SAVING, GROWTH, AND INVESTMENT: A MACROECONOMIC ANALYSIS USING A PANEL OF COUNTRIES

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Abstract—This paper provides a descriptive analysis of the long- and short-run correlations among saving, investment, and growth rates for 123 countries over the period 1961–94. Three results are robust across data sets and estimation methods: i) lagges saving rates are positively related to investment rates; ii) investment rates Granger cause growth rates with a negative sign; iii) growth rates Granger-cause investment with a positive sign.

I. Introduction and Motivation

THE MAIN AIM of this paper is to provide an exhaustive and careful descriptive analysis of the correlations among saving, investment, and growth rates. We want to establish what are the main (aggregate) ''stylized facts'' that link these variables. For such a purpose, we use a new data set, gathered by the World Bank that contains a wide range of variables for 150 countries over the post-WWII period. The data set is probably the best panel of countries available to date.

In what follows, we analyze both contemporaneous correlations and dynamic models. Most of the analysis, however, is focused on the dynamic relationships among the variables of interest. We will be using the statistical concept of Granger causality to denote the fact that a variable (the caused one) is correlated with lagged values of the other (after controlling for its own lags). Obviously, one should refrain from giving a causal or structural interpretation to these results.

We estimate flexible dynamic (reduced-form) models and identify long-run and short-run correlations among the variables of interest. The empirical regularities we document should complement those observed in microeconomic data sets and constitute the benchmark against which different models of saving, consumption, and growth are evaluated. While the scope of this paper is not the estimation of a structural model that links growth, saving, and investment rates, it is worth thinking about the implications of some of the standard models for the correlations we consider. The theoretical predictions for both the long-run and short-run correlations among the variables of interest are often ambiguous. Nonetheless, measuring such correlations is informative about the relative importance of various factors.

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A natural theoretical framework that is used to think about the correlation between saving and growth is the lifecycle model. Such a model might imply both a long-run relationship between past growth and current saving rates and between future expected growth and current saving. If wealth is accumulated during the first part of the lifecycle and decumulated during retirement, population and/or productivity growth might lead to higher aggregate saving, if the saving of the young exceeds the dissaving of the old, in the steady-growth equilibrium. However, it is easy to reverse such prediction if one makes individual earning profiles steep enough and lets the young borrow against their future income. If the borrowing (negative saving) of the young is large enough at the aggregate level, a strong productivity growth might lead to a negative correlation between saving rates and growth rates. The picture is further complicated if one considers the possibility of liquidity constraints, precautionary savings, habit formation, and general equilibrium effects on the rate of return. In fact, the sign of the long-run equilibrium correlation depends upon the precise shape of the utility function, the demographic structure, the presence of productivity changes, and other such factors.

The lifecycle model, in which individual saving is an explicitly forward-looking variable, also predicts Granger causation, possibly with a negative sign, running from saving to growth. Rational individuals anticipating declines in future income will increase savings. This is the ''saving for a rainy day'' mechanism illustrated, for instance, by Campbell (1987), and it is worth stressing if nothing else to emphasize that one should use particular caution in interpreting Granger causality results.[1] Other saving-to-growth linkages are also possible through an (almost passive) physical capital accumulation. Obviously, this link is only an indirect one.

The considerations of the last three paragraphs clarify the potential utility of measuring saving-growth correlations to establish which of the various factors at play are more likely to be of importance. For the same reason, it is important to distinguish between long- and short-run effects and to identify indirect effects through other variables, such as investment rates. It should also be clear, however, that the evidence we present can constitute only a piece of the puzzle. If one is interested in explaining cross-country differences in saving and growth (and their relationship), the aggregate evidence should be complemented with microeconomic evidence on the shape of earning profiles, age distribution, and so forth. The dynamic relationship between saving and growth rates has recently been studied by Carroll

[1] A short-run negative correlation emerges also in the standard IS-LM framework, because a positive shock to saving leads to a subsequent decline in income and production.

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and Weil (1994), who explicitly used the concept of Granger causation. We will analyze Carroll and Weil results in detail, partly for their intrinsic interest and partly to illustrate some of the methodological points that we want to make.

When considering the association between saving and investment rates, it is natural to think in terms of the integration (or lack of) of international financial markets. Indeed, in an influential contribution, Feldstein and Horioka (1980) interpreted the cross-country correlation between saving and investment rates as evidence of low international capital mobility. In this case, saving is likely to be a limiting factor for investment. A saving-to-investment link could therefore arise because ‘‘an increase in national saving has a substantial effect on the level of investment’’ (Feldstein and Bacchetta (1991)), as investment must be supported by saving and domestic firms compete for the flow of available domestic saving.

This interpretation has often been challenged: In fact, in the long run, technological variables and the demographic structure of the population could drive both variables, thereby inducing positive correlation even with perfect capital mobility (Baxter and Crucini (1992); Taylor (1994).[2]

Our results show that the correlation between saving and investment is, indeed, a robust finding. Moreover, we show that such a correlation has an important dynamic component, in that lagged saving rates are strongly correlated with current investment rates. It is therefore interesting to establish whether such a correlation survives also the introduction of various controls.

Obviously, Granger causation running from investment to saving is also possible. While the exact mechanisms at work are hard to spell out in detail, if an increased demand for capital goods stimulates saving—maybe through interest rate effects or the endogenous development of the financial instruments that permit the mobilization of saving—saving might adjust to investment.

The positive contemporaneous association between rate of investment and growth is usually explained in terms of a causal link running from the former variable to the latter. Several well-known theoretical explanations can be offered for such a link. Some growth models, for instance, suggest that a rise in productivity growth causes both growth rates and investment rates to move together (possibly coupled with the accumulation of human capital). This is the type of mechanism mentioned, for instance, by Barro (1991) when considering the simultaneous determination of growth and investment rates (as well as fertility rates) and investigated empirically more recently by Caselli, Esquirrel, and Lefort (1995) and Islam (1996). In what follows, we stress, once again, the dynamic nature of the relationship between investment and growth and show that the dynamic correlation can be quite different from the contemporaneous ones.

A dynamic link running from growth to investment might also hold. Higher growth might drive saving up, leading in turn to higher investment. However, Blomstrom, Lipsey, and Zejan (1996) