excessive control variables may result in endogeneity and collinearity issues.

the idiosyncratic error. This means that if the policy year is used as a factor, the baseline level is reset to the year 2013. When the parallel-trend assumption holds, the coefficients of a treatment variable are expected to be close to zero in the pre-treatment period without a noticeable trend. Otherwise, it invalidates the DID model, where the results will have no causal interpretations.

It is conventional to take the logarithmic transformation of financial variables to facilitate the interpretation of regression coefficients. However, in studies using the DID method, it is crucial to adopt a proper measurement of the variable that does not violate the parallel-trend test (Huntington-Klein 2022). If parallel trends are present for a dependent variable in its original measurement form, they will not be maintained for the logarithmic transformation of the dependent variable, and vice versa (Huntington-Klein 2022). Therefore, to validate the choice of the measurement form of dependent variables, this study performs parallel-trend tests on all examined DID variables and their logarithmic transformations. A detailed explanation and justification regarding whether to take the logarithm of each variable are provided in Appendix A.2.

4.4.2 Main analysis - profitability, firm structure and risks

This research aims to examine the impacts of a policy-induced demand shock on a firm from three aspects. First, I probe whether the HtB policy has significantly boosted the profitability of participating firms. This is achieved by applying DID to five pertinent metrics: gross profit, profit before interest and taxation (PBIT), profit after taxation (PAIT), return on capital employed (ROCE), and profit increase rate. Second, to elucidate the effect of HtB on a firm's organisational structure, the DID is applied to five metrics: total assets, total liabilities, total equity, debt ratio. Third, critical risk indicators are analysed to comprehend the financial health disparities induced by HtB. These include the coverage ratio, current ratio, quick ratio, and cash flow ratio[14].

[14]A detailed explanation and comparison of variables can be found in Appendix A.1.

4.4.3 Cost effects

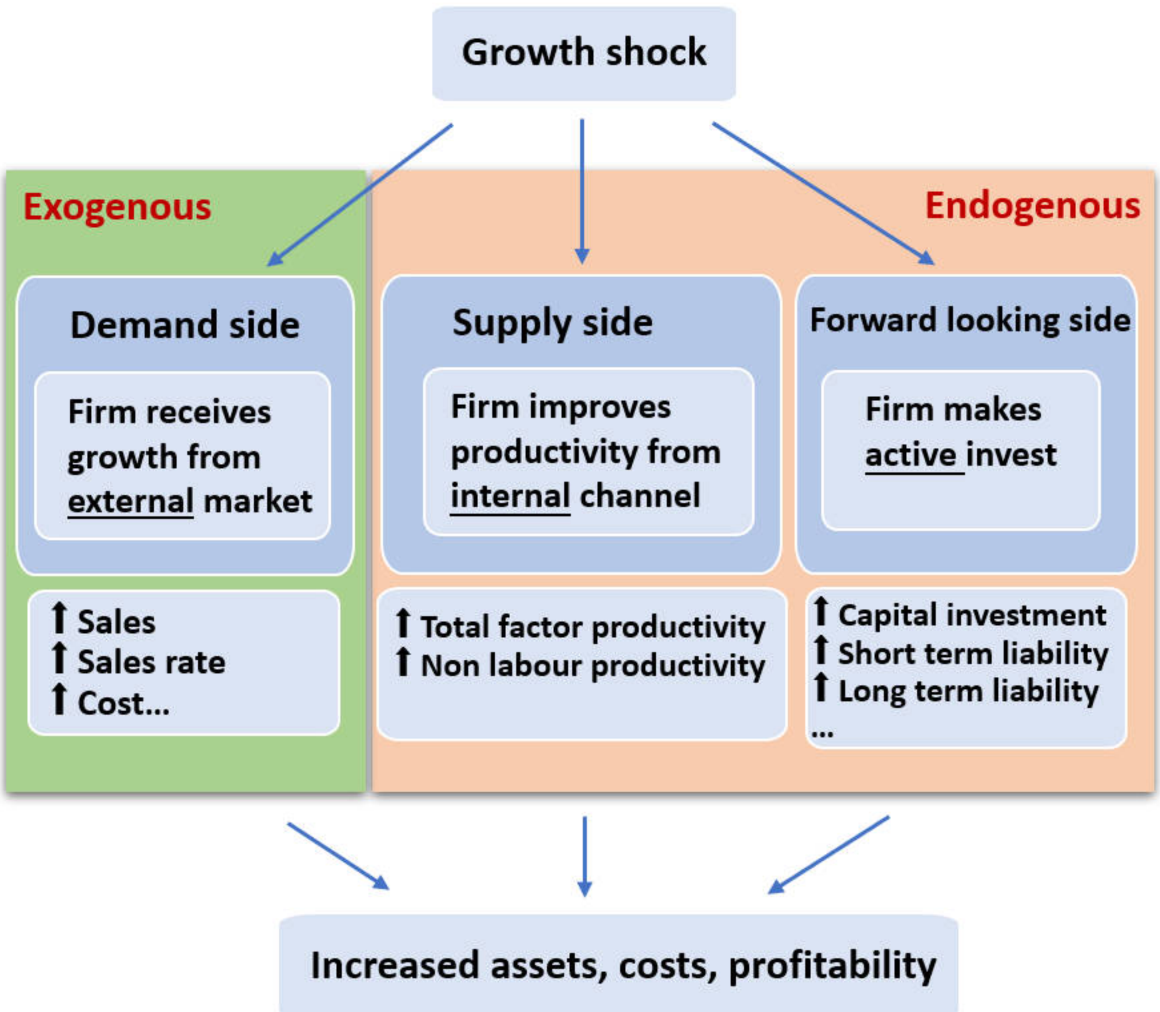
When there is a credit expansion shock, the market will be dominated by the cost effect and revenue effects simultaneously. Positive cost effect refers to the decrease in a company's cost structure as a result of certain factors, such as changes in production methods, raw materials prices, labour costs, and regulatory requirements. Upon reviewing the financial reports of HtB participants, it has been observed that the predominant cost effects of HtB are negative. The increased demand brought by HtB has a significant impact on the value of residential development land, contributing to the negative cost effects[15]. According to the statistics from the Home Builder Federation, a significant increase in planning delays and reductions in both labour and land availability have been observed since 2008 and persist until the present day[16]. To measure the HtB induced cost changes, the DID study is implemented on three key cost measurements: cost of sales, administrative cost, wages and salaries[17].

4.4.4 Revenue effects

In neoclassical investment theory, the revenue effect is closely related to the value-added output in the Cobb-Douglas production function. The revenue effect can stem from two factors: (1) an increase in sales due to market demand, and (2) an increase in sales inspired by research and development or technological advancements. For residential property developers, the first variable signifies an exogenous element influenced by demand, while the second corresponds to an endogenous factor driven by from internal and supply perspective (Ding et al. 2018). These two aspects are developed within the investment model discussed in the methodology section of Chapter 2.1.4

[15]See for example, the statistics of the reports by Savills: The value of land.
[16]See the report regarding the shortage of planning and labour, published by Home Builder Federation.
[17]A detailed explanation and comparison of variables can be found in Appendix A.1.

Figure 4.1: The exogenous and endogenous channels in affecting company's productivity



Note: This plot illustrates the channels through which a credit expansion policy can affect a company's productivity. The policy can induce a positive demand shock from an exogenous perspective, as observed through increases in first and second-order variables such as sales and inventory. Additionally, the demand shock can trigger internal production breakthroughs by increasing R&D or demand shock multiplier effects, resulting in an increase in total factor productivity. Furthermore, firms may also make active investment plans in order to take advantage of the market opportunities created by the policy, resulting in increased capital investment and cash flow intensities.

Demand side

This study examines the revenue effects through six aspects: (1) sales - revenue generated from the sale of properties or real estate developments. (2) inventory - properties or real estate developments available for sale by the company. (3) inventory increase rate. (4) sales increase rate. (5) excess sales growth. (6) net demand increase rate. The first four metrics are the most commonly used factors for measuring exogenous demand shocks (Guiso and Parigi 1999; Sharpe 1994), while the latter two are extensions from recent studies, implemented to better capture the pure demand shock induced by a policy or event.

Excess sales growth, calculated by demeaning the sales increase rate within the HtB and non-HtB groups separately each year, provides additional insights into revenue effects (Ding et al. 2018). In addition to the HtB, an increase in sales could also be influenced by variations in relative market share, which can be attributed to disparate management strategies between HtB and non-HtB groups (Ding et al. 2018). In our scenario, participant firms are incentivised by the government to promote HtB products and establish specialised sales agents[18] (Finlay et al. 2016). My investigation also reveals that all HtB firms utilise trademarks and advertising on their websites to stimulate HtB property sales. Given these findings, excess sales growth is calculated in a demeaned manner to measure the effect on revenue. This approach controls for the factor of relative market share, while primarily focusing on the increase in sales rate brought about by eased credit constraints.

The net demand increase rate provides a more stringent perspective based on the notion that advancements in technology and productivity could also lead to increased revenue. I hope to control this factor in measuring policy impact. Firstly, HtB participant firms implement more building technology upgrades in construction. For instance, the Modern Methods of Construction is a framework that promotes the adoption of

[18] It is a strategy proven effective in selling HtB properties.

innovative building techniques by builders and has been popular since 2005. Its implementation has been incorporated into government-supported development projects in Britain. The implementation of relevant technologies should be evaluated by specialists as part of the initiatives with all HtB properties[19]. A property evaluated under Modern Methods of Construction by the government greatly facilitates information sharing among clients, advisors, lenders, investors, warranty providers, building insurers, and valuers. This potentially boosts the sales of properties. Secondly, there could be a reverse selection bias where more technologically advanced or larger firms are more likely to join the HtB scheme. This study introduces a two-stage residual DID approach, building upon the work of Ding et al. (2018) to calculate the net demand shock change in sales growth. This approach adjusts for potential impacts associated with technology adoption and marketing strategies. The factors are assessed using total factor productivity (TFP hereafter) and administrative expenditure, respectively, as they are the two most significant unrelated factors. Furthermore, it is commonly held that large companies have the advantage of efficient mass production and are less susceptible to information asymmetry, granting them greater access to external funding. Small companies may face financial limitations that restrict their ability to invest in key areas such as advertising and logistics systems (Ding et al. 2018; Guariglia 2008). To account for the potential impacts of firm size on the results, I control for firm fixed effects. The net demand shock is calculated as follows

$$\Delta Sales_{i,t} = a_0 + a_1 AdminCost_{i,t} + a_2 \mathrm{TFP}_{i,t} + v_i + v_t + \epsilon_{i,t}, \tag{4.3}$$

The residual of the change in sales, $\epsilon_{i,t}$, is the variable used to measure the net demand increase rate. The $\Delta Sales_{i,t}$ represents the change in sales of firm i at time t, measured by the difference in the natural logarithm of sales; $AdminCost_{i,t}$ is proxied by the administrative cost of the firm; $\mathrm{TFP}_{i,t}$ measures TFP calculated by the method of D. A. Ackerberg et al. (2015). The details are reviewed in Chapter 2.1.3; vi and v_t

[19] More information can be accessed from the Independent Report published by DLUHC.

represent firm and time fixed effects, respectively.

Supply side

The HtB policy can also impact developers' finances by influencing the participants' innovative construction[20], market power, financing ability, and marginal productivity, which could result in changes in TFP and subsequently lead to alterations in supply (Prescott 1998). Therefore, this study conducted a DID analysis of TFP as a complementary approach to the revenue analysis.

The TFP represents the portion of increased productivity that cannot be attributed to fundamental variables of labour, capital, and intermediate inputs. It is frequently used as a metric for measuring technological progress or improvements in industrial organisation studies (Bellocchi et al. 2021; Goodridge et al. 2018; Solow 1957). Ding et al. (2018) suggest TFP can serve as a metric for measuring growth stemming from supply-side shocks. The external demand shocks typically affect TFP and, as a result, revenue through improvements in management efficiency. Foster et al. (2008) demonstrate that a rise in productivity could reduce marginal costs, leading to an indirect increase in marginal profits. The argument is also supported by a meta-survey study by Syverson (2011), which proposes that differences in TFP are a fundamental dynamic and play a "strikingly high" role in impacting a company's productivity.

The TFP is calculated as the residual of the Cobb-Douglas production function, which is widely considered challenging to estimate. I adopt three methods for estimation, represented by TFP-OP (Olley and Pakes 1992), TFP-LP (Levinsohn and Petrin 2003), and TFP-ACF (D. Ackerberg et al. 2006; D. A. Ackerberg et al. 2015), with details reviewed in Chapter 2.1.3. For robustness, non-labour productivity (non-labour TFP) is also analysed using the DID method. Non-labour TFP is calculated by removing the labour effect from the production function. Labour productivity tends to accumulate

[20] More information can be accessed from the Independent Report published by DLUHC.

in a relatively linear way yet plays a crucial role in construction output[21]. The aim is to discern whether the HtB policy has brought about any event-based technological shocks to productivity. Thus, assessing non-labour TFP helps in determining whether the HtB has impacted productivity with the exclusion of the influence of the labour factor.

4.4.5 Marginal profitability

The second research question investigates whether participating firms have accrued excess profit from the HtB policy at the level of marginal profitability. Marginal profitability is gauged by markup, defined as the price over marginal cost. A higher markup signifies a firm's capacity to levy a higher premium beyond its marginal cost (De Loecker et al. 2020).

Selling a higher volume of properties at smaller margins and selling with larger margins can both enhance builders' profitability. However, the empirical evidence differentiating these two scenarios remains limited. As Carozzi et al. (2020) report, the HtB policy has stimulated an increase in overall construction supply, potentially counteracting property price inflation. Yet, they also observe an interesting pattern in regions with restricted land supply planning, where the HtB policy has led to a significant surge in new property prices.

Such findings highlight the necessity of examining the economic and policy implications of the HtB policy's efficacy in enhancing social welfare. A surge in market power among suppliers suggests incomplete competition and burgeoning market inequality (De Loecker et al. 2020). Hence, carrying out DID study on markup and determining whether the HtB policy has bolstered builders' market power is essential for policy evaluation.

[21]As argued by Sherekar et al. (2016), labour productivity is pivotal in determining a construction company's profitability, as workers and craftsmen make up over 80 percent of a project team and their wages and salaries account for more than 40 percent of the total project cost.

Quantifying markup using financial report data poses a significant challenge, as it doesn't encompass the quantity of property sales (De Loecker et al. 2020, 2016). To overcome this hurdle, I utilise a novel production-based approach proposed in recent literature (De Loecker et al. 2016). This method alleviates the need for assumptions regarding market competition and demand patterns, thereby simplifying the calculation of markup using financial report data (De Loecker et al. 2020). The method is briefly introduced as follows.

With a common notion of the Cobb-Douglas production function in an economy with N firms, indexed by $i = 1...N$. The goal of the firm's production planning is to minimise the Lagrangian objective cost function that:

$$\mathcal{L}\left(V_{i,t}, K_{i,t}, \lambda_{i,t}\right) = P_{i,t}^{V} V_{i,t} + r_{i,t} K_{i,t} + F_{i,t} - \lambda_{i,t}\left(Q(\cdot) - \bar{Q}_{i,t}\right), \tag{4.4}$$

The $\boldsymbol{V} = \left(V^1, \ldots, V^J\right)$ is a vector of production input variables (consisting of labour, materials, intermediate inputs etc.). P^V is the vector of the input prices. r denotes the capital cost of user, and F denotes the fixed capital costs. The λ is the Lagrange multiplier, which also represents the marginal input-output elasticity mathematically. Q(.) is the technology production function which has variables of production inputs and productivity. The function is assumed to be dynamically minimised, where the investment maximisation plan of the current period is minimised, given the conditions in the previous period. Assuming the inputs adjust in a frictionless way. Taking the first-order condition with respect to the input variable V as:

$$\frac{\partial \mathcal{L}_{i,t}}{\partial V_{i,t}} = P_{i,t}^{V} - \lambda_{i,t} \frac{\partial Q(.)}{\partial V_{i,t}} = 0 \tag{4.5}$$

Rearranging the the above function with $\frac{\partial Q(.)}{\partial V_{i,t}}$ on the left hand side and multiplying by $\frac{V_{i,t}}{Q_{i,t}}$ produces:

$$\frac{\partial Q(.)}{\partial V_{i,t}} \frac{V_{i,t}}{Q_{i,t}} = \frac{1}{\lambda_{i,t}} \frac{P_{i,t}^{V} V_{i,t}}{Q_{i,t}} \tag{4.6}$$

Now the left-hand side of the function $\frac{\partial Q(.)}{\partial Q_{i,t}} \frac{\partial V_{i,t}}{V_{i,t}}$ is the expression of the elasticity of bundle input, which can be denoted as $\theta^v_{i,t}$. According to the definition, the markup of a firm is $\mu \equiv \frac{P_{i,t}}{\lambda_{i,t}}$, where the $P_{i,t}$ is the price of the output. Substituting the expression of $\lambda_{i,t}$ in the equation (4.6) lead to the expression for markup:

$$\mu_{i,t} = \theta^v_{i,t} \frac{P_{i,t} Q_{i,t}}{P^V_{i,t} V_{i,t}} \tag{4.7}$$

Markup is computed by considering two primary components: the share of aggregate input in relation to revenue $\frac{P_{i,t} Q_{i,t}}{P^V_{i,t} V_{i,t}}$, and the output elasticity of variable input $\theta^v_{i,t}$. The output elasticity of input $\theta^v_{i,t}$ can be obtained from the coefficient of the production function. For a more in-depth explanation of the production function estimation, please refer to Chapter 2.1.3.

4.4.6 Capital investment

Contrasting with the ex-post analysis in the preceding section, the third part of the chapter aims to provide an ex-ante understanding of the HtB scheme's influence on participant involvement compared to non-participants. I illustrate how the scheme has influenced the developers' construction and supply decisions from the perspective of capital investment.

The fixed capital investment, in contrast to the marginal profitability measured by markup, represents another significant aspect of financial decision-making[22]. From an investment theory perspective, capital investment is the primary driver of production, with marginal investments in materials and labour serving as subsequent consequences (Tobin 1969). The expenditure on tangible capital constitutes a significant cost for construction firms[23]. Meanwhile, capital investment can amplify the productivity of

[22]This highlights the different dimensions of business strategy - one focuses on maximising the return on individual products, while the other centres on the broader financial and strategic investments that can enhance overall business performance.

[23]This is substantiated in Chapter 3, where construction firms are classified into the high asset

both labour and materials, thus leading to increased overall output. Therefore, the financial influence on fixed capital investment holds a crucial role in assessing the cost-benefit evaluation of the HtB scheme, which provides valuable insights into its overall effectiveness and efficiency.

Capital investment decisions in firms are based on the expected return and cost of capital investment in fixed tangible assets[24]. The primary effect of the HtB policy is that it could directly increase marginal capital return by enhancing sales. The HtB policy could considerably reduce the adjustment cost of capital investment and land (Grimes and Aitken 2010). As reviewed in Chapter 2, investments in fixed tangible assets tend to occur within an inter-temporal context, marked by a degree of rigidity. Higher adjustment costs could stem from more unpredictable market demand as it incurs greater adjustment costs or sunk costs. The reduction in investment uncertainty leads to lower adjustment costs and, consequently, an increase in investment returns. This cost-saving effect serves as a primary incentive for developers to supply more homes to the market. This increased return and reduced adjustment cost result in enhanced marginal productivity, indicative of the marginal Q in Q theory. Although the impact of the HtB scheme on the increase in participants' marginal productivity cannot be directly quantified due to its marginal mathematical nature, as reviewed in Chapter 2, this study attempts to propose new approaches to observe these effects.

Firstly, Q theory suggests that firm operators will respond to the policy-induced demand shock, raising capital investment to meet the market demand for HtB properties. The changes in the source and stock of capital can directly reflect the increased profitability of capital investment from a managerial standpoint. Secondly, the decrease in the adjustment cost of capital investment is demonstrated by the heightened marginal sensitivity, indicated by an increase in both investment-cash flow sensitivity and debt-cash flow sensitivity. They highlight a marginally increased trend towards greater financial efficiency and enhanced capital utilisation.

tangibility group, based on rankings of asset tangibility ratio and earnings per capital.

[24] A more systematic framework is presented by Acemoglu (2012).

(A) The capital source and stock

Debt financing and equity financing are the two dominant methods of financing. Compared to other developed countries in the European Union and the United States, the United Kingdom has a relatively smaller market for corporate bonds and commercial papers. The concentration of venture capital firms is less marked compared to other nations. The banking and equity markets are subject to rigorous regulatory oversight (Guariglia 2008). As 99% of the firms in our sample are not publicly listed, our primary focus is not on equity stock or corporate bond financing. Therefore, it is expected that in these firms, debt and internal cash flow are the primary channels for financing.

The increases in the source of capital indicate the increase in capital needs. Given this context, I first examine the change in the sources of capital investment by DID methods with three variables: (1) Internal cash flow, measured by the sum of turnover, depreciation, and amortisation. Internal cash flow is a significant source of funding for the firms in our sample. Small and medium-sized firms often face financial constraints due to issues such as asymmetric information and market inefficiencies. Consequently, companies utilise internal cash flow as a source to make capital investment (Ding et al. 2018; Fazzari et al. 1987; Kaplan and Zingales 1997; Moshirian et al. 2017). Meanwhile, the debt financing of most unquoted firms is significantly constrained by their cash flow (Lian and Ma 2021). An increase in cash flow due to the HtB scheme could significantly enhance capital productivity. (2) Long-term liabilities, measuring debts or obligations due more than one year into the future. These can include loans, bonds, or lease obligations. (3) Current liabilities, measuring debts or obligations due within one year. Current liabilities include short-term loans, accounts payable, and income taxes payable.

The increase in capital investment can be observed from three accounting categories: (1) Working capital, measuring the amount by which a company's current assets exceed its current liabilities. It gauges a company's ability to meet its short-term obligations and is considered a vital indicator of its overall financial health. (2) Tangible assets, measuring physical assets that hold monetary value and can be sold, such as property, machinery, or equipment. (3) Fixed capital, measured by the sum of tangible assets, intangible assets, and investment terms. (4) Fixed capital investment, measured by the annual change in fixed capital.

(B) Investment-cash flow sensitivity

I observe marginal productivity increase by comparing the ICFS, which measures the marginal increase in capital investment corresponding to an increase in internal cash flow (Fazzari et al. 1987). An increase in ICFS denotes a company's intensified usage of its internal cash flow for capital investment and an elevated capital investment intensity. The ICFS provides an internal perspective, pricing firms' growth expectations through expenditures on internal cash flows. It serves as an estimation of the point where capital investment becomes marginally profitable, that is, when the savings effect from the reduced adjustment cost outweighs the increased cost generated by the demand shock. This metric quantifies the marginal increase in capital profitability that cannot be captured with markup. As delineated in Chapter 3, construction companies are known to depend heavily on fixed assets and the ICFS has been declined in the last three decades due to low investment return. If the dominant saving effect of adjustment costs is evident, a more significant surge in the ICFS is expected to be observed in the HtB participant group during the pre- and post-HtB periods.

The ICFS is estimated using a model commonly extended from the work of Fazzari et al. (1987):

$$\mathrm{INV}_{i,t} = \alpha_{i,t} + \beta_0 + \beta_1 \mathrm{INV}_{i,t-1} + \beta_2 Q_{i,t-1} + \beta_3 \mathrm{CF}_{i,t} + \varepsilon_{i,t} \tag{4.8}$$

The dependent variable $\mathrm{INV}_{i,t}$ represents the investment in the capital of firm i in year t, measured by the change in tangible assets and scaled by the beginning-of-period capital stock, which is proxied by total assets in this study; $Q_{i,t-1}$ is marginal

Q in the Q theory, which measures the marginal productivity of capital. This study measures marginal Q using the change in the logarithm of sales (i.e., sales increase rate), following the previous study of Guraiglia (2008). For a robust test, this study also controls for the marginal Q using proxies for TFP, as TFP can also reflect standard growth opportunities for small and medium-sized firms (Ding et al. 2018). $CF_{i,t}$ is the internal cash flow, measured by summing firm i's profit before interest with depreciation and amortisation, scaled by the beginning-of-period capital stock. The $\alpha_{i,t}$ denote the firm's fixed effect and time-fixed effect, respectively.

Equation 4.8 postulates that a firm's capital expenditure not only depends on the growth opportunities measured by the marginal Q, but also on the level of internal cash flow. Therefore, in our analysis, the β_2 coefficient captures the investment-Q sensitivity, and the β_3 is the ICFS. A statistically significant coefficient for β_3 suggests that the firm is enhancing its capital investment intensity in response to the demand shock.

As the dynamic Model 4.8 contains lag terms $I_{i,t}/A_{i,t-1}$ as explanatory variables, which can potentially produce biased results with OLS estimation due to endogeneity issues. Therefore, following existing literature, I estimate Model 4.8 using a first difference GMM estimator, which uses moments conditions for estimation to overcome endogeneity issues[25]. The companies are classified into groups based on the time period (2008-2013 and 2013-2020) and whether they participated in the HtB programme or not, and then test the coefficients for each group over pre and post HtB periods respectively.

(C) Debt-cash flow sensitivity

Debt-cash flow sensitivity outlines the relationship between a firm's cash flow and its levels of debt, indicating how variations in cash flow affect the company's inclination and capacity to take on debt. This sensitivity is typically negative because an increase

[25] More detail is discussed in Chapter 2.2.

in cash flow tends to result in a decrease in debt (i.e., debt is recorded as a negative value on the balance sheet, so a decrease in debt signifies a higher magnitude). Contrary to the Modigliani-Miller theorem, which assumes that firms can freely raise capital, in reality, companies are often compelled to finance their operations based on their internal cash flow.

An elevated sensitivity could suggest a firm's growing reliance on internal cash flow for debt financing, which could imply more intense financing needs. The study of Lian and Ma (2021) shows that the vast majority of non-financial private firms heavily rely on cash flow for their debt finance. And a company's borrowing constraints heavily hinge on its ability to generate cash flow, i.e., its operational earnings. Thus, an increased magnitude of sensitivity reflects the heightened leverage of cash flow-based borrowing, indicating relaxation of borrowing constraints, reduced financing costs, and enhanced financial efficiency. So it can be used to assess investment efficiency and determine whether the HtB provides developers with more funding to meet their construction objectives (Ding et al. 2013; Larkin et al. 2018). An increase in the magnitude of sensitivity is indicative of increased demand in the capital market, making it an alternative to ICFS for observing developers' marginal capital productivity.

Following the study of Larkin et al. (2018), the debt-cash flow sensitivity is estimated by the model that

$$\Delta \mathrm{Debt}_{i,t} = \alpha_{i,t} + \beta_0 + \beta_1 Q_{i,t-1} + \beta_2 \mathrm{CF}_{i,t} + \beta_3 \mathrm{X}_{i,t} + \varepsilon_{i,t} \tag{4.9}$$

Here, ΔDebt represents the change in total liabilities, normalised by the total assets of the initial period. The term $\mathrm{X}_{i,t}$ measures firm characteristics control factors, quantified by firm size and age. The remaining terms are consistent with those in the Model 4.8. The model is estimated by OLS estimation.

4.5 Data and Summary Statistics

The financial data for builders is taken from the FAME database (Bureau Van Dijk), Bureau Van Dijk Electronic Publishing's Financial Analysis Made Easy (FAME) database. FAME collects information on companies in the UK from various sources. The information includes financial and accounting data from balance sheets, cash flow statements, and profit and loss statements, as well as legal entity details, merger and acquisition activity, news, corporate structures, and ownership.

A significant objective of this study is to compile an exhaustive list of new home providers in the UK, identifying those participating in the HtB scheme. To accomplish this, I have collected and cross-referenced information from multiple sources. Firstly, the names of registered new home providers are collected from the government list[26]. Secondly, I explored the historical archives of builders as recorded by Google, including developers registered with the Home Builders Federation and key British housing websites such as Zoopla and New-Homes. As noted in the second section, the government has enforced specific regulations encouraging firms to advertise their properties online[27]. Based on these pieces of information, I classify a company as a non-HtB builder if it is neither registered with the government office nor does it have archived advertisements for HtB homes.

The initial data includes 981 companies for the period 2005-2020. Firms with no registered number or no matched information in FAME are excluded from our sample. Firms with missing values in turnover, profit before interest, and total assets are excluded from the sample. This results in a final sample of 797 firms (685 HtB companies and 112 non-HtB companies). I present the geographical representation of the main

[26] The lists are published under the name of Help To Buy Scheme - Listing of Registered Qualifying Contractors. They are published by the governments of England, Wales, Scotland, and Ireland, respectively, on the government website.

[27] Companies are mandated to provide HtB related information and distinctly mark HtB properties with a unique HtB trademark endorsed by the government. This mandate not only aids in the extensive search for builder information but also allows for the accurate identification of their participation in the HtB scheme.

operating locations of developers, as indicated in their registration, in Figure 4.4 in Appendix A.3.

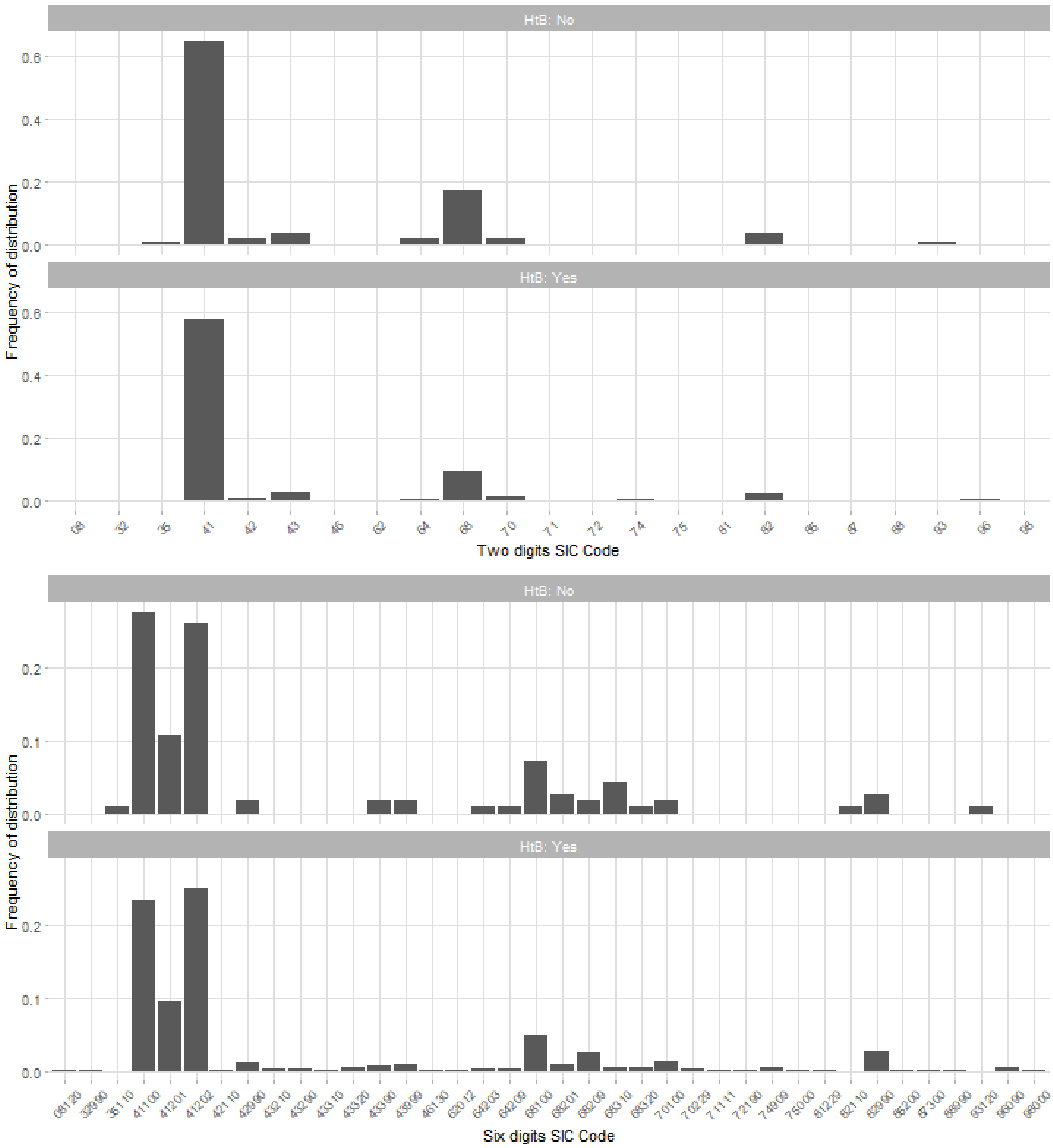
In terms of firm composition, conducting a DID study with more homogeneous groups can provide major support for the parallel trends assumption. I use three approaches to ensure the homogeneity of control and treatment groups. First, I search the firm description to verify that they are officially engaged in providing new homes as their primary operational activity[28]. Second, I manually searched for every company to ensure that there was a company website and Zoopla marketing properties, indicating that participating companies were advertising and selling properties in a similar manner to non-participants. Third, I conducted an industry SIC description and summarised the results in Figure 4.2. This figure demonstrates the firm's composition of HtB and non-HtB group. The first and second figures represent the two-digit SIC frequency bar plots of HtB and non-HtB firms. The two-digit Standard Industrial Classification code summarises the registered primary operational activity of the firms. It is evident that over 85% of the sample companies primarily engage in construction (code 41-43) and real estate activities (code 68). The six-digit code provides a more detailed description, and it can be observed that the distributions of HtB and non-HtB firms are highly homogeneous. This provides strong evidence for using the DID method to measure the impact of the policy.

4.5.1 Data Summary

Table 4.1 presents a summary of the main financial report variables utilised in this study. The other ratios and variables are obtained from these key variables. Initially, it can be noted that the median number of employees is 46, while the mean is 410. The disparity between the median and mean suggests a right-skewed distribution, with a larger concentration of smaller developers. This aligns with the fact that 99% of

[28]Developers are designated as "new home" developers in distinct ways through registration in government lists, the Home Builders Federation, and New Home.

Figure 4.2: The summary of industrial classification of developers



Note: This figure summarises the main operational activities of developers between participants and non-participants, measured by industrial classification. The y-axis indicates the percentage of the firms registered under each industry code. The first and second figures represent the two-digit SIC frequency bar plots of HtB and non-HtB firms, respectively. The third and fourth figures represent the six-digit SIC summary statistics. From the figure, we can see that developers in both the control and treatment groups engage in similar activities, indicating a high level of homogeneity between the two groups.

British companies are classified as SMEs[29]. This is further evidenced by the discrepancy between the mean and median of all other variables.

Table 4.1: The summary statistics of main variables

Statistic	N	Median	Mean	St. Dev.	Pctl(25)	Pctl(75)	Max
Gross profit	3,481	3,637	39,838	126,994	1,094	15,455	1,179,900
Profit before interest	3,276	2,550	32,713	108,438	605	11,704	1,103,100
Profit after taxation	3,059	1,690	23,372	83,135	405	7,432	886,400
Cost of sales	3,336	18,429	159,935	447,485	6,257	66,025	4,265,600
Administration expense	3,833	2,369	21,054	62,164	811	11,211	1,114,900
wages and salaries	2,975	3,362	20,779	46,827	1,333	12,895	364,079
Total assets	8,851	3,602	146,116	640,339	468	23,729	7,889,900
Total liabilities	5,217	5,610	146,470	525,774	1,164	37,033	6,885,900
Current assets	8,738	3,006	103,988	476,608	352	20,837	6,555,900
Working capital	6,421	2,685	74,835	339,939	296	16,301	4,799,400
Inventory	6,239	3,643	107,716	466,545	663	20,773	6,017,800
Sales	3,640	23,458	192,660	534,726	7,694	89,378	4,874,800
Tangible assets	5,939	176	37,258	322,312	25	1,178	6,695,300
Fixed assets	6,367	431	60,409	406,112	43	2,930	7,431,500
Long term liabilities	5,255	799	66,719	366,776	100	7,021	6,239,000
Current liabilities	7,978	1,893	54,907	237,834	362	12,866	4,376,191
Number of employees	4,126	46	410	1,239	8.2	183	16,265

Note: The table presents summary statistics of the main financial report variables used in this study. All other variables and ratios are computed based on the main variables. The unit of monetary variables is thousand pounds. The sample period is from 2005 to 2020. N represents the total number of firm-year observations. Additionally, summary statistics such as the median, mean, standard deviation, first and third quartiles, and maximum value are reported. Notice that while cost and liability terms in financial reports are typically recorded as negative values, they are recorded in absolute values in this study for the purpose of comparison.

The sales, total assets, total liabilities, and cost of sales have the highest magnitude, with average values of 192.7 million, 146.1 million, 146.5 million, and 159.9 million, respectively. This is followed by a high inventory stock of 107.7 million. The median values of total assets, total liabilities, and inventory are notably lower in magnitude.

The average overhead cost (administration expenses) is considerably lower than the cost of sales, indicating that for developers, the main challenges do not lie in expenditures related to marketing or interest payments. This aligns with a recent study that suggests that land and labour costs are the major expenditure for developers. The labour cost is higher among smaller firms. Sherekar et al. (2016) demonstrate that at a marginal level, workers and craftsmen make up over 80% of the project team, and their wages and salaries account for more than 40% of the total project cost. Their data also demonstrate a right-skewed trend with an average marginal profit ratio (calculated as

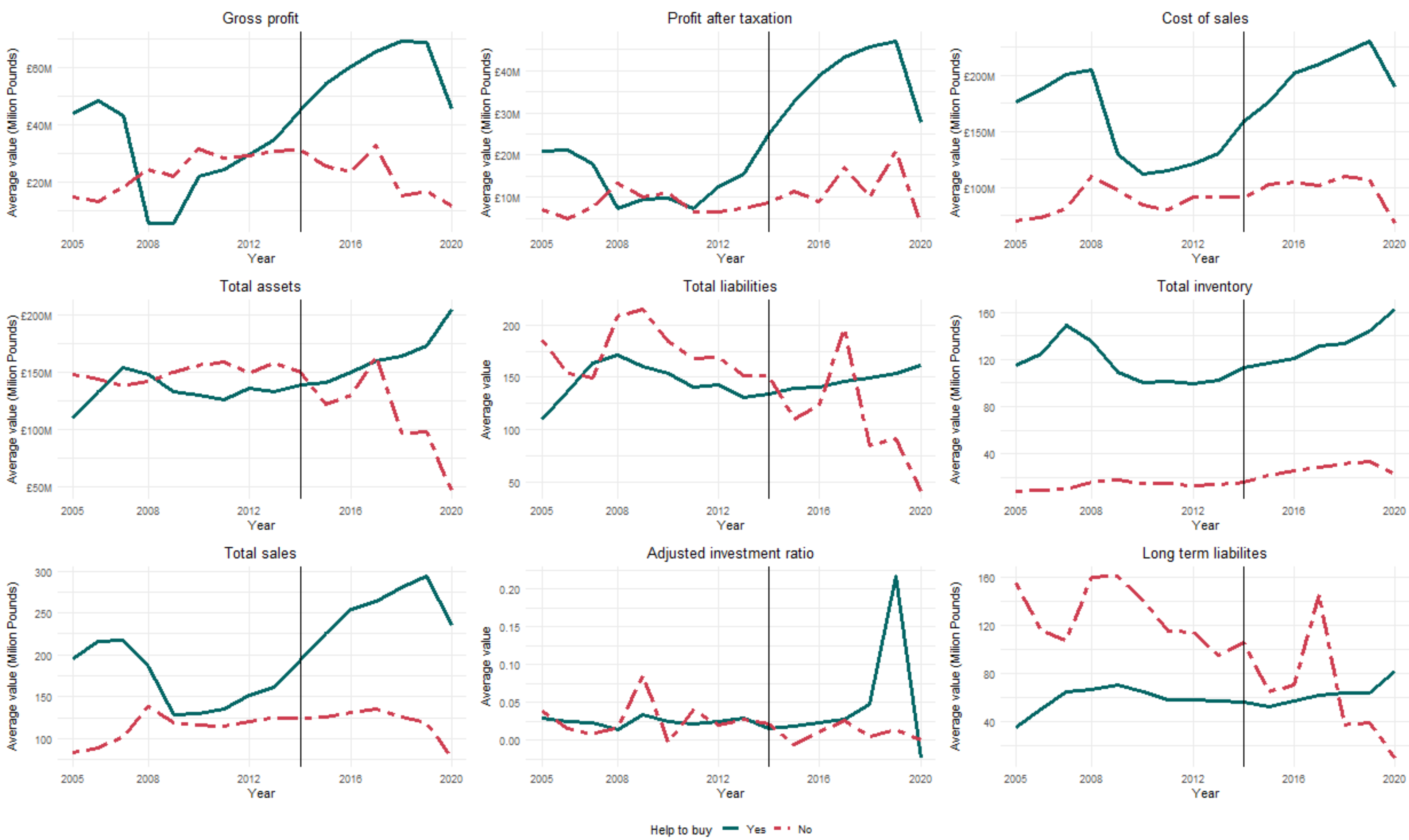
[29]For more information, please read Business population estimates for the UK and regions 2022.

the gross profit divided by sales) of 20.68%, while the median value stands at 15.5%.

Firms in my sample tend to maintain a high level of current assets, which is possibly attributable to specific properties recorded as inventory items. This might indicate a strong capacity to meet short-term obligations, from both the mean and median perspectives.

However, there appears to be a disparity between current and long-term liability terms. The median value of long-term liability is not only substantially lower compared to total assets, but also significantly less than current liability. However, their mean values are quite similar. This may suggest that many small companies do not utilise long-term liability to finance their investments and only larger companies are able to afford the higher interest payments and have greater access to financing markets with less liquidity risk. Conversely, the higher current liabilities median indicate that smaller developers may face relatively higher short-term financial risks.

Figure 4.3: Mean comparison of HtB and non-HtB variables over time



Note: This plot presents the time-varying comparison of the mean values of the primary variables used in this study. They are calculated within HtB and non-HtB participant groups each year. The year 2014 is indicated by a vertical line and serves as a benchmark for post-implementation of HtB. Notice that, the total liabilities and current liabilities are recorded as negative values in the balance sheet, their absolute values are used for comparison purpose.

The figure shown in Figure 4.3 provides a comparison of the average values of the primary variables between firms that engaged in HtB and those that did not. The year 2014 is indicated by a dark vertical line, marking the point where a potential divergence in the data can first be observed. From the data presented in the figure, several observations can be made. Firstly, there appears to be no significant difference in terms of firm size between the HtB and non-HtB participant firms, as indicated by the total asset level. However, a divergent trend is observed following the initiation of the HtB scheme. Similar divergences are also noted in the mean values of profitability metrics (gross profit, profit after taxation) and capital investment metric (investment ratio).

On the other hand, the cost of sales, inventory, and sales exhibit a discrepancy prior to the initiation of HtB. The discrepancies are further amplified after the initiation of HtB. In contrast, the total liability presents a distinct pattern. The total liability is higher in the non-HtB group prior to 2014, and then decreases in the non-HtB group while increasing in the HtB firm group after 2014.

4.6 Results

4.6.1 Main results: profitability, firm structure and risks

Our literature analysis predicts that the credit expansion policy will boost the demand and supply of new residential properties[30]. This section presents the DID study findings regarding profitability, firm structure, and risk indicators, estimated by Model 4.1. All models have been tested using Model 4.2, which shows no evidence to reject the parallel trend assumption. The pre-trend parallel test plots can be found in Appendix A.5. The choice of dependent variables for the DID analysis (using logarithmic or original values)

[30]The aggregate impact of the policy on developers' net profitability could not be confirmed prior to regression analysis, as the heightened demand may also result in increased costs.

is determined based on the results of the parallel tests.

Table 4.2: The impact of HtB on the profitability of builders

	Gross profit		Profit before interest		Profit after taxation		ROCE		Profit increase rate	
	1	2	3	4	5	6	7	8	9	10
HtB*PostPolicy	38765.171**	40198.706**	32367.479**	33661.631**	22980.305**	23584.209***	0.022**	0.021*	−0.503*	−0.543*
	(284.421)	(121.895)	(78.128)	(147.242)	(224.933)	(8.703)	(0.000)	(0.001)	(0.013)	(0.009)
Firm characteristics	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Num. obs.	3013	3013	2589	2589	2438	2438	2589	2589	3013	3013
R^2 (full model)	0.669	0.671	0.743	0.744	0.714	0.714	0.368	0.426	0.173	0.174
Adj. R^2 (full model)	0.625	0.627	0.704	0.705	0.669	0.669	0.272	0.339	0.064	0.065

Note: This table displays the results of the DID estimation for Model 4.1 with different profitability measurements as the dependent variable, as indicated in the first row of the table. The standard errors of the estimated coefficients are presented in parentheses. The first column of each variable represents the coefficients estimated without incorporating firm characteristics, while the second column reports the estimations with full control of the model. The treatment group (HtB) consists of firms that participated in the HtB scheme. The pre-treatment period is from 2005-2012 and the post-treatment period ($PostPolicy$) is from 2013-2020. The Num. obs. reports the total number of firm-year observations. The R^2 and Adjusted R^2 are reported as measures of the model's goodness-of-fit. The standard errors are clustered at the HtB and non-HtB group level. The significance level is denoted as: $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

Table 4.2 presents DID study results on developers' profitability using five metrics. For each metric, the coefficients in the first and second columns denote the impact of the HtB policy without and with controlling for firm characteristics. The results consistently indicate a significant and positive effect of HtB on profitability. The ensuing discussions primarily draw from the second-column result of each metric.

Table 4.2 shows that participating developers experience an increase in gross profit by 40,198 thousand pounds, and an increase in PBIT by 33,661 thousand pounds as a result of HtB. Moreover, the net profit, denoted by profit after taxation, record an increase of 23,584 thousand pounds. The difference between the gross profit and PBIT includes administrative expenses, other operation costs, and any exceptional profits (for instance, profits from investment and financing activities). The two figures imply that although HtB can lead to an increase in these expenses (shall be shown in Table 4.5), on average it has not significantly attenuated the profitability. Meanwhile, the difference between the increases in PBIT and profit after taxation is larger, implying that the policy might have led to a substantial rise in tax and interest payments. This is expected given the increase in net profit and liabilities.

Furthermore, the significant coefficient of 0.021 for ROCE underscores the HtB's positive impact on profitability, implying that participants can generate higher profit relative to the capital employed due to the policy. However, a decline in the rate of gross profit increase is observed. This may be attributed to the HtB-induced supply increase partially offsetting the sales, which will be further explored in subsequent analyses.

Table 4.3: The impact of HtB on the asset structure of builders

	Total assets		Total equity		Total liabilities		Debt ratio	
	1	2	3	4	5	6	7	8
HtB*PostPolicy	73184.389***	75129.076**	58040.610*	64743.660**	46795.987*	54528.702	0.042*	−0.175
	(60.918)	(270.058)	(1015.622)	(814.845)	(1035.781)	(5876.394)	(0.003)	(0.081)
Firm characteristics	No	Yes	No	Yes	No	Yes	No	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Num. obs.	8851	8851	5216	5216	5217	5216	5216	5216
R^2 (full model)	0.900	0.900	0.853	0.854	0.872	0.875	0.152	0.186
Adj. R^2 (full model)	0.890	0.890	0.834	0.835	0.855	0.858	0.041	0.078

Note: This table displays the results of the DID estimation for Model 4.1 with different firm structure measurements as the dependent variable, as indicated in the first row of the table. The standard errors of the estimated coefficients are presented in parentheses. The first column of each variable represents the coefficients estimated without incorporating firm characteristics, while the second column reports the estimations with full control of the model. The treatment group (HtB) consists of firms that participated in the HtB scheme. The pre-treatment period is from 2005-2012 and the post-treatment period ($PostPolicy$) is from 2013-2020. The Num. obs. reports the total number of firm-year observations. The R^2 and Adjusted R^2 are reported as measures of the model's goodness-of-fit. The standard errors are clustered at the HtB and non-HtB group level. The significance level is denoted as: $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

Table 4.3 demonstrates the impact of the HtB on the asset structure of participating firms. The policy positively influences the total assets and equity levels of participants, leading to an average increase of 75,129 thousand pounds and 64,743 thousand pounds, respectively. The rise in equity, which signifies the growth in the value or ownership of a firm's assets, could be attributed to asset appreciation, new investments, or profits in the business (Ross et al. 1999). Therefore, on average, HtB enhances the wealth of participating firms and increases value for shareholders.

The significant rise in equity is accompanied by no significant change in total liabilities, as shown in Table 4.3. The debt ratio (the proportion of total liabilities to total assets) remains unchanged statistically after the HtB. As analysed in the summary statistics, the median of long-term liabilities is significantly lower compared to current liabilities or total assets. Thus, it is possible that the unchanged total liability can be attributed to the unchanged long-term liability. This is reasonable as most firms in my sample are unquoted, and face limited access to long-term liabilities due to asymmetric information and a lack of collateral value (Guariglia 2008). In this case, the HtB scheme does not result in any significant difference in their approach towards financing long-term liabilities. This will be further discussed in the capital analysis part. With equity on the rise and liabilities remaining unchanged, the implementation of HtB at an average level, mitigates participants' financial risk by reducing the proportion of debt relative to total assets for participating firms. This yields long-term advantages, such as improved financial flexibility, more collateral for future debt leveraging, and reduced capital market financing costs.

Table 4.4 delves deeper into the liquidity risk. It reveals that the HtB scheme hasn't led to an increase in the coverage ratio for the participating firms[31]. The coverage ratio, calculated by dividing a company's PBIT by its interest expenses, gauges a company's ability to fulfil its debt and obligation payments. In this situation, the unchanged coverage ratio could be due to the rise in interest payments, which result from the

[31] A high coverage ratio, indicating a significant cash flow relative to debt obligations, generally signifies fewer internal financial constraints.

Table 4.4: The impact of HtB on the risk indicators of builders

	Coverage ratio		Current ratio		Quick ratio		Cash flow ratio	
	1	2	3	4	5	6	7	8
HtB*PostPolicy	52.154*	52.989	0.163*	0.170**	0.135*	0.107*	0.293*	0.288**
	(2.397)	(5.998)	(0.003)	(0.001)	(0.002)	(0.008)	(0.009)	(0.001)
Firm characteristics	No	Yes	No	Yes	No	Yes	No	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Num. obs.	2571	2570	2568	2568	2355	2355	2566	2566
R^2	0.301	0.301	0.741	0.742	0.662	0.675	0.594	0.601
Adj. R^2	0.190	0.190	0.700	0.701	0.609	0.623	0.530	0.537

Note: This table displays the results of the DID estimation for Model 4.1 with different risk measurements as the dependent variable, as indicated in the first row of the table. The standard errors of the estimated coefficients are presented in parentheses. The first column of each variable represents the coefficients estimated without incorporating firm characteristics, while the second column reports the estimations with full control of the model. The treatment group (HtB) consists of firms that participated in the HtB scheme. The pre-treatment period is from 2005-2012 and the post-treatment period ($PostPolicy$) is from 2013-2020. The Num. obs. reports the total number of firm-year observations. The R^2 and Adjusted R^2 are reported as measures of the model's goodness-of-fit. The standard errors are clustered at the HtB and non-HtB group level. The significance level is denoted as: $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

increase in short-term liabilities. This, in turn, partially counterbalances the rise in profit.

On the other hand, there are observed increases in the current ratio (0.170) and quick ratio (0.107) as a result of HtB. The current ratio, calculated by dividing current assets by current liabilities[32], and the quick ratio, calculated by dividing the difference between current assets and inventory by current liabilities, both measure a firm's ability to meet its short-term obligations with its current assets. The quick ratio is a more stringent measure as it excludes inventory from the calculation of liquid assets. The significant coefficients suggest that the HtB has a positive impact on reducing firms' short-term liquidity risk. The increase in both ratios suggests that the HtB scheme has led to a rise in current assets, which on average increases faster than current liabilities.

The last column of Table 4.4 shows that the HtB has brought a positive impact on the cash flow ratio (with a coefficient of 0.288) to participating developers. This ratio is calculated by dividing the net cash flow[33] by current liabilities, indicating an increased

[32]The denominator contains inventory, trade debtors, bank deposits and deferred taxes, and other current assets and investments.

[33]Cash flow typically includes inflows and outflows from operating activities (such as sales, supplier payments, and employee salaries), investing activities (such as purchases of property, plant, and

ability for participants to generate enough cash flow to meet their short-term obligations. Unlike the current assets account, which records stock value, cash flow measures the yearly change (accumulation) in cash flow. This implies a more substantial easing of financial constraints, as cash, due to its liquidity, provides a more flexible means of covering incurred interest payments.

4.6.2 Cost effects

Table 4.5 presents the results of a DID study of three cost measurements. The cost of sales represents the incremental expenses directly tied to the sale of product units, such as direct labour costs and material costs. Administrative expenses capture overhead costs that cannot be directly attributed to sales, including marketing costs, administrative salaries, and other financial outlays. The wages and salaries reported in the profit and loss statement encompass the labour costs for all workforce. There are certain overlaps between the wages and salary terms with the other two cost measures.

Table 4.5 demonstrates that the implementation of HtB has a significant positive impact on all three cost measurements, with a coefficient of 0.231 in cost of sales, 0.231 in administrative expenses, and 0.140 in labour costs. The proportional increase of the first two variables is approximately 26%[34]. The percentages evaluated at the sample mean indicate an increase of 41,583 thousand pounds in cost of sales and 5,474 thousand pounds in administrative expenses. This is consistent with the information from the descriptive financial reports. As reported by firms, the acquisition of land and the wages of builders are two major expenses for construction companies. Meanwhile, the primary cause of the increase in cost is inflation, followed by the impact of HtB.

The average increase in labour costs (15%, equivalent to 3,117 thousand pounds on

equipment or investment in securities), and financing activities (such as borrowing from banks or issuing bonds).

[34] As the DID analysis is performed on the logarithm of the variables in this table, the proportional difference in the variables is calculated as $\Delta Variable = e^{coefficient} - 1$.

average) is not as pronounced as that of the other costs. However, this trend is expected to intensify over time, as the data analysed does not encompass a sufficient period post-Brexit. The depletion of skilled construction talents due to Brexit has been identified as a factor impacting the supply of new homes in the market. This subsequently impacts property prices in the future[35].

Finally, the interest payment and tax payment experienced an average increase of 4,245 thousand pounds and 2,920 thousand pounds in the participant group, respectively. This outcome is in line with expectations, as the increase in interest payment primarily comes from the rise in current liabilities, and the increase in tax payment results from the increase in net profit.

[35] For additional information, refer to the report by economist Hansen Lu - What will Brexit mean for housebuilders.

Table 4.5: The impact of HtB on the costs of builders

	Cost of sales - Log		Admin expenses - Log		Wage and salaries - Log		Interest payment		Taxation	
	1	2	3	4	5	6	7	8	9	10
HtB*PostPolicy	0.329^{*}	0.231^{**}	0.325^{**}	0.232^{**}	0.165^{**}	0.140^{**}	4408.101^{**}	4245.913^{*}	2869.217^{*}	2920.834^{*}
	(0.006)	(0.001)	(0.003)	(0.002)	(0.002)	(0.002)	(16.244)	(130.336)	(165.168)	(165.973)
Firm characteristics	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Num. obs.	3333	3332	3833	3832	2975	2974	3266	3265	1278	1278
R^2 (full model)	0.859	0.889	0.874	0.909	0.929	0.946	0.775	0.779	0.383	0.385
Adj. R^2 (full model)	0.841	0.875	0.859	0.898	0.920	0.939	0.746	0.751	0.268	0.269

Note: This table displays the results of the DID estimation for Model 4.1 with different cost measurements as the dependent variable, as indicated in the first row of the table. The standard errors of the estimated coefficients are presented in parentheses. The first column of each variable represents the coefficients estimated without incorporating firm characteristics, while the second column reports the estimations with full control of the model. The treatment group (HtB) consists of firms that participated in the HtB scheme. The pre-treatment period is from 2005-2012 and the post-treatment period ($PostPolicy$) is from 2013-2020. The Num. obs. reports the total number of firm-year observations. The R^2 and Adjusted R^2 are reported as measures of the model's goodness-of-fit. The standard errors are clustered at the HtB and non-HtB group level. The significance level is denoted as: $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

4.6.3 Revenue effects

Demand side

Table 4.6 presents the DID result of the revenue effect on the demand side, indicating how sales have been influenced by the policy due to external market demand. As seen from the second column of both variables, there's an increase of 0.114 in inventory stock and 0.223 in sales due to HtB. These point estimates correspond to percentage increases of 11.98% and 24.98%, respectively. When evaluated at the sample mean level, the HtB strategy has resulted in an average increase of £12,904 thousand in inventory and £48,126 thousand in sales for participating firms.

Table 4.7 provides further insights into the impact of the HtB on inventory and sales in terms of first-order increases. The increase rate of inventory has significantly increased by 0.076, and there has not been a similar increase in the sales increase rate. This could lead to an explanation. From the outset, the market demand for HtB properties incentivises developers to increase construction and sales. As more time passes and the HtB supply grows, the market demand is partially met by this increased supply, resulting in elevated inventory levels and an uptick in the inventory growth rate. Therefore, a gradual increase in the sales growth rate is not observable.

The explanation can be supported by the change in the remaining metrics. The excess sales increase rate is a demeaned sales increase rate, where the mean sales increase rate is calculated within the HtB and non-HtB groups separately in each year. This approach seeks to control the effects of other non-policy shock factors that may impact sales among participants and non-participants of firms, such as market share and marketing strategies (Ding et al. 2018). Columns 5 and 6 both reveal a significant decrease (-0.041 and -0.064) in the excess sales growth.

The net demand increase in the last column provides a more comprehensive perspective than the excess sales increase rate. It is the residual of the sale growth rate that partials out all sales growth resulting from factors that are not related to the buyer's affordability. The technological difference is controlled using TFP, the market share is controlled using firm size, and expenditures in building better marketing strategies and logistics systems are controlled using administration expenses. Firm and time-fixed effects are also controlled to ensure that the filtered sales growth accurately reflects demand from HtB scheme aspect. In the second stage, the DID approach is applied to the filtered sales growth (i.e., net demand increase rate). Compared to Column 6, Column 8 demonstrates a more significant decrease (-0.086).

Both the excess sales growth rate and net demand growth show a decline due to the implementation of HtB, indicating that supply has met the increase in demand. Carrozi et al.'s study (2020) corroborates this finding in their examination of HtB's impact on property prices. They reveal that the HtB scheme primarily causes an increase in property prices in areas with inelastic supply, but not in less desirable locations.

Table 4.6: The impact of HtB on demand side opportunities

	Inventory stock - Log		Sales - Log	
	1	2	3	4
HtB*PostPolicy	0.064*	0.114**	0.310*	0.223*
	(0.003)	(0.002)	(0.005)	(0.014)
Firm characteristics	No	Yes	No	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes
Num. obs.	6223	6223	3638	3637
R^2 (full model)	0.883	0.937	0.874	0.899
Adj. R^2 (full model)	0.869	0.929	0.859	0.887

Note: This table displays the results of the DID estimation for Model 4.1 with different demand side growth measurements as the dependent variable, as indicated in the first row of the table. The standard errors of the estimated coefficients are presented in parentheses. The first column of each variable represents the coefficients estimated without incorporating firm characteristics, while the second column reports the estimations with full control of the model. The treatment group (HtB) consists of firms that participated in the HtB scheme. The pre-treatment period is from 2005-2012 and the post-treatment period ($PostPolicy$) is from 2013-2020. The Num. obs. reports the total number of firm-year observations. The R^2 and Adjusted R^2 are reported as measures of the model's goodness-of-fit. The standard errors are clustered at the HtB and non-HtB group level. The significance level is denoted as: $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

Table 4.7: The impact of HtB on second order demand side opportunities

	Inventory increase rate		Sales increase rate		Excess sales increase rate		Net demand increase rate	
	1	2	3	4	5	6	7	8
HtB*PostPolicy	0.058^{*}	0.076^{*}	-0.045^{***}	-0.069	-0.041^{*}	-0.064^{*}	-0.067^{***}	-0.086^{*}
	(0.002)	(0.003)	(0.000)	(0.007)	(0.002)	(0.005)	(0.000)	(0.004)
Firm characteristics	No	Yes	No	Yes	No	Yes	No	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Num. obs.	5473	5473	3167	3167	3167	3167	2818	2818
R^2 (full model)	0.156	0.216	0.193	0.197	0.177	0.181	0.000	0.010
Adj. R^2 (full model)	0.047	0.113	0.087	0.090	0.069	0.072	-0.137	-0.127

Note: This table displays the results of the DID estimation for Model 4.1 with further demand side growth measurements as the dependent variable, as indicated in the first row of the table. The standard errors of the estimated coefficients are presented in parentheses. The first column of each variable represents the coefficients estimated without incorporating firm characteristics, while the second column reports the estimations with full control of the model. The treatment group (HtB) consists of firms that participated in the HtB scheme. The pre-treatment period is from 2005-2012 and the post-treatment period ($PostPolicy$) is from 2013-2020. The Num. obs. reports the total number of firm-year observations. The R^2 and Adjusted R^2 are reported as measures of the model's goodness-of-fit. The standard errors are clustered at the HtB and non-HtB group level. The significance level is denoted as: $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

Supply side

Studying whether the HtB policy has spurred any positive implications on a firm's technological advancements is crucial in controlling endogenous issues when quantifying the policy's revenue effect. Previous research has suggested that an external shock can significantly impact a firm's technological advancements or TFP, thus further impacting output (Ding et al. 2018; Foster et al. 2008; Syverson 2011; Van Beveren 2012). An increase in TFP can result in improved management efficiency from multiple perspectives, including the reduction of marginal costs, the decrease in financing costs, and the promotion of market competition. Thus, external policies such as HtB can affect a firm's profitability through their impact on the firm's supply-side productivity improvement.

As demonstrated in Table 4.8, none of the TFP or non-labour TFP measurements show a significant coefficient[36], even after controlling for firm characteristics. These results are helpful in inferring that the increase in revenue attributed to HtB is primarily driven by the demand shock created by the relaxation of credit constraints.

This finding aligns with the broader literature on TFP in British firms. Research has revealed that productivity growth in the United Kingdom, along with other OECD countries, has been lacklustre, with little growth in value-added per working hour since 2008 (Bournakis and Mallick 2018; Braconier and Ruiz-Valenzuela 2014). Moreover, the value-added per working hour has hardly grown since 2008 in the UK, while it is estimated that the average annual growth was 2.64% before the financial crisis (2000-2007). At this rate, the productivity level was 13% lower than it could have been. This phenomenon is referred to as the UK productivity puzzle, and a recent study attributes this puzzle to an underdeveloped gap in labour productivity (Goodridge et al. 2018). My results suggest that HtB does not appear to impact the reversal of the sluggish TFP puzzle in the construction industry.

[36]There is a significant coefficient for the ACF TFP measure. However, it does not pass the parallel test, indicating that it cannot be interpreted as a causal effect.

Table 4.8: The impact of HtB on supply side opportunities - TFP and non-labour TFP

	Total factor productivity			Non labour productivity		
	OP	LP	ACF	OP	LP	ACF
HtB*PostPolicy	-0.124	0.082	-0.217^{*}	0.143	0.174	-0.026
	(0.104)	(0.088)	(0.092)	(0.084)	(0.091)	(0.089)
Firm characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.893	0.908	0.954	0.698	0.852	0.958
Adj. R^2	0.879	0.896	0.948	0.655	0.831	0.952
Num. obs.	2363	2300	2577	2970	2519	2970

Note: This table displays the results of the DID estimation for Model 4.1 with different TFP and non-labour TFP measurements as the dependent variable, as indicated in the first row of the table. The OP, LP, ACF denote different methods used in estimating total factor productivity. The standard errors of the estimated coefficients are presented in parentheses. The first column of each variable represents the coefficients estimated without incorporating firm characteristics, while the second column reports the estimations with full control of the model. The treatment group (HtB) consists of firms that participated in the HtB scheme. The pre-treatment period is from 2005-2012 and the post-treatment period ($PostPolicy$) is from 2013-2020. The Num. obs. reports the total number of firm-year observations. The R^2 and Adjusted R^2 are reported as measures of the model's goodness-of-fit. The standard errors are clustered at the HtB and non-HtB group level. The significance level is denoted as: $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

4.6.4 Marginal profitability

The previous section demonstrates that the HtB has boosted the profitability on an annual aggregate level. In this section, the second research question sets out to study whether the HtB continues to exert a positive influence at the marginal level of a product. Marginal profitability is gauged through markup, defined as the ratio of price to marginal cost. This markup serves as a reflection of a firm's ability to ask for higher selling prices and is frequently used as a barometer of a firm's market power. A decrease in markup under HtB implies intensified competition and a decrease in firms' marginal profitability, while an increase in markup suggests that HtB allows firms to set more aggressive prices, potentially through land banking or reducing supply.

Table 4.9 indicates that the HtB policy does not lead to an increase in a developer's market power. Instead, a decrease in markup is observed among participating firms. The markup calculations are based on production function estimation, and for robustness, they are estimated using three methods - OP, LP, and ACF. The table demonstrates that the decreasing markup is robust across these three estimation methods, whether or not firm characteristics are controlled for. This finding aligns with the cost analysis from Table 4.5, which discloses a significant uptick in development costs at the aggregate level and led us to anticipate low marginal profitability. Meanwhile, the TFP study in Table 4.8 does not show any difference, suggesting there's no positive endogenous technology effect to offset cost expenditure. The decrease in markup signifies a decrease in market power and marginal profitability. These findings indicate that the excess profitability of participant firms is not created by higher profit margins per property, but rather by an increase in sales volume. This conclusion aligns with our earlier conjecture regarding the increased inventory growth rate and decreasing sales growth rate and profit growth rate. It is inferred from these stagnant growth rates that supply has effectively met the market's demand.

A decreased marginal markup and increased sales cost suggest that the excess prof-

Table 4.9: The impact of HtB on firm's markup - estimated by three methods

	OP markup		LP markup		ACF markup	
	1	2	3	4	5	6
HtB*PostPolicy	-0.231^{*}	-0.206^{*}	-0.453^{**}	-0.434^{**}	-0.357^{*}	-0.364^{*}
	(0.015)	(0.014)	(0.004)	(0.001)	(0.006)	(0.019)
Firm characteristics	No	Yes	No	Yes	No	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Num. obs.	2814	2813	2814	2813	2595	2594
R^2 (full model)	0.651	0.653	0.598	0.599	0.262	0.263
Adj. R^2 (full model)	0.608	0.609	0.548	0.549	0.168	0.168

Note: This table displays the results of the DID estimation for Model 4.1 with different markup measurements as the dependent variable, as indicated in the first row of the table. The standard errors of the estimated coefficients are presented in parentheses. The first column of each variable represents the coefficients estimated without incorporating firm characteristics, while the second column reports the estimations with full control of the model. The treatment group (HtB) consists of firms that participated in the HtB scheme. The pre-treatment period is from 2005-2012 and the post-treatment period ($PostPolicy$) is from 2013-2020. The Num. obs. reports the total number of firm-year observations. The R^2 and Adjusted R^2 are reported as measures of the model's goodness-of-fit. The standard errors are clustered at the HtB and non-HtB group level. The significance level is denoted as: $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

itability of participant firms (as shown in Table 4.2) is due to an increase in sales volume. An exception to this could be if HtB participant firms were selling non-HtB properties at substantially lower marginal profitability while selling HtB properties at slightly higher marginal profitability. Such a scenario could challenge the theory of increased sales volume. However, by analysing total sales from the Land Registry Price Paid Data, we can potentially rule out this exception.

Table 4.10 demonstrates that, since the launch of the HtB scheme, the number of HtB properties sold has seen a significant annual increase. This growth is apparent from both the HtB properties sold column and the ratio of HtB sales to total sales. On average, HtB sales intensity has been increasing annually. This macro-level analysis indicates that it's unlikely that most participant developers have been selling an equal amount of low markup non-HtB properties to counterbalance the high markup of HtB property sales. This observation further supports the inference that the increased profitability of participant firms results from increased sales volume. As a result, the

HtB scheme appears to be an effective public policy for increasing the supply of new properties in the British market. This finding could contribute to future policy-making and evaluation studies.

Table 4.10: Summary statistics of new property and HtB property sales

Year	New properties sold	Total value of sales	HtB properties sold	HtB sales value	HtB sales ratio	HtB sales value ratio
2005	122,696	25,158.11	—	—	—	—
2006	136,268	28,301.86	—	—	—	—
2007	100,818	21,116.46	—	—	—	—
2008	75,986	15,548.39	—	—	—	—
2009	66,234	12,997.38	—	—	—	—
2010	59,796	12,777.73	—	—	—	—
2011	59,852	13,012.92	—	—	—	—
2012	65,348	15,442.82	—	—	—	—
2013	76,366	19,482.40	14,023	2,840.37	0.18	0.15
2014	86,634	24,422.08	28,377	6,160.55	0.33	0.25
2015	98,838	29,814.22	31,845	7,403.51	0.32	0.25
2016	107,570	35,257.66	38,411	9,898.25	0.36	0.28
2017	108,430	37,171.50	46,295	12,994.00	0.43	0.35
2018	113,243	39,397.34	52,143	15,214.50	0.46	0.39
2019	112,612	39,498.13	52,246	15,764.39	0.46	0.40
2020	90,421	33,174.15	49,839	15,756.04	0.55	0.47

Note: The table presents summary statistics of HtB sales from the Land Registry Price Paid Data and official websites. Column 1 represents the year, while Column 2 shows the number of new properties sold in each year. Column 3 displays the total value of the sold properties in each year. Column 4 shows the number of properties sold under HtB in each year, and Column 5 represents their total value. The sixth column displays the ratio of HtB sales to the total number of sales (Column 4 to Column 2), while Column 7 shows the ratio of the HtB sales value to the total sales value (Column 5 to Column 3). The units in columns 2 and 4 are in millions of pounds.

4.6.5 Capital investment

(A) The capital source and stock

This section aims to further analyse how the HtB scheme encourages developers to supply more properties while reaping financial benefits from the policy. As posited by the investment Q theory, a consistent, long-term demand shock can significantly diminish the adjustment cost of capital investment, leading to an increase in marginal capital productivity. The high demand shock, coupled with prospective cash flow, could be the primary driver for developers to supply more HtB properties to the market while maintaining good profitability. This analysis begins with an examination of capital sources and stocks. I demonstrate the degree to which the HtB scheme enables cost savings in fixed investment by comparing differences in capital investment intensity and debt cash flow sensitivity.

Table 4.11 presents the changes in capital investment sources. The primary sources of capital funding for firms in the sample are liabilities and internal cash flows (Guariglia 2008). Given that most of the sample comprises small and medium-sized firms, their access to finance from corporate bonds or the equity market is limited. The results indicate that the HtB policy has led to an average increase of £27,878 thousand in internal cash flow and an increase of £9,532 thousand in current liabilities for participating firms. No change is observed in long-term liabilities. The markedly smaller increase in current liabilities compared to internal cash flows suggests that the majority of the additional capital investment is driven by an increase in internal cash flow.

Table 4.11: The impact of HtB on changes in capital sources - Ex ante perspective

	Internal cash flow		Long term liabilities - Log		Current liabilities	
	1	2	3	4	5	6
HtB*PostPolicy	28214.523**	27878.126**	−0.175*	−0.047	8483.974**	9532.440*
	(104.898)	(279.094)	(0.011)	(0.009)	(21.439)	(358.904)
Firm characteristics	No	Yes	No	Yes	No	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Num. obs.	3308	3306	5255	5249	7978	7957
R^2 (full model)	0.751	0.751	0.833	0.855	0.873	0.874
Adj. R^2 (full model)	0.716	0.717	0.811	0.836	0.859	0.860

Note: This table displays the results of the DID estimation for Model 4.1 with different capital source measurements as the dependent variable, as indicated in the first row of the table. The standard errors of the estimated coefficients are presented in parentheses. The first column of each variable represents the coefficients estimated without incorporating firm characteristics, while the second column reports the estimations with full control of the model. The treatment group (HtB) consists of firms that participated in the HtB scheme. The pre-treatment period is from 2005-2012 and the post-treatment period ($PostPolicy$) is from 2013-2020. The Num. obs. reports the total number of firm-year observations. The R^2 and Adjusted R^2 are reported as measures of the model's goodness-of-fit. The standard errors are clustered at the HtB and non-HtB group level. The significance level is denoted as: $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

Table 4.12 presents the changes in the stock of working capital[37], tangible assets and fixed assets due to HtB. With regards to the short-term capital stock, the HtB policy has resulted in an average increase of 58,991 thousand pounds in working capital in participating firms. An increase in working capital indicates that the company is effectively managing its liquidity, as it is able to maintain a sufficient level of current assets to meet its current liabilities without relying too heavily on debt financing. As demonstrated previously in Table 4.6 and Table 4.11, there is a major increase in inventory stock and its increase rate, with only a minor increase in current liabilities among participant firms. This suggests that the increase in working capital is mainly derived from an increase in current assets.

Effective management of short-term capital is vital, especially for traditional firms that heavily rely on fixed assets (Dunn and Cheatham 1993). Compared to fixed capital investment, working capital inputs do not suffer from the constraints of irreversible investments or high adjustment costs. The studies of Fazzari et al. (1993) and Ding et al. (2013) both propose that companies actively invest in working capital to smooth their fixed capital investment and adjust their working capital in response to shocks in demand.

On the other hand, the profitability of assets decreases with its asset tangibility, which makes investment in working capital less beneficial (Bhattacharya 2014). Participating firms might be aware of this, as substantial increases in the other three long-term capital variables are also observed. The HtB has resulted in an increase of 0.488 in the logarithm of tangible assets, which represents a 62.9 percent increase in absolute value. The coefficients of 0.309 signify a 36.2 percent increase in the fixed capital term. Estimated at the sample mean, HtB has lead increases of 23,435 thousand pounds and 21,868 thousand pounds in tangible assets and fixed capital. There is also a significant

[37] An increase in working capital refers to a rise in a company's current assets, such as cash, accounts receivable, inventory, and other short-term assets, relative to its current liabilities, such as accounts payable, short-term loans, and other obligations that are due within a year. This increase in working capital can be seen as an indication of improved financial health, as it suggests that the company has more resources available to meet its short-term obligations and carry out its day-to-day operations.

increase in the last column, which is the first-order capital stock (i.e., the capital investment term), with a coefficient of 0.192.

As reviewed in the literature section, the fixed investment budget plan is highly forward-looking, and the policy HtB has been discussed before it was officially launched. This can be observed from the parallel test in Appendix A.5 that the upward trend of the fixed tangible term begins one year earlier. The enduring and robust investment activity suggests that participating firms have a high level of confidence in long-term market demand. The substantial volume of investment potentially signifies a significant increase in capital productivity.

Table 4.12: The impact of HtB on changes in capital stocks - Ex post perspective

	Working capital		Tangible assets - Log		Fixed capital - Log		Fixed capital investment - Log	
	1	2	3	4	5	6	7	8
HtB*PostPolicy	56834.627***	58991.298**	0.490**	0.488**	0.293**	0.309**	0.226*	0.192*
	(89.098)	(234.763)	(0.004)	(0.005)	(0.001)	(0.003)	(0.006)	(0.005)
Firm characteristics	No	Yes	No	Yes	No	Yes	No	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Num. obs.	6421	6421	5939	5939	6367	6367	4374	4374
R^2 (full model)	0.865	0.866	0.844	0.863	0.861	0.886	0.851	0.865
Adj. R^2 (full model)	0.848	0.849	0.826	0.847	0.845	0.873	0.828	0.844

Note: This table displays the results of the DID estimation for Model 4.1 with different capital stock measurements as the dependent variable, as indicated in the first row of the table. The standard errors of the estimated coefficients are presented in parentheses. The first column of each variable represents the coefficients estimated without incorporating firm characteristics, while the second column reports the estimations with full control of the model. The treatment group (HtB) consists of firms that participated in the HtB scheme. The pre-treatment period is from 2005-2012 and the post-treatment period ($PostPolicy$) is from 2013-2020. The Num. obs. reports the total number of firm-year observations. The R^2 and Adjusted R^2 are reported as measures of the model's goodness-of-fit. The standard errors are clustered at the HtB and non-HtB group level. The significance level is denoted as: $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

(B) The capital investment intensity and cash flow intensity

As proposed, a continuous, stable demand shock brought about by the HtB could significantly decrease the high adjustment cost of capital investment and enhance marginal capital productivity. This is illustrated in Table 4.13, which compares the time-varying investment-cash flow sensitivities. The coefficients in the table are estimates derived from Model 4.8, obtained using the first difference GMM estimation method. These coefficients compare the ICFS of HtB participants and non-HtB participants in sub-periods before and after the introduction of the HtB scheme. A significantly positive coefficient indicates that firms make more capital investments when they have more internal cash flow. Given that a higher internal cash flow predicts greater future marginal productivity, this increase is considered an indicator of the enhanced capital investment intensity, which is a result of improved productivity (Guariglia 2008; Moshirian et al. 2017).

The data in the first and third columns of Table 4.13 are the ICFS estimates derived from data collected from 2005 to 2013. The second and fourth columns contain ICFS estimates obtained from data collected from 2013 to 2020. The ICFS are found to be statistically significant only for the HtB participant group in both sub-periods, with values of 0.014 and 0.561, respectively. It should be noted that both the capital investment and cash flow ratios are scaled by total assets. This means that a unit increase in the cash flow ratio results in a 29.8% and 49.1% increase in the capital investment ratio. In contrast, the ICFS values for non-HtB participant firms are not significant in either of the two periods. This suggests that these firms did not expect a major increase in sales or productivity, hence they did not increase their investments in fixed capital.

Using ICFS as an indicator of capital investment intensity often faces potential criticism due to the possibility of mismeasuring the control variable Q (Erickson and Whited 2000; Jason and Jenny 2012). The control variable Q accounts for the impact of marginal capital productivity, which is the primary factor impacting capital investment.

Table 4.13: The impact of HtB on firm's capital investment intensity

	Capital Investment - Pre HtB		Capital Investment - Post HtB	
	Not Participants	HtB Participants	Not participants	HtB Participants
Cash flow	0.005	0.014^{***}	0.432	0.561^{***}
	(0.046)	(0.003)	(0.319)	(0.106)
Firm fixed effects	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes
Num. obs.	621	3146	735	4387
Sargan Test: p-value	0.341	0.056	0.525	0.004
Wald Test Coefficients: p-value	0.001	0.000	0.001	0.000

Note: This table displays the results of the ICFS estimation for Model 4.8: $\text{INV}_{i,t} = \alpha_{c,t} + \beta_0\text{INV}_{i,t-1} + \beta_1 Q_{i,t-1} + \beta_2\text{CF}_{i,t} + \varepsilon_{i,t}$. The dependent variable $\text{INV}_{i,t}$ represents the investment in the capital of firm i in year t, measured by the change in tangible assets and scaled by the beginning-of-period total assets; $CF_{i,t}$ is the internal cash flow, measured by summing firm i's profit before interest with depreciation and amortisation, scaled by the beginning-of-period capital stock. β_2 is the ICFS. We are interested in the differences in ICFS between HtB developers and non HtB developers in pre and post HtB subperiods. The pre-treatment period is from 2005-2012 and the post-treatment period is from 2013-2020. The Num. obs. reports the total number of firm-year observations. The Sargan test and Wald test results are reported as measurements of the validity of the instruments used and goodness-of-fit for the model, and the significance level is denoted as: $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

Measuring marginal productivity is challenging when relying on balance sheet variables, as these variables represent an aggregate value rather than a marginal value (Jason and Jenny 2012). This could lead to an overestimation of ICFS. To address this issue, I have chosen TFP as an alternative proxy for Q, in accordance with the study of Ding et al. (2018). This is because marginal capital productivity can only be observed by firm operators during the production process, and TFP can accurately reflect this internal observation. The sample of ICFS study limits to firms that participate in the HtB programme. As depicted in Table 4.17 in Appendix A.4, the findings remain consistent with all three control variables showing positive and significant results in both subperiods.

As indicated in Table 4.13, non-HtB participants do not show a significant upward trend in their ICFS either before or after the HtB. To confirm that the increased capital investment intensity (i.e., ICFS) among HtB participant firms is indeed due to anticipated increases in capital productivity, I carry out a robust test that examines the first-order correlation of cash flow, following the study of Moshirian et al. (2017)[38]. Autocorrelation is estimated using a WLS regression to account for the heteroscedasticity effect. This measures the persistence (or predictability) of cash flow. As suggested by Moshirian et al. (2017), firms tend to make more intensive capital investments when they expect a high and stable future cash flow. High cash flow persistence under the policy can reflect a higher degree of marginal productivity from a management perspective.

Table 4.14 reveals a strong first-order autocorrelation in the group of HtB participants in both periods, with the correlation increasing from 0.298 to 0.491 following the initiation of the HtB, representing a significant jump. This rise indicates that participant firms have anticipated a predictable higher internal cash flow on average, which incentivises them to use more cash to invest, leading to the increased ICFS seen in Table 4.13. This evidence further confirms that the heightened capital investment intensity results from increased productivity, and this augmented fixed capital is the primary driver for improved supply.

The evidence gains more credibility when viewed against a broader economic backdrop. Both the ICFS and the persistence of cash flow have significantly diminished in recent years in the US and other developed countries, in part due to the decreased investment return on fixed capital (Jason and Jenny 2012; Moshirian et al. 2017; Zhen and Chu 2021). Particularly, as examined in Chapter 3, there has been a substantial decrease in the investment return on fixed capital in the UK construction industry, leading to an overall decrease in domestic capital investment intensity. The increase in ICFS in Table 4.13 and cash flow persistence in Table 4.14 both signal a positive outlook in sales growth, which is inferred to be induced by the demand shock associated with the HtB. Without a similar level of strong cash flow persistence, non-participants are less likely to make excessive capital investments, as shown in Table 4.13.

[38]The model is $\mathrm{CF}_{i,t} = \alpha_{i,t} + \theta_0 + \theta_1 \mathrm{CF}_{i,t-1} + \theta_2 \mathrm{X}_{i,t} + \mu_{i,t}$. The estimation controls for time and firm fixed effects through $\alpha_{i,t}$. The firm characteristics of age and size are controlled through $\mathrm{X}_{i,t}$.

Table 4.14: The impact of HtB on firm's cash flow persistence

	Cash flow - Pre HtB		Cash flow - Post HtB	
	Not Participants	HtB Participants	Not participants	HtB Participants
Cash flow Lag (1)	0.101	0.298***	0.153	0.491***
	(0.055)	(0.025)	(0.094)	(0.027)
Firm characteristics	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes
R^2	0.852	0.904	0.925	0.910
Adj. R^2	0.798	0.878	0.898	0.886
Num. obs.	202	1045	210	1187

Note: This table displays the results of the first-order autocorrelation of cash flow. The model is estimated by WLS to control the heteroscedasticity. We are interested in the differences in cash flow autocorrelation between HtB developers and non-HtB developers in pre and post-HtB subperiods. The pre-treatment period is from 2005-2012 and the post-treatment period is from 2013-2020. The Num. obs. reports the total number of firm-year observations. The R^2 and adjusted R^2 results are reported as measurements of goodness-of-fit for the model, and the significance level is denoted as $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

(C) The financial constraints and firm characteristics

A final component of the analysis explores the impact of HtB on debt-cash flow sensitivity, which measures the changes in debt in accordance with changes in cash flow. A negative coefficient suggests that an increase in cash flow leads to an increase in the availability of debt financing. It helps measure whether HtB has reduced the financing cost of capital investment. Table 4.11 shows that developers' capital is primarily sourced from self-financing (internal cash flow) and debt financing (current liabilities). Financing from internal cash flow is typically less expensive than debt financing (Fazzari et al. 1987). Moreover, it has been demonstrated that most unquoted firms primarily resort to cash flow-based lending for their borrowing needs (Lian and Ma 2021). A demand shock leading to increased sales can deliver more cash flow to the firm, thereby enabling self-financing and debt-financing at a lower cost. It further signifies an increase in the marginal productivity of capital investment. This, in turn, may reflect increased profitability and the drive to invest in and expand operations.

Table 4.15 presents the debt-cash flow sensitivity estimated from Model 4.9. It is observed that only HtB companies show significant coefficients in both periods, and the magnitude becomes much larger after HtB is implemented (an absolute coefficient increase from 0.366 to 0.840). As previously shown, HtB has significantly increased the cash flow of participant firms. This increased debt-cash flow sensitivity suggests that the HtB scheme has allowed participating firms to invest more while experiencing fewer borrowing constraints. This serves as a robust corroboration of the heightened ICFS, suggesting that firms are acknowledging the increased capital productivity from an internal financial management perspective.

In addition to the borrowing constraint relaxation, the increase in ICFS often indicates the level of needs for capital. I present how the needs have varied among HtB participant firms with different characteristics in Table 4.16. The model tests data from 2012 onwards, thus displaying the financial constraints experienced by HtB firms during the implementation of the scheme. I initially interact cash flow with an age variable. This age variable is categorical and classified into three categories: YOUNG, MID, and OLD. These categories denote firms whose age falls below the first, second, and third quantiles of the distribution, respectively. I also classify firms into three size groups SML, MID, LAG based on the level of their total assets. The interaction coefficient between cash flow and firm characteristic terms is of main interest[39].

A monotonic trend can also be observed in the interaction variable of age. The debt-cash flow sensitivity increases as firms age, from -4.153 to -5.653. This suggests that older participant firms in the HtB scheme experience greater financial resources (and a steeper return on capital investment) than their younger counterparts. A similar trend is also observed among firms of different sizes. Larger firms exhibit more significant sensitivity of debt to their internal cash flow. These firms are less likely to suffer from negative factors causing financial constraints such as asymmetric information.

An increase in interaction terms generally indicates an enhanced positive return and a growing need for more capital funding. As the impact of the HtB leads to higher

[39]The age category YOU and size category SML are absorbed as a baseline in estimations.

Table 4.15: The impact of HtB on firm's credit constraints

	ΔDebt ratio - Pre HtB		ΔDebt ratio - Post HtB	
	Not Participants	HtB Participants	Not participants	HtB Participants
Cash flow	0.056	-0.366^{**}	0.485	-0.840^{***}
	(0.292)	(0.119)	(0.371)	(0.058)
Firm characteristics	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes
R^2	0.373	0.548	0.432	0.436
Adj. R^2	0.110	0.410	0.213	0.280
Num. obs.	157	785	174	1071

Note: This table displays the results of the DCFS estimated from Model 4.9: $\Delta\text{Debt}_{i,t} = \alpha_{c,t} + \beta_0 + \beta_1 Q_{i,t-1} + \beta_2 \text{CF}_{i,t} + \varepsilon_{i,t}$. The dependent variable ΔDebt is represented by the change in debt, normalized by the initial period's total assets; $CF_{i,t}$ is the internal cash flow, measured by summing firm i's profit before interest with depreciation and amortisation, scaled by the beginning-of-period capital stock. β_2 is the DCFS. We are interested in the differences in DCFS between HtB developers and non HtB developers in pre and post HtB subperiods. The pre-treatment period is from 2005-2012 and the post-treatment period is from 2013-2020. The Num. obs. reports the total number of firm-year observations. The R^2 and adjusted R^2 results are reported as measurements of goodness-of-fit for the model, and the significance level is denoted as: $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

productivity, larger, older developers tend to have an increased ability to generate capital productivity compared to their younger, smaller counterparts.

To get a deeper understanding of the impact from the perspective of developers, I collect financial reports from Companies House. Companies House is an executive agency of the UK government that keeps track of all registered companies in the United Kingdom. By using Optical Character Recognition (OCR) techniques to pick out keywords, I find that 766 reports mention the positive financial impact brought by the HtB scheme. The companies that report the number of HtB sales show a rising proportion of properties sold under the HtB scheme. Meanwhile, none of the reports indicate that the increased supply has led to a decrease in their profit margins. Additionally, 148 reports document an increase in costs, particularly in land costs, as a result of the policy. As reported by firms, the acquisition of land and the wages of builders are two major expenses for construction companies. The primary cause of the increase in cost is inflation, followed by the impact of HtB. This descriptive information is summarised in Appendix A.3.

Table 4.16: The Impact of HtB on firm's credit constraints - by firm characteristics

	Debt change	
	(1)	(2)
Cash flow	4.288^{***}	4.264^{***}
	(0.010)	(0.010)
Age_{MID}	0.255^{***}	
	(0.045)	
Age_{OLD}	0.365^{***}	
	(0.066)	
Cash flow*Age_{MID}	-4.153^{***}	
	(0.186)	
Cash flow*Age_{OLD}	-5.653^{***}	
	(0.011)	
Size_{MID}		-0.689^{***}
		(0.104)
Size_{LAG}		-0.581^{***}
		(0.108)
Cash flow*Size_{MID}		-3.614^{***}
		(0.154)
Cash flow*Size_{LAG}		-5.631^{***}
		(0.011)
Firm characteristics	Yes	Yes
Firm fixed effects	Yes	Yes
Time fixed effects	Yes	Yes
R^2	0.996	0.997
Adj. R^2	0.996	0.997
Num. obs.	1201	1201

Note: This table displays the results of the DCFS interacted with firm characteristics split dummies, estimated from Model 4.9. The dependent variable ΔDebt is represented by the change in total liabilities, normalised by the initial period's total assets; $CF_{i,t}$ is the internal cash flow, measured by summing firm i's profit before interest with depreciation and amortisation, scaled by the beginning-of-period capital stock. β_2 is the DCFS. We are interested in the coefficients of in DCFS interacted with firm characteristics dummy. The age is classified based on the three quantiles of the distribution of a firm's age. The size is classified based on the three quantiles of the distribution of the firm's total assets. The data are from HtB participant firms in the post-treatment period 2013-2020. The Num. obs. reports the total number of firm-year observations. The R^2 and adjusted R^2 results are reported as measurements of goodness-of-fit for the model, and the significance level is denoted as $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

4.7 Conclusion and further impact

4.7.1 Conclusion

As one of the most successful tools in facilitating housing affordability and risk sharing between borrowers and lenders, the HtB policy has drawn much attention since 2013. The significant number of properties sold under the scheme shows that the policy is historically unique. This study challenges the previous criticisms that the HtB is mainly assisting developers to gain mega profit instead of increasing affordability. The previous discussion mainly focuses on the housing transaction price and quantity and seldom uses counterfactual analysis to evaluate the developer's finance. Thus, this study enriches the existing literature by offering a cost-benefit analysis of builders' finances, enabling an understanding of how developers' output is influenced by the HtB scheme.

At the firm aggregate level, there are significant increases in the profitability of firms that participate in the scheme. The HtB brought about a 40 million and 23 million increase in gross profit and net profit to participant firms on average. The equity averaged profitability, as measured by ROCE, is also heightened. As a result of increased profitability, both total assets and equity have shown to present an increase in participating firms after the implementation of the HtB.

The HtB programme spurs participating firms to accumulate both current assets and current liabilities. However, the increase in current assets outweighs the rise in current liabilities. On average, participating firms' liquidity metrics, including the current ratio, quick ratio, and cash flow ratio, all demonstrate an increase attributable to the HtB scheme. The HtB scheme has been demonstrated to significantly alleviate short-term liquidity risk for participating firms.

According to my analysis, all cost terms have shown significant increases in participating firms after the launch of the HtB programme. These increases, as reported by the firms in their descriptive financial reports, are primarily driven by a shortage of labour, increased land costs, and other expenditures boosted by inflation. The HtB programme has also demonstrated a positive impact on revenues, leading to significant increases in sales and inventory stock. The first-order increase has only appeared in inventory levels, not in sales. I propose that this might be due to the policy-induced demand shock in the market being largely absorbed, as evidenced by the observed decrease in net sales growth and excessive sales growth.

In addressing the second research question, I examine the HtB's effect on a firm's property-level profitability, as measured by markup. Opting to sell fewer properties at a higher margin or selling more properties at a lower margin can both result in significant profit. British developers have been criticised for exerting excessive market power and indulging in land banking at a time when housing affordability is a major concern[40], particularly in high-demand areas. Recent theoretical research also suggests that various forms of credit expansion can amplify the business cycle by creating bubbles or enhancing a firm's market power in transactions. The demand shock brought about by the HtB scheme has intensified scrutiny of the developers' role in the market.

This study presents alternative evidence to counter potential criticisms. Despite Carrozi et al.'s (2020) study indicating that the HtB programme increased property prices in some regions, my analysis suggests that, on average, the markup for participating developers has decreased due to the HtB scheme. The examination of the reduced markup, in conjunction with the data from the Land Registry Price Paid, indicates that the HtB scheme effectively intensifies competition among participating developers and stimulates an increase in property supply. The surplus profits brought by the HtB are achieved by selling a higher volume of properties.

In the third section, this study examines the impact of the HtB scheme from a capital

[40]See for example: Gove slams housebuilders hoarding almost a million plots of land as 'completely unacceptable'.

investment perspective. This analysis further elucidates how participants are able to achieve higher profits with a decrease in markup. I propose that the scheme introduces a demand shock, followed by a sustained growth prospect in sales for developers. A stable growth prospect can mitigate losses incurred from high adjustment costs, particularly those associated with land purchases. Meanwhile, given that the majority of unlisted firms rely on cash-based lending for financing, an increase in sales can further ease their self-financing and borrowing constraints, thereby reducing their financing costs. The prospect of elevated sales and cost savings contributes to an overall increase in marginal capital productivity. Anticipating potential profitability growth, participating firms decide to increase their investments in construction, leading to a greater supply of properties.

An increase in marginal productivity is difficult to observe empirically. This study proposes novel angles by observing from the firm's angle. An increase in capital stock, investment-cash flow sensitivity, and debt-cash flow sensitivity can demonstrate improved marginal productivity from an internal perspective. This provides important insights into how such a policy intervention interacts with the internal dynamics of firms, leading to an improvement in their financial performance, and supply. The HtB programme's effects can extend beyond simply increasing housing supply or supporting first-time homebuyers. It also plays a pivotal role in enhancing the financial and operational capabilities of participating developers.

4.7.2 Further impact

Lastly, I briefly discuss how this financial study of HtB links to a wider economic map. The credit supply expansion in more general terms, refers to an increased willingness to lend, with all other factors fixed (Mian et al., 2020). It can be driven by various factors that include but are not limited to deregulation, financial liberalisation, behavioural motivations, growing outside wealth and savings glut, and mostly importantly, government-backed programs[41]. The Great Recession has sparked discussions about the effects of credit expansion on the housing mortgage market. Researchers have realized that the surge in housing demand and the resulting increase in mortgage debt played a large role in predicting the severity of the downturn across the United States and other developed economies (Mian et al. 2017).

I propose that the impact of government-backed credit expansion policies on property providers' financial and working mechanisms is particularly worthy of examination for two reasons. First, compared to slowly and spontaneously formed credit expansion, policy-oriented mortgage credit expansion is precise and influential to the targeted beneficiaries. Investors are found to be effectively responsive with more financing and investing activities as the expectation of asset prices significantly increases, which further leads to the expansion of subprime credit with greater subsidisation risk (Mian and Sufi 2009). Secondly, mortgage credit expansion policies have become a common adjustment tool to subsidise housing consumption, enabling investments in the housing market to proceed more affordably in financial constraint contexts. The severe economic downturn caused by the 2020 pandemic has made governments worldwide seek more powerful mortgage credit expansion policies to stimulate demand in the housing market[42]. But such a strategy has previously been known to immediately lead to housing price inflation without a corresponding increase in land supply, as discussed in the literature review. Identifying whether these policies, with their intended good faith of improving social welfare, were working as expected or had hidden repercussions is rather meaningful in terms of post-pandemic governance.

Research has shown that credit expansion policies can affect the business cycle through two main channels (Bahadir and Gumus 2016; Mian et al. 2020). Firstly, it can induce an overall household demand shock, which occurs when the policy makes it easier

[41] More details are discussed in the literature of Bordalo et al.(2018), Carozzi et al. (2020), Favara and Imbs (2015), Gennaioli et al. (2012), Justiniano et al. (2019), Landvoigt (2016).

[42] See various mortgage credit expansion policies worldwide with the quantity statistics from the IMF Statistics of IMF: Policy responses to COVID 19.

for market participants to consume and invest more. This can lead to increased demand for goods and services, which can in turn stimulate economic growth. Secondly, it can increase operational productivity and production capacity. When credit expansion policies allow firms to borrow and grow, they can invest in new equipment, technology, and other resources that can increase their productivity and capacity. This can lead to increased output and economic growth. Empirical researches and quasi-natural experiment analysis suggest that the ripple effect of credit expansion in publicly listed or non-listed sectors is closely connected to economic fluctuations (Jordà et al. 2013; Krishnamurthy and Muir 2017; Mian et al. 2017; Reinhart and Rogoff 2009). Overall, credit expansion policies can have a significant impact on the business cycle, both by stimulating demand and by increasing the productive capacity of firms. By understanding these channels, policymakers can better design and implement credit expansion policies that support economic growth and stability.

This research is motivated by the second channel. which has received significantly less attention in comparison to the first channel. This thesis fills a research gap by introducing a causal cost-benefit framework that effectively quantifies the impact of policy on suppliers. The framework developed in this study has the potential to be applied to firms in different industries and countries, enabling the analysis of variations in the demand shock induced by the relaxation of buyers' financial constraints. Future research could build on the findings of this study by investigating the impact of the supplier's finance on various aspects of the manufacturing process, such as material cost, land cost, consumer price and producer price, among others. This would allow for a more comprehensive understanding of the effects of the policy on the broader economy.

A Appendix

A.1 Variable explanation

This section contains explanations of the variable studied in this chapter.

Profit variables

(1) Gross profit, commonly referred to as gross margin, is a crucial metric in determining a firm's profitability. It is calculated by subtracting the cost of goods sold from total sales, representing the profit made from the sale of goods or services before accounting for other expenses such as administrative costs and interest payments. (2) Profit before interest and taxation (PBIT) is a financial metric that represents a company's earnings before deducting interest expenses and income taxes. It is calculated by subtracting the cost of goods sold and operating expenses from the company's total revenue and is used as a measure of a company's operating performance. PBIT provides a more comprehensive view of a company's profitability as compared to other metrics such as net profit. (3) Profit after taxation (PAIT), which represents a company's net profit, is calculated after accounting for all expenses, including taxation and interest. It is considered the final measure of a company's profitability and is used to determine its ability to generate income for its shareholders. It is an essential indicator of a company's financial performance and is used by investors, analysts, and management to make decisions regarding the company's future. (4) Return on capital employed (ROCE) is a financial ratio that measures the amount of profit a firm generates from its capital. It is calculated by dividing the firm's profit before interest and tax by its capital employed, which includes both its equity and its long-term debt. ROCE differs from other metrics because it takes into account the effect of scale on different companies. This makes it possible to compare the profitability of firms of different sizes and provides valuable insights into a firm's effectiveness and ability to generate returns on its capital. (5) Profit increase rate is calculated by dividing the annual increase

of gross profit by the beginning year's gross profit. This measures the profitability that purely leads by the main operating activities over time. As it measures first-order profitability, investors and analysts use the profit increase rate as a critical metric to evaluate a company's investment potential, as a higher rate of increase in profitability indicates a more efficient use of resources and a stronger financial position. In addition, it provides a basis for projecting future profits and helps management in planning and budgeting.

Firm structure variables

(1) Total assets. The sum of all assets owned by a company, including both current assets (such as cash, accounts receivable, and inventory) and long-term assets (such as property, plant, and equipment). (2) Total Liabilities. The sum of all debts and obligations owed by a company, including both current liabilities (such as accounts payable and short-term loans) and long-term liabilities (such as bonds and loans with longer repayment terms). (3) Equity: Equity, also known as shareholders' equity or owners' equity, represents the residual interest in a company's assets after deducting liabilities. It reflects the amount of ownership that shareholders have in a company. (4) Debt Ratio: The proportion of a company's total liabilities in relation to its total assets. It is calculated by dividing total liabilities by total assets and is expressed as a percentage. The debt ratio provides an indication of a company's financial leverage or the extent to which it relies on debt financing. A high debt ratio suggests a higher degree of financial risk, while a low debt ratio suggests a stronger financial position. It provides insight into a company's financial leverage and the risk associated with its debt financing.

Risk variables

(1) Coverage Ratio. It is calculated by dividing the PBIT by the interest payments. The coverage ratio is a financial metric used to evaluate a company's ability to meet its long-term obligations, such as debt payments, by measuring the amount of cash

flow generated by the company relative to its debt obligations. A higher coverage ratio indicates both a stronger ability to service debt and a lower level of external financial constraints. (2) Current Ratio: It is calculated by dividing current assets by current liabilities. The current ratio is a liquidity metric that measures a company's ability to pay its short-term obligations by comparing its current assets to its current liabilities. A higher current ratio indicates that a company has a stronger ability to meet its short-term obligations. (3) Quick Ratio: It is calculated by dividing the difference between current assets and inventory by the current liabilities. It is a more stringent measure of a company's short-term liquidity than the current ratio, which indicates a company's ability to pay its short-term obligations with its most liquid assets, such as cash and cash equivalents. (4) Cash Flow Ratio: It is calculated by dividing the net cash flow from operations by the current liabilities. It is a financial metric that measures a company's ability to generate sufficient cash flow to cover its short-term obligations.

Cost variables

(1) Cost of sales, refers to the direct costs incurred in producing the goods or services that a company sells. These costs include the cost of materials and the cost of labour directly related to the production of the goods or services sold during a given period. (2) Administrative costs, which are also known as overhead costs, include all non-production costs incurred by a company, such as management, marketing, and financial expenses. These costs are not directly related to the production of goods or services but are necessary for the company's operation. (3) Wages and salaries, which include base pay, bonuses, and benefits, are typically the largest component of a company's labour costs. Wages and salaries are included in the calculation of the cost of sales if they are direct labour costs associated with production, or administrative costs if they are indirect labour costs.

A.2 Variable pre-process

There are two major reasons why researchers often use logarithms in economic studies. The first reason is to address the issue of heteroscedasticity in regression analysis. Heteroscedasticity refers to a situation where the variance of the residuals in a regression model is not consistent across different levels of the independent variable(s). This violates the assumption of homoscedasticity, which is necessary for traditional statistical methods, such as Ordinary Least Squares (OLS), to provide unbiased and efficient estimates of the regression coefficients.

Taking the logarithm of a variable can help mitigate heteroscedasticity by reducing the variance of the variable. This statistical approach is commonly employed to ensure that the effect of extreme values does not overpower the effect of other data points. For example, when studying the relationship between property characteristics and transaction price, the price of a luxury house is typically much higher than that of a one-bedroom flat. The substantial variation in price among expensive properties can overshadow the impact on cheaper properties, resulting in biased and inefficient estimates of the regression coefficients. To address this issue, it may be necessary to consider techniques such as stratification or controlling for extreme values to analyse the relationship accurately. Taking the logarithm of the dependent variable can help in this regard, as it compresses larger values and expands smaller values, thereby achieving a more consistent variance across all levels of the independent variable(s) and addressing the problem of heteroscedasticity. Additionally, taking logarithms can help account for bias caused by long-tailed and skewed distributions, which is another important statistical consideration.

The second reason for using logarithms in economic studies relates to the economic perspective. To illustrate this, let's consider an example based on the work of Angrist and Pischke (2009). Suppose the study aims to examine the impact of a dummy variable, such as participation in the HtB on a financial indicator

$$\ln Y_i = \alpha + \beta P_i + e_i \tag{4.10}$$

Where Y_i represents the financial indicator and P_i represents a dummy variable that takes a value of 1 for HtB participants. When holding other factors constant, the financial indicator for HtB participants is

$$\ln Y_{i,P_i=1} = \alpha + \beta + e_i \tag{4.11}$$

And the financial indicator for non-HtB participant is

$$\ln Y_{i,P_i=0} = \alpha + e_i \tag{4.12}$$

The β represents the difference between participants and non-participants that

$$\beta = \ln Y_{i,P_i=1} - \ln Y_{i,P_i=0} \tag{4.13}$$

The coefficient β can be interpreted as the approximate elasticity of change between these two groups of developers

$$\beta = \ln \frac{Y_i, P_i = 1}{Y_i, P_i = 0} = \ln \left(1 + \frac{Y_{i,P_i=1} - Y_{i,p_i=0}}{Y_{i,P_i=0}} \right) = \ln\left(1 + \Delta\% Y_p\right) \approx \Delta\% Y_p \tag{4.14}$$

This indicates that the variables in this study have the potential to undergo logarithmic transformation. However, it is crucial to note that taking the logarithm of a variable should only be done when it is appropriate and justified based on the characteristics of the data and the research question under investigation. This is particularly important in DID studies, as highlighted by Huntington-Klein (2022). The author emphasizes the necessity of conducting parallel tests to determine whether logarithmic transformation should be applied to financial variables. The reason behind this is that while parallel trends may hold for the dependent variable Y_i, they may not hold for lnY_i (and vice versa).

To illustrate this point, let's consider a hypothetical scenario. In the pre-treatment period, assume that the value of Y is 10 for the control group and 20 for the treated group. In the post-treatment period, assuming no treatment effect, Y would be 15 for the control group and 25 for the treated group. This results in a pre-treatment gap of 10 units and a post-treatment gap of 10 units as well, indicating parallel trends. However, this parallel trend does not hold when we consider the logarithmic transformation. The pre-treatment gap becomes $\ln(20) - \ln(10) = 0.693$, while the post-treatment gap becomes $\ln(25) - \ln(15) = 0.511$. Therefore, it is essential to conduct parallel tests on each dependent variable in the DID analysis to determine whether applying a logarithmic transformation is appropriate.

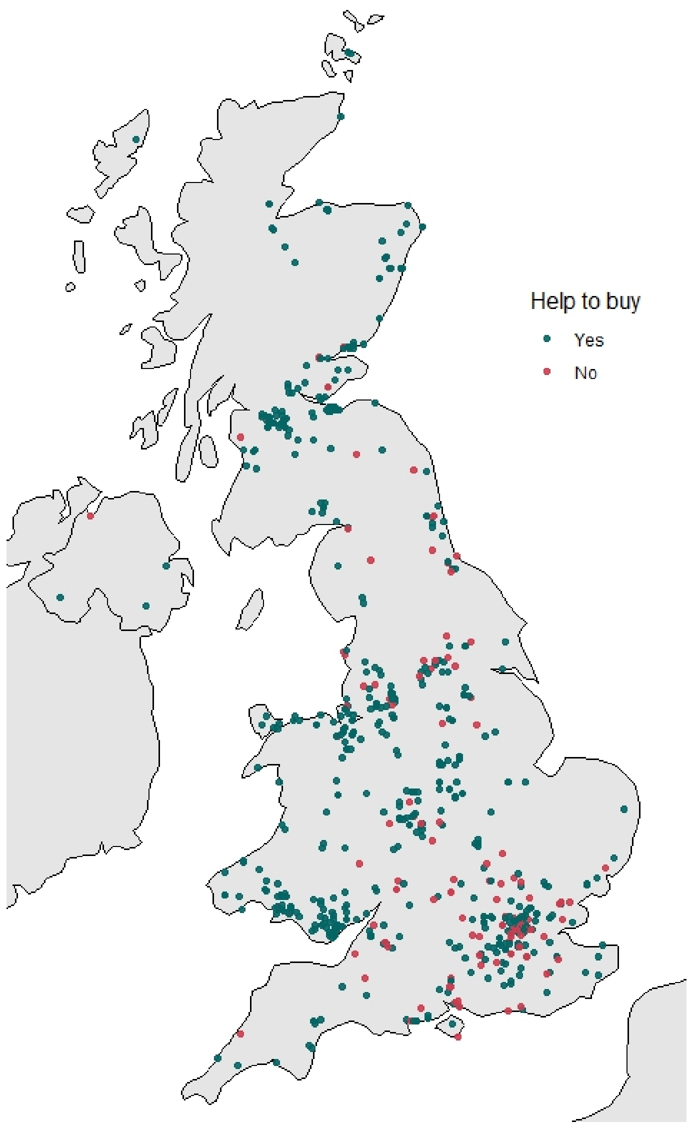
By conducting parallel tests, I can make an informed decision about whether to apply a logarithmic transformation to the data.

A.3 Remarks of sample developers

Representative evidence

I reviewed the financial reports of developers who made a special statement regarding HtB. In this section, I provide direct quotations extracted from a randomly selected financial report in various years within my database. Upon reviewing all of the reports, it can be deduced that the quoted passages concerning the effect of the HtB on developers and the broader construction environment are particularly salient compared to other financial reports. The impact of the HtB scheme is found to be highly influential

Figure 4.4: The geographic distribution of HtB and non-HtB participating developers



Note: This plot illustrates the geographic distribution of HtB and non-HtB participating developers. The green dots represent HtB participants and the red dots represent non-HtB participants.

in these quoted paragraphs. In the examined financial reports, the low interest rate is identified as the main factor contributing to the rise in developers' profitability, followed by the HtB scheme as the second most frequently cited driving force. In the short term, HtB is viewed as an effective incentive to stimulate demand and encourage more buyers to invest in properties. Over the long term, the continued implementation of this policy creates a stable financing and investment environment, enabling developers to secure funding and expand their operations.

Taylor Wimpey Plc. (Registered number 00296805) states in the 2013 report that

> 1. Underscoring the importance of house-building to the UK economy, the Government implemented HELP TO BUY, the most significant programme to date, from the beginning of the second quarter, effectively replacing the FirstBuy programme and having a quick and direct impact on the affordability of mortgages. Following the implementation of HELP TO BUY, we saw a significant set up in both interest levels and sales rate.
>
> 2. In the first half of 2013 the Group saw a sustained improvement in the UK housing market and the wider economy, with increased mortgage availability, lower interest rates together with enhanced customer confidence following the launch of the Government's HELP TO BUY scheme in April 2013. The UK housing market continued the positive trend into the second half, in particular the fourth quarter following the Government's announcement of the accelerating the HELP TO BUY phase two scheme, adding further confidence to consumers and the housing market more widely.

Bovis Homes Group Plc. (Registered number 00306718) states in the 2014 report that

> 1. With the improving consumer confidence supported by the Government HELP TO BUY scheme, the level of demand in the housing market improved substantially in 2013, although this has moderated during 2014.

2. HELP TO BUY provided the industry with increased certainty of support in the medium term. The Group views this development positively, providing further time for the mortgage market to develop under the positive control delivered by the Mortgage Market Review.

St Modwen Plc. (Registered number 00349201) states in the 2018 report that

> ...our house building volumes continue to benefit from HELP TO BUY. We assume a gradual recovery in prices after this back to pre-Brexit levels by 2023, with margins beyond 2020 helped by the consequent lower cost base, similar to the post-2009 recovery for house builders.

Persimmon Plc. (Registered number 01818486) states in the 2019 report that

> Affordability is a key factor influencing the wider economic picture for the housing demand. Our customers' ability to afford a home has been supported by low interest rates, favourable competition in the availability of mortgage products and the government's HELP TO BUY policy.

A.4 Robust analysis for investment cash flow sensitivity study

Table 4.17: The robust test of capital investment intensity regression

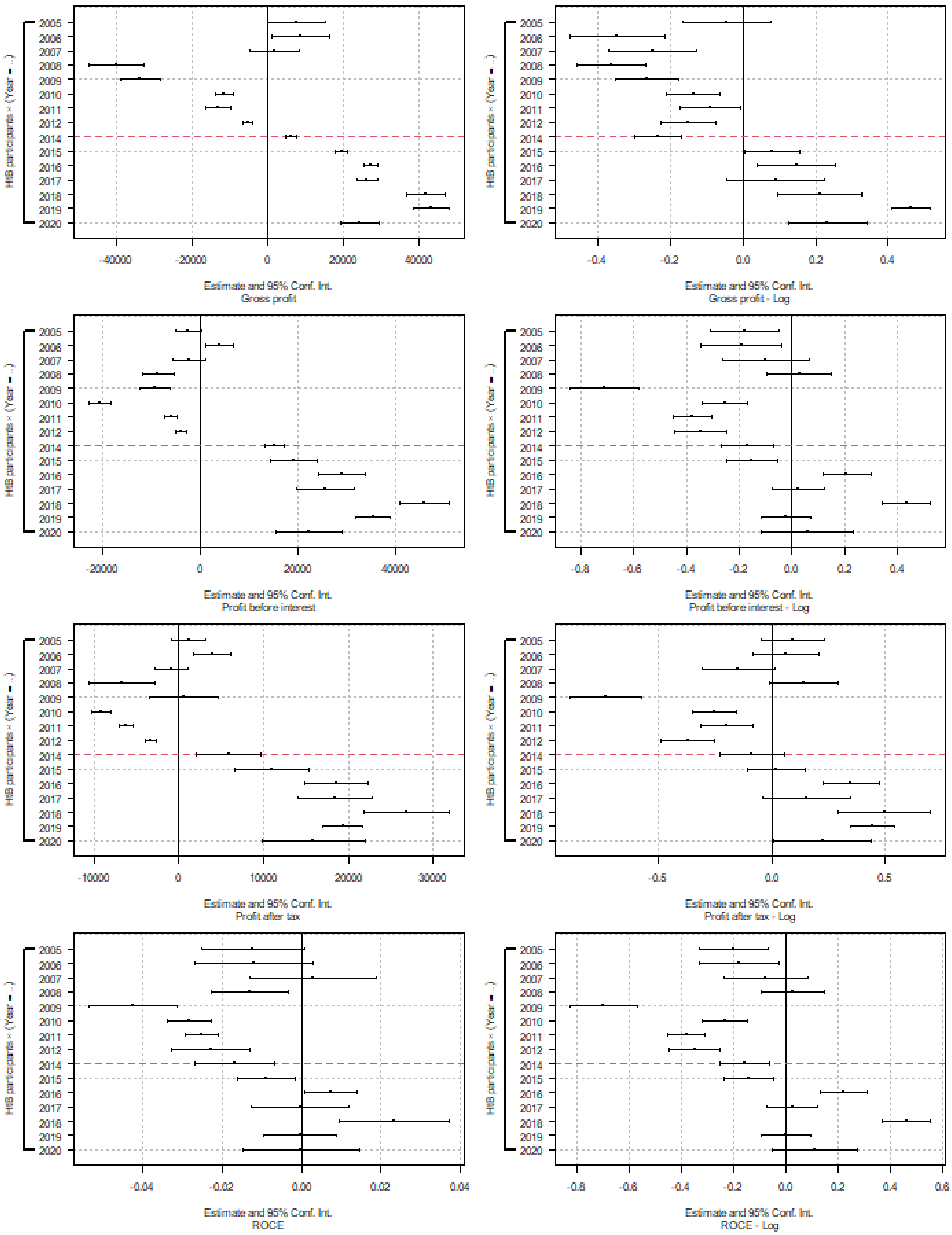
	Dependent variable: Capital investment of HtB participants					
	Pre HtB	Post HtB	Pre HtB	Post HtB	Pre HtB	Post HtB
Cash flow	0.255^{***}	0.660^{***}	0.238^{**}	0.658^{***}	0.332^{**}	0.641^{***}
	(0.075)	(0.014)	(0.081)	(0.015)	(0.109)	(0.033)
TFP_{OP}	0.001	-0.005^{***}				
	(0.001)	(0.001)				
TFP_{LP}			0.002	-0.006^{***}		
			(0.001)	(0.001)		
TFP_{ACF}					-0.001	-0.014^{***}
					(0.002)	(0.004)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Num. obs.	828	1004	821	958	925	1060
Sargan Test: p-value	0.005	0.070	0.004	0.024	0.052	0.009
Wald Test Coefficients: p-value	0.001	0.000	0.003	0.000	0.000	0.000

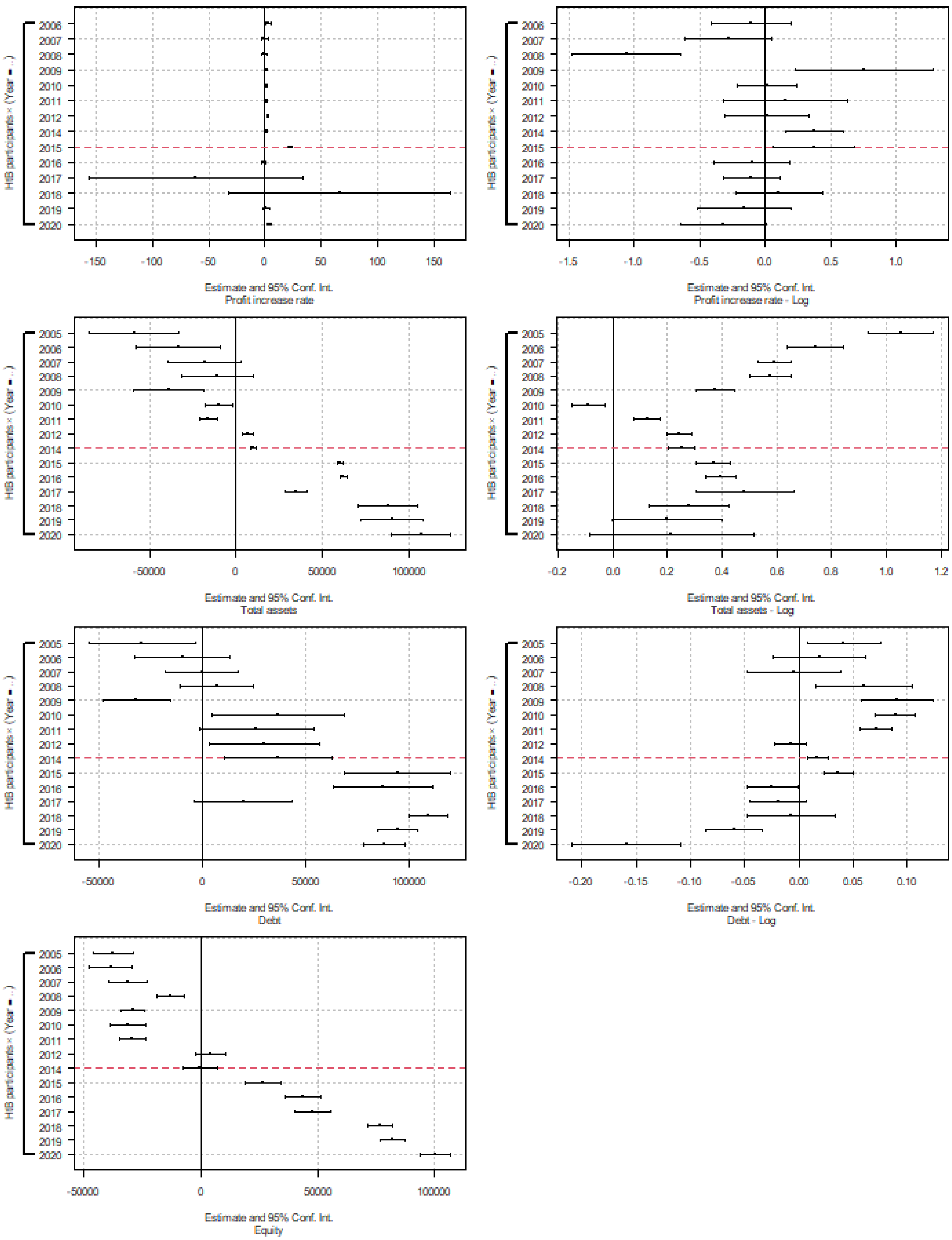
Note: This table displays the robust analysis results of the ICFS estimation for Model 4.8: $\text{INV}_{i,t} = \alpha_{c,t} + \beta_0 \text{INV}_{i,t-1} + \beta_1 Q_{i,t-1} + \beta_2 \text{CF}_{i,t} + \varepsilon_{i,t}$. The dependent variable $\text{INV}_{i,t}$ represents the investment in the capital of firm i in year t, measured by the change in tangible assets and scaled by the beginning-of-period total assets; $CF_{i,t}$ is the internal cash flow, measured by summing firm i's profit before interest with depreciation and amortisation, scaled by the beginning-of-period capital stock. β_2 is the ICFS. The robust model measures marginal capital return Q by three different calculations of TFP. The subscript OP, LP, ACF stands for the corresponding TFP calculation methods. We are interested in the differences in ICFS of HtB developers in pre and post HtB subperiods. The pre-treatment period is from 2005-2012 and the post-treatment period is from 2013-2020. The Num. obs. reports the total number of firm-year observations. The Sargan test and Wald test results are reported as measurements of the validity of the instruments used and goodness-of-fit for the model, and the significance level is denoted as $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

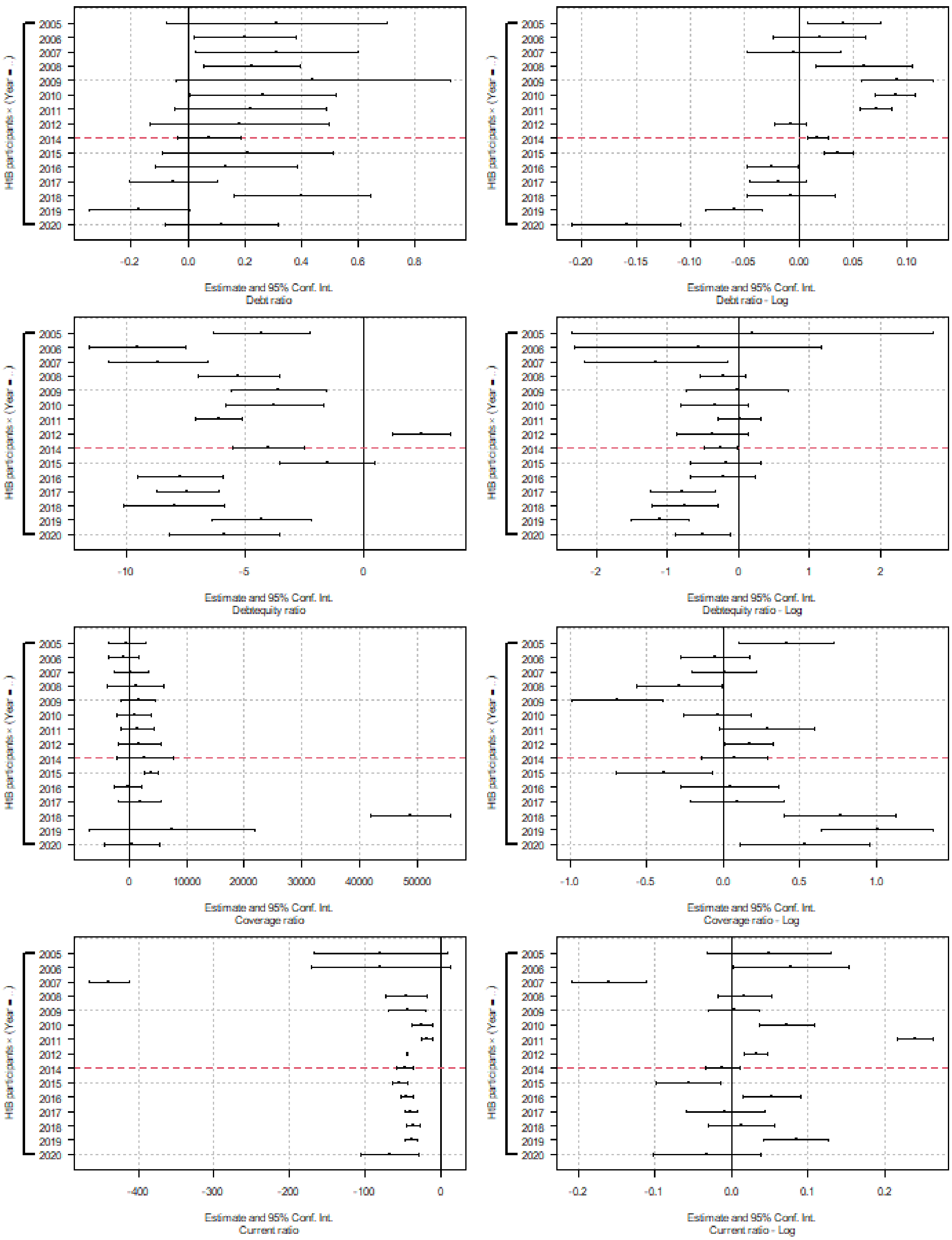
A.5 Parallel tests for main variables

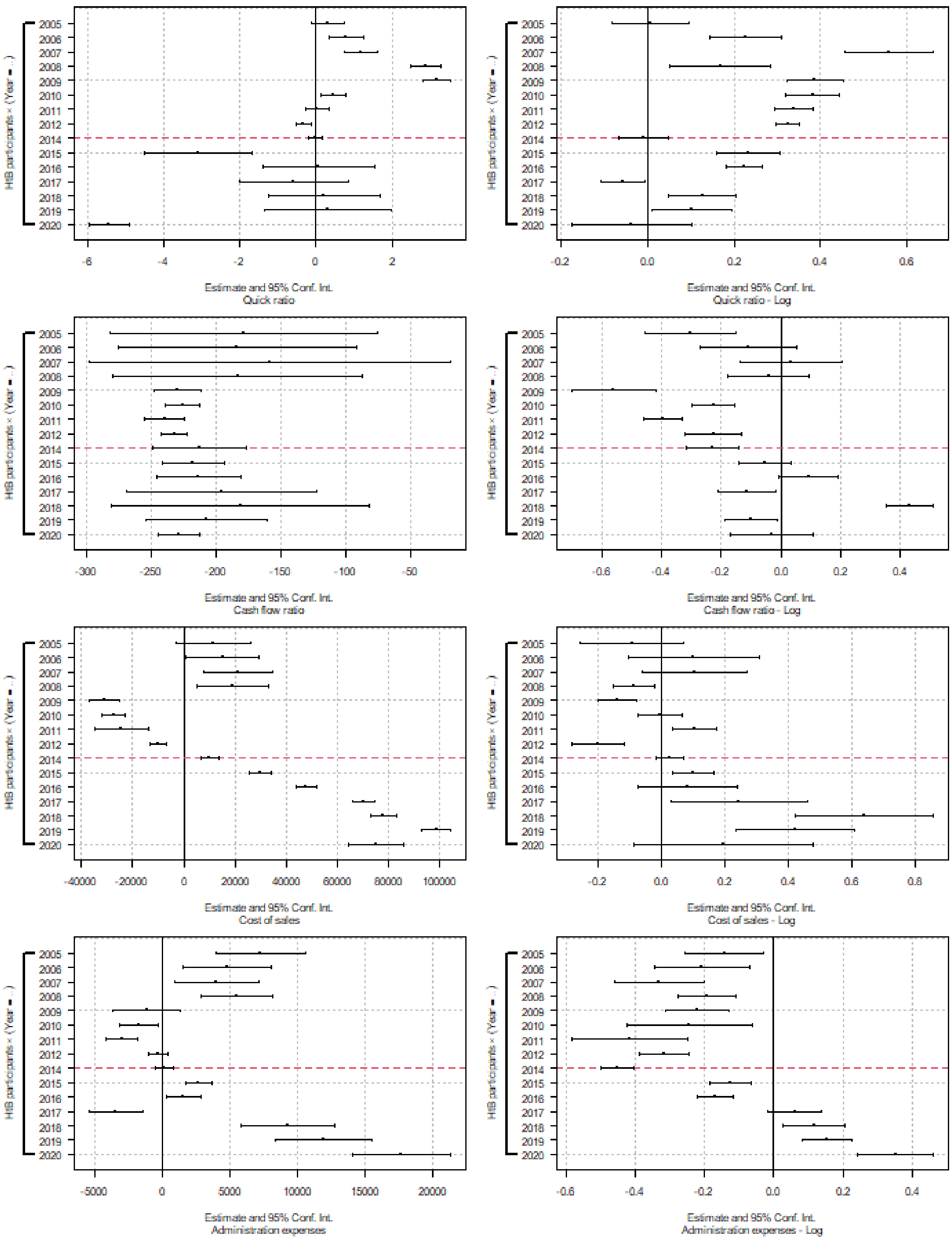
This section presents the parallel tests for all variables tested by DID studies.

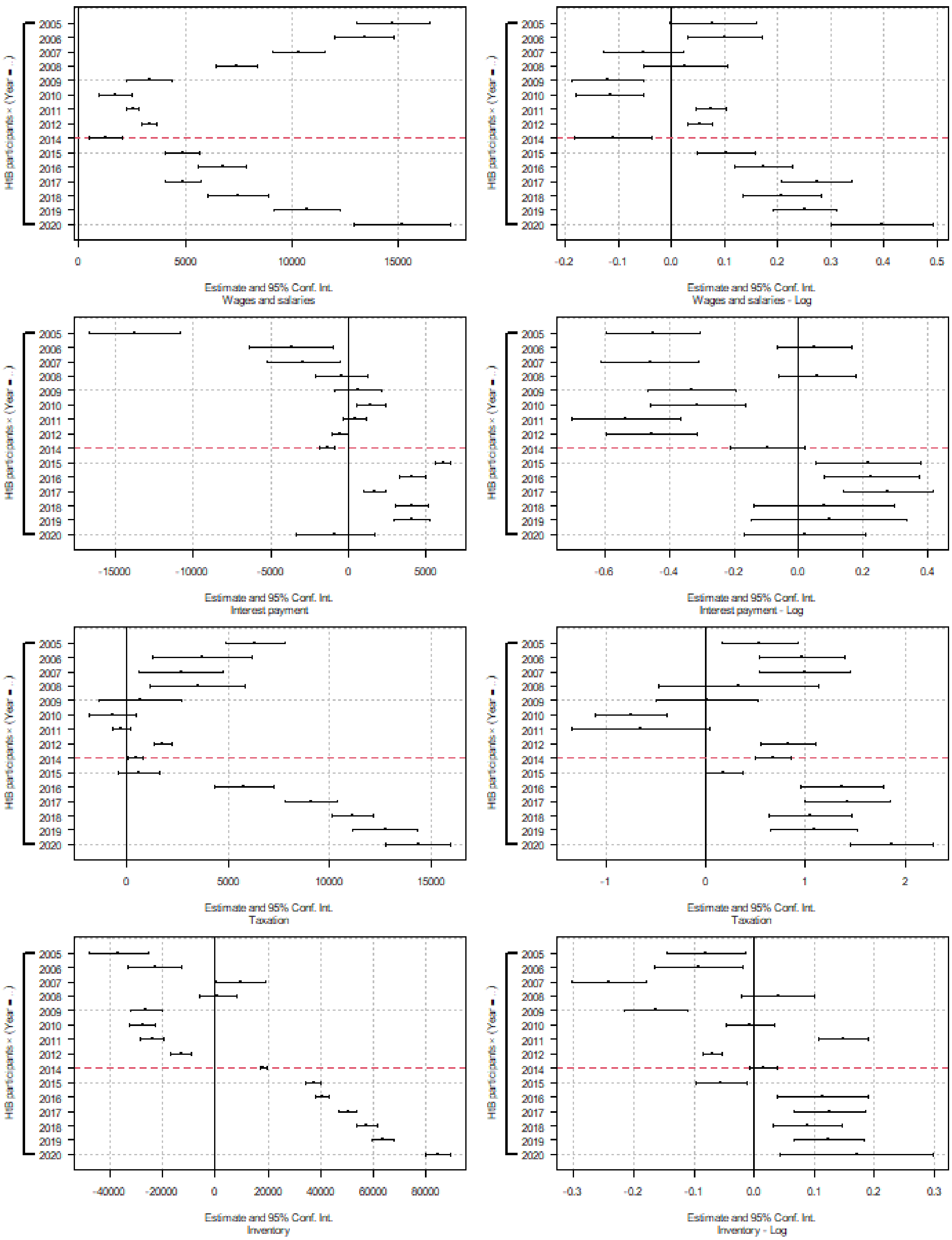
Figure 4.5: The parallel tests for DID studies

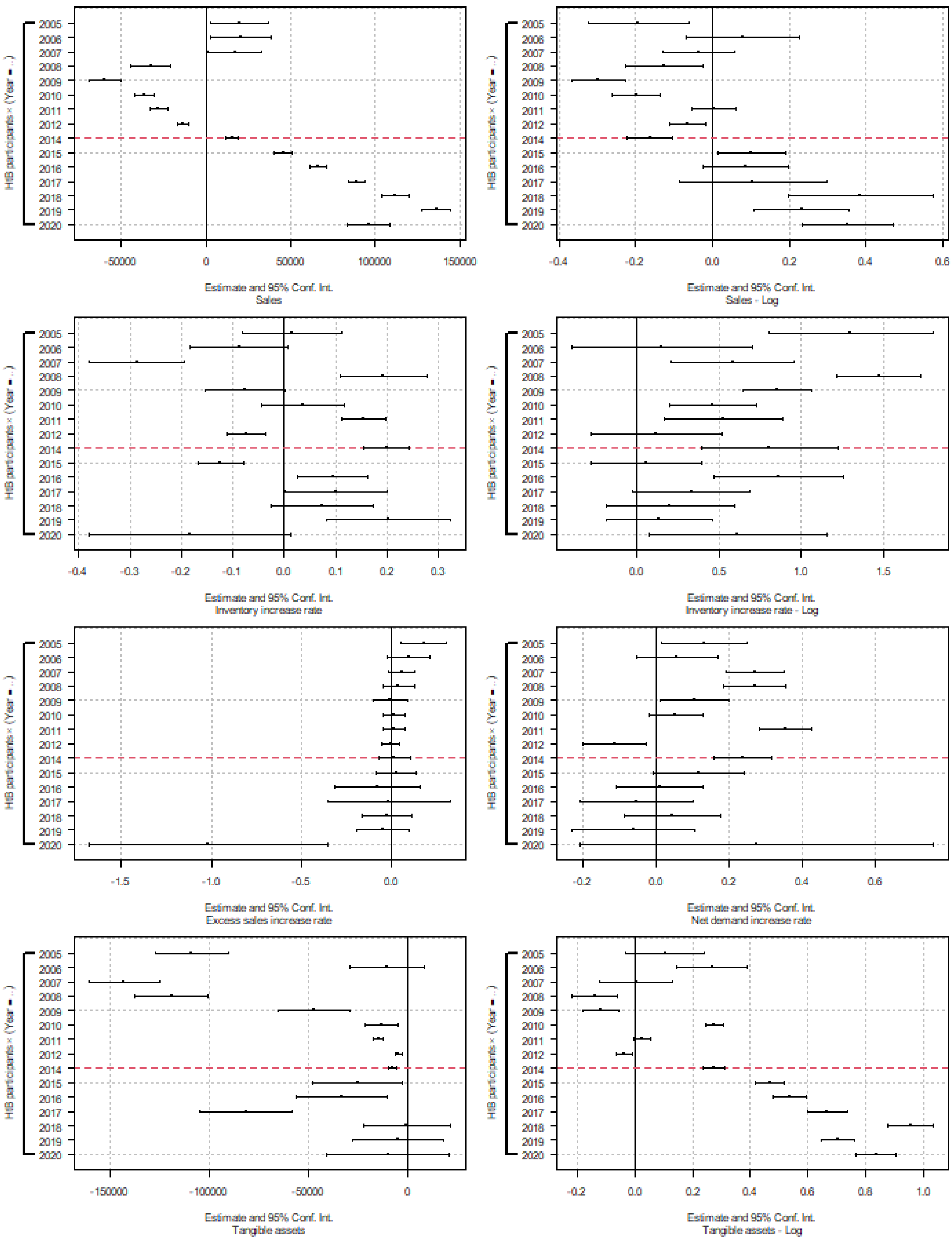


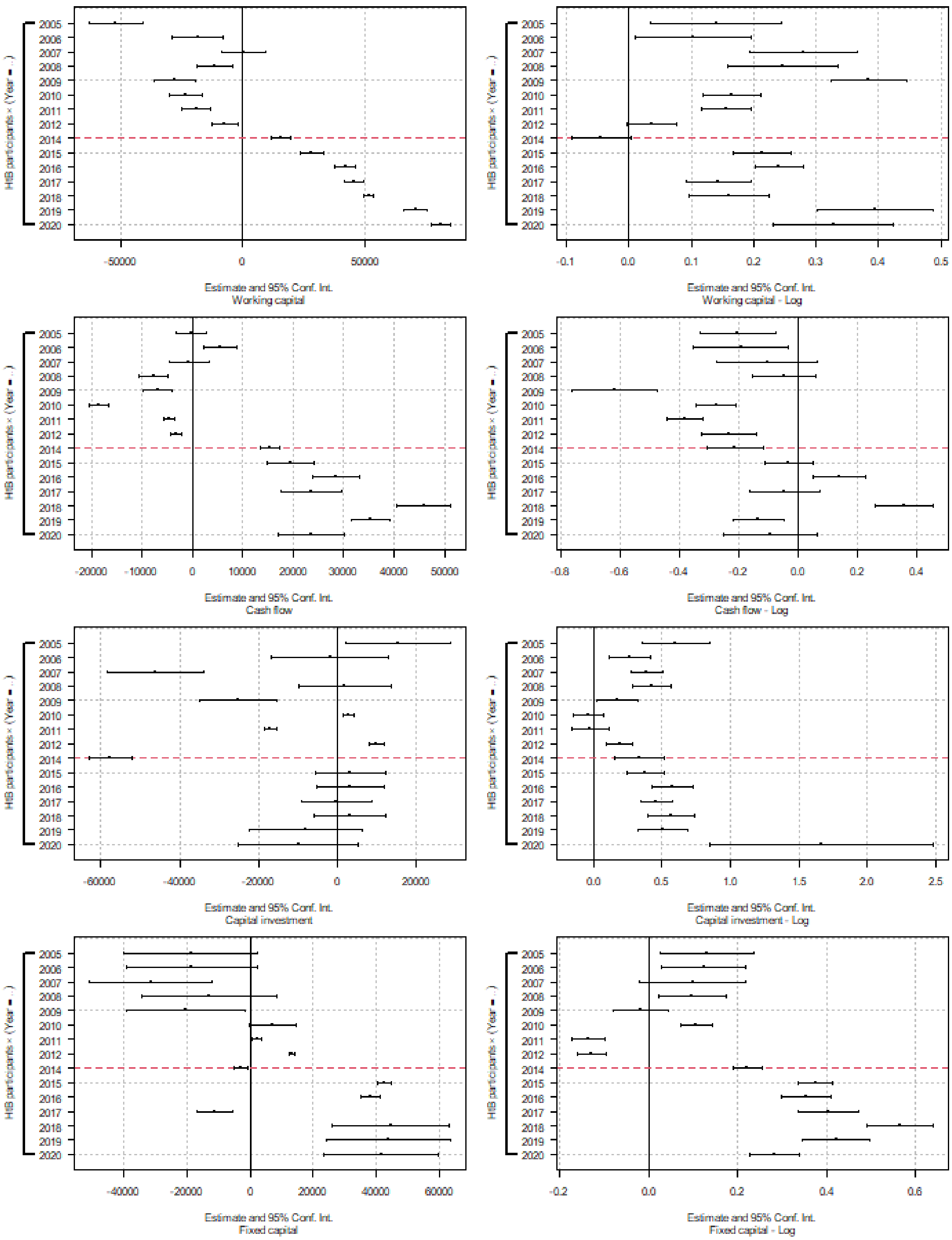

HtB participants × (Year = ..)
Estimate and 95% Conf. Int.
Profit increase rate
Estimate and 95% Conf. Int.
Profit increase rate - Log
Estimate and 95% Conf. Int.
Total assets
Estimate and 95% Conf. Int.
Total assets - Log
Estimate and 95% Conf. Int.
Debt
Estimate and 95% Conf. Int.
Debt - Log
Estimate and 95% Conf. Int.
Equity

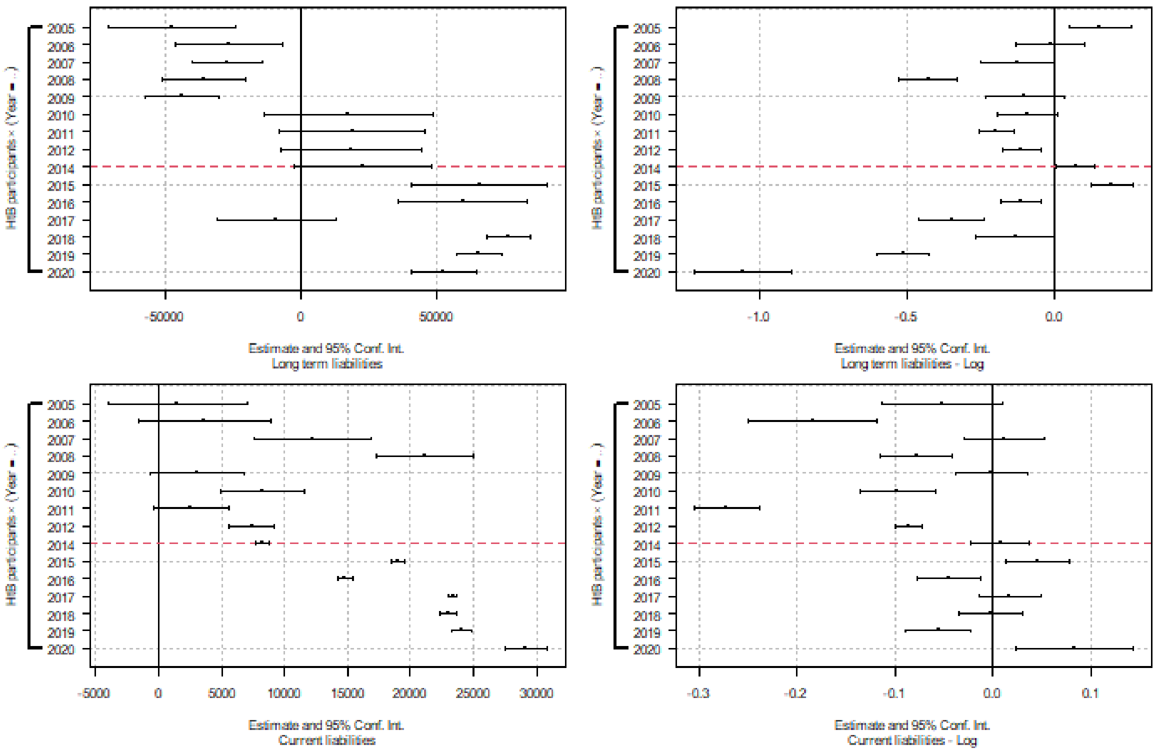

Estimate and 95% Conf. Int.
Debt ratio
Estimate and 95% Conf. Int.
Debt ratio - Log
Estimate and 95% Conf. Int.
Debt/equity ratio
Estimate and 95% Conf. Int.
Debt/equity ratio - Log
Estimate and 95% Conf. Int.
Coverage ratio
Estimate and 95% Conf. Int.
Coverage ratio - Log
Estimate and 95% Conf. Int.
Current ratio
Estimate and 95% Conf. Int.
Current ratio - Log
2005
2006
2007
2008
2009
2010
2011
2012
2014
2015
2016
2017
2018
2019
2020


Estimate and 95% Conf. Int.
Quick ratio
Estimate and 95% Conf. Int.
Quick ratio - Log
Estimate and 95% Conf. Int.
Cash flow ratio
Estimate and 95% Conf. Int.
Cash flow ratio - Log
Estimate and 95% Conf. Int.
Cost of sales
Estimate and 95% Conf. Int.
Cost of sales - Log
Estimate and 95% Conf. Int.
Administration expenses
Estimate and 95% Conf. Int.
Administration expenses - Log


Estimate and 95% Conf. Int.
Wages and salaries
Estimate and 95% Conf. Int.
Wages and salaries - Log
Estimate and 95% Conf. Int.
Interest payment
Estimate and 95% Conf. Int.
Interest payment - Log
Estimate and 95% Conf. Int.
Taxation
Estimate and 95% Conf. Int.
Taxation
Estimate and 95% Conf. Int.
Inventory
Estimate and 95% Conf. Int.
Inventory - Log


HIB participants × (Year = ...)
Estimate and 95% Conf. Int.
Sales
Estimate and 95% Conf. Int.
Sales - Log
Estimate and 95% Conf. Int.
Inventory increase rate
Estimate and 95% Conf. Int.
Inventory increase rate - Log
Estimate and 95% Conf. Int.
Excess sales increase rate
Estimate and 95% Conf. Int.
Net demand increase rate
Estimate and 95% Conf. Int.
Tangible assets
Estimate and 95% Conf. Int.
Tangible assets - Log


HIB participants × (Year = ...)
2005
2006
2007
2008
2009
2010
2011
2012
2014
2015
2016
2017
2018
2019
2020
-50000
0
50000
Estimate and 95% Conf. Int.
Working capital
-0.1
0.0
0.1
0.2
0.3
0.4
0.5
Estimate and 95% Conf. Int.
Working capital - Log
-20000
-10000
0
10000
20000
30000
40000
50000
Estimate and 95% Conf. Int.
Cash flow
-0.8
-0.6
-0.4
-0.2
0.0
0.2
0.4
Estimate and 95% Conf. Int.
Cash flow - Log
-60000
-40000
-20000
0
20000
Estimate and 95% Conf. Int.
Capital investment
0.0
0.5
1.0
1.5
2.0
2.5
Estimate and 95% Conf. Int.
Capital investment - Log
-40000
-20000
0
20000
40000
60000
Estimate and 95% Conf. Int.
Fixed capital
-0.2
0.0
0.2
0.4
0.6
Estimate and 95% Conf. Int.
Fixed capital - Log



HB participants × (Year = ..)
2005
2006
2007
2008
2009
2010
2011
2012
2014
2015
2016
2017
2018
2019
2020
-50000
0
50000
Estimate and 95% Conf. Int.
Long term liabilities
-1.0
-0.5
0.0
Estimate and 95% Conf. Int.
Long term liabilities - Log
-5000
0
5000
10000
15000
20000
25000
30000
Estimate and 95% Conf. Int.
Current liabilities
-0.3
-0.2
-0.1
0.0
0.1
Estimate and 95% Conf. Int.
Current liabilities - Log

Chapter 5

Conclusion and further discussion

5.1 Conclusion

This thesis offers a glimpse into the modern evolution of neoclassical investment models by exploring three recent queries from both theoretical and empirical perspectives. In this chapter, I briefly outline the questions examined in the thesis and highlight the main contributions made in each chapter.

Chapter 2 is grounded in theory. The neoclassical investment theory has been evolving since the 1960s, with its roots in Tobin's pioneering introduction of the investment Q model. This model was the first to consolidate the measurement of relevant variables within a generalised stochastic framework. The theory has sparked many influential works on optimal capital investment, facilitating the efficient and sustainable allocation of capital in empirical markets. This thesis is underpinned by the theory of optimal investment.

The neoclassical model posits that a firm's capital investment should be determined solely based on the shadow price of capital. This suggests that a firm should undertake capital investments when the marginal return on capital exceeds the cost of financing. This model setting has garnered extensive popularity, as it accurately reflects the stochastic, forward-looking nature of a firm's capital investment decisions in empirical applications. However, this theoretical characteristic also introduces challenges for empirical extensions, given that the cost-benefit point of marginal capital productivity is not directly observable from market information (Blundell et al. 1992a). Previous research has employed a variety of proxies to measure marginal capital productivity (i.e. marginal Q), including the book-to-equity ratio, sales growth, total factor productivity, and an autoregressive model-based index (Ding et al. 2018; Guariglia and Yang 2016; Larkin et al. 2018). However, all of the metrics used in previous research are prone to the common criticism of being average values. The theoretical marginal Q is only equal to the average Q under very stringent and rare market assumptions.

Chapter 2 provides insights into this research gap by introducing a recently published novel method for measuring markup. This method is developed in the industrial organisation study of calculating market power. The previous method of calculating markup faces the same criticism as marginal Q for being calculated using average values derived from balance sheet data. De Loecker et al. (2020) describe the new approach as a radically different approach as it can estimate price over marginal cost on the basis of the production function. This means the measurement no longer relies on stringent assumptions of market competition and the requirement of product quantity and price to calculate marginal profitability. Drawing from a summary and revision of the derivation of the optimal investment framework, I propose and elaborate how this metric serves as a more effective measure of marginal Q compared to the averaged Q metrics utilised in prior research. The production-based markup approach is a theoretical formula that requires estimating the production function to calculate the metric empirically. However, estimating the production function using balance sheet data can be challenging. In this study, I propose three distinct methodologies to estimate the production-based markup using balance sheet data.

Using the metric developed in Chapter 2, Chapter 3 investigates the capital investment trend in recent decades. With financial constraints being a common issue, firms often find it difficult to achieve optimal capital stock due to high financing costs. This leads them towards self-financing, and they tend to invest more when their internal cash flow increases. This behaviour typically results in a strong correlation between a firm's investment and its cash flow, leading to the widely observed ICFS. Recent research has indicated a major decline in the ICFS in developed economies, a trend that has spurred considerable investigation. This thesis contributes to the discussion by examining the impact of asset tangibility on its decline. I demonstrate that the ICFS has declined among non-listed firms, with a decrease in asset tangibility being the main driver of this decline within British firms. Distinct from the exploratory work of Moshirian et al. (2017) and Zhen and Chu (2021), this study focuses on all sample firms within a specific and homogeneous economic context. The UK, with its well-regulated financial system that is not affected by geographic development imbalances, presents an ideal sample for studying the trend and causes of change in the ICFS. The ICFS is typically seen to be more prevalent among firms facing greater financial constraints. Hence I argue that using a sample from all sample firms in the UK offers a more representative view and provides a clearer reflection of the financing conditions among ordinary companies in developed economies.

The analysis of Chapter 3 reveals that asset tangibility is the primary factor affecting the ICFS. As the asset tangibility ratio decreases among British firms, the ICFS also decreases. The results are robust to testing with two models. Firstly, I test the declining ICFS using the traditional model proposed by Fazzari et al. (1987) and estimate it using OLS. However, this model is flawed as it fails to fully control for marginal capital productivity and doesn't account for the potential endogeneity of the explanatory variables. To enhance robustness, an improved error correction model with GMM regression is used to test the ICFS. The interaction coefficients between cash flow and the asset tangibility ratio prove to be significant in all baseline regression tests, indicating that the ICFS is, in fact, a sensitivity relating to investment, cash flow, and tangible capital. To further explore how the ICFS varies among firms, the sample is classified into two groups based on differing levels of asset tangibility. They are tested in each group over six subperiods spanning from 1984 to 2019. The results reveal that firms with high asset tangibility exhibit a higher ICFS and have experienced a steeper decline over the past three decades.

As the ICFS is frequently utilised as a measure of capital intensity, this research enriches the literature by further explaining why asset tangibility can result in a decrease in capital asset tangibility. It demonstrates that there has been a decline in the return on fixed capital investment, and this decrease is more marked in firms with high asset tangibility. These high asset tangibility firms mainly belong to traditional yet essential industries such as manufacturing and construction. This insight offers a vital understanding of the economic evolution in the UK. According to the studies of Goodridge et al. (2018) and Bournakis and Mallick (2018), the TFP in the UK (as well as many countries in Europe) has experienced sluggish growth following the financial crisis. And the phenomenon cannot be attributed to the reallocation of labour or labour mobility. The findings of this research indicate that the low return on firm capital investment and external financial constraints may contribute to the underdevelopment. This finding is noteworthy and differs from research by the likes of Moshirian et al. (2017) and Zhen and Chu (2021), which suggest that the decline in ICFS is due to most companies gaining more access to financial resources for investment, coupled with technological advancements boosting the return on fixed capital investment. The conclusion highlights that this trend does not apply to non-listed firms, and the discrepancy in development could be exaggerated without a thorough understanding of the different economic conditions between ordinary and superstar firms.

Chapter 3 poses a natural query: is there a way to improve the sluggish investment return trend? Chapter 4 explores this possibility by delving into a policy intervention. The study delves into the financial implications of a highly successful credit expansion policy, the HtB, on the developers participating in the program. With tremendous popularity, the policy has enabled the sale of over three hundred thousand properties, with a total price exceeding £86 billion under the scheme. As the price of new homes has significantly increased during the policy period, there are suspicions that this policy is more about augmenting developers' profitability than promoting homeownership.

This success of the HtB makes me particularly interested in examining how much of the financial gains (losses) in participating firms can be traced back to the demand shock triggered by relaxing credit constraints for buyers. This study uses DID method to study the causal effect of the policy. There exists a group of developers who have not enrolled in the HtB scheme, allowing for the use of the scheme as a quasi-natural experiment to compare the financial performance between participants and non-participants and to assess the impact of the policy. The DID results reveal that the HtB policy has a substantial impact on the increase of costs, sales, and profit for participating firms. In particular, the policy is demonstrated to result in increases in net profit and equity, coupled with growth in both the current ratio and quick ratio. This suggests that the HtB provides benefits for participating companies in terms of both long-term wealth accumulation and short-term liquidity enhancement. This policy brings a rather prominent financial impact on the construction industry, against the backdrop of a general decline in capital productivity outlined in Chapter 3.

Another question meriting exploration is whether, at the property level, the HtB policy has conferred more benefits to participating than non-participating firms, or whether participating firms have manipulated their supply to inflate property prices to maximise profitability. The absence of property-level sales data makes this question challenging to answer. This study proposes an innovative approach to tackle this problem. Firstly, an uptick in inventory and sales is observed in participating firms following the implementation of the HtB policy. However, only an increase in the inventory growth rate is detected in terms of first-order rates. In contrast, the increase in sales rate, as measured by two different metrics, shows a decrease. It's the first evidence that participating firms have supplied a sufficient quantity of properties to significantly meet market demand. This argument is bolstered by the second piece of evidence. Through a novel calculation of markup, it is discovered that the HtB policy leads to a decrease in markup among participating firms. Meanwhile, the Land Registry Price Paid Data shows that the portion of properties sold under the HtB scheme has steadily risen during the policy period. All the evidence jointly points to that the enhanced profitability is a result of increased sales volumes, rather than an increase in bargaining power in market pricing.

In the third part, I elucidate how the policy has facilitated the construction of more properties while simultaneously increasing the profits of participating developers without inflating their markup. Critics have overlooked the fact that enhancing investment efficiency in fixed capital can significantly boost developers' marginal profitability.

The enhancement in marginal productivity is difficult to observe directly due to its stochastic forward-looking nature. However, this study proposes innovative approaches to measure it, based on the knowledge from Chapter 3. According to the investment Q theory, the major capital costs for developers are the adjustment and financing cost, which is closely tied to sales uncertainty. Without effective estimation of market demand, firms could suffer from high sunk costs, adjustment costs, and financing costs associated with over- or under-investment. Analysing the financial reports of participants reveals that developers anticipated the HtB scheme could lead to a long-term, steady increase in demand. This expectation significantly reduces the adjustment costs. Developers foresee a rise in marginal capital productivity and invest and construct accordingly. Furthermore, with reduced uncertainty and more cash available for self-financing and cash-based lending, they achieve better profitability during this period. This is evident from the increased capital levels, and the heightened investment-cash flow sensitivity and debt-cash flow sensitivity.

The contribution of Chapter 4 is to provide a systematic framework for understanding the developers' reaction to a demand shock induced by the HtB policy. Estimating the pure effect of the relaxation of credit constraints is challenging, as the increased profitability can result from multiple factors, such as increased marginal prices, reduced marginal costs, improved productivity, or additional increases brought by policy targeted marketing strategies designed to drive sales. The framework provided enables readers to corroborate findings from different perspectives while controlling for irrelevant factors with strong econometric supports. This approach can be applied to future policy evaluation studies.

5.2 Future studies

In understanding the evolution of neoclassical investment theory, our main contributions can be summarised in three aspects: measuring marginal Q, detecting capital investment trends, and studying the impact of a policy intervention.

The thesis demonstrates a clear trend indicating that the average investment return and intensity have been declining. However, it also suggests that a proper policy can change this trend. This provides a different perspective for studying the productivity puzzle in the UK and Europe (Bellocchi et al. 2021; Goodridge et al. 2018). Although current studies have not reached a definitive conclusion regarding the cause of sluggish productivity, our findings in Chapter 4 imply that a well-designed policy can potentially mitigate further productivity decline without inflating the market by boosting suppliers' market power. The HtB has been considered a significant policy intervention, but there is still a lack of discussion regarding which terms of its policy design are crucial for its success. As discussed in the literature in Chapter 4, a change in policy or demand shock could lead to price fluctuation, yet ensuring ideal policy impact without attenuating buyers' affordability requires analysis from different market participants.

A promising avenue for future research stemming from this thesis is to study the terms and keys to the success of HtB, along with its possible positive social impact. One potential approach is to compare HtB with similar credit expansion policies such as mortgage interest deductions in the US or mortgage guarantees in the Netherlands.

The application of markup helps measure the theoretical Q in unlisted firms. Hence, in future studies, we could compare the markup power of developers in countries with similar policies to see if they have also shown a similar impact on firm productivity, without gaining too much premium. Based on quantitative analysis, further interviews and surveys can be conducted with developers, potential buyers, agent brokers, and others.

Another approach is to compare HtB with similar subsidy policies. For example, Huang and Milcheva (2022) study the impact of the Stamp Duty Holiday (SDH) on housing prices. The SDH was a policy that temporarily removed housing transaction taxes in the UK during 2020, aiming to stimulate housing market activity during the early stages of the Covid pandemic and help the housing market adjust to new living and commuting patterns. The SDH led to a boost in market activity, resulting in a 53% increase in housing transactions, with housing prices increasing by around 2% during the SDH period. They also show that sellers benefited from a stronger bargaining position, leading to a greater surplus for them. Thus, the affordability concern of SDH is that, while it achieved its intended goals, it inadvertently reduced housing affordability for those most in need of housing. Primarily, the SDH differs from HtB with a shorter policy time window and lacks benefits from the credit aspect. This leaves suppliers not only with a shorter time to react to increase the supply but also with a stronger desire to close deals. Comparing the differences between these two policies might help understand the long-term benefits of HtB in terms of its dynamic and sustainable effects.

5.3 Limitation

Despite aiming to understand the evolution of neoclassical investment theory, this thesis covers only a small fraction of the subject due to its limited scope. The main focus of this study is quantitative analysis. This thesis has not covered the impact of the evolution on the social and broader economic environment from qualitative aspects.

To conduct such a study, one would need to overcome the hurdle of data acquisition. For example, while going through the annual reports from each company in Chapter 4, the description related to HtB only appears three or four times on average. Most of the disclosed information does not contain specifics of the implementation and sales of HtB. The land supply and pricing are also important factors. Upon reviewing the annual reports, it is quite common to notice that the land supply is scarce in some of the busiest areas in the UK and that the supply is rather inelastic to the Help to Buy policy. It would be beneficial to identify the policy impact at the property level if we could obtain more detailed information, such as specific locations and Help to Buy property sales volumes, as well as related land supply and pricing every year. Unfortunately, this information is not disclosed in the annual reports. Therefore, these aspects can be further explored in future studies.

In future work, researchers could utilise modern web crawling techniques to collect ongoing sales information from each developer. Information such as HtB sales quantity, sale proportion, HtB-related development costs, and HtB-related administration costs could significantly help us understand the impact of a successful macroeconomic policy that improves capital investment returns.

Meanwhile, the Large Language Model (LLM) can be used to broaden the horizon of our analysis from qualitative perspective. The regression models widely adopted in this thesis have limitations as they draw conclusions based on average statistical trends with data from spotlights. This leaves gaps of unstudied details such as sentiments and perception changes. While our focus has primarily been on studying capital investment from a theoretical perspective, it's important to recognise that the evolution of investment return is intricately linked to the evolution of social-economic norms. These pieces of information are predominantly stored in non-quantitative form.

By leveraging LLM, researchers can delve deeper into the qualitative aspects of investment behaviour and outcomes. The LLMs have the capability to process vast amounts of textual data, including news articles, social media posts, and economic reports, allowing for a more comprehensive understanding of investor sentiments and market dynamics. Furthermore, they can help identify patterns and trends in language use that may indicate shifts in economic perceptions or expectations, providing valuable insights into the factors driving investment decisions. Incorporating LLM analysis alongside traditional quantitative methods can enrich our understanding of the complexities of investment behaviour and help identify new avenues for research and policy intervention.

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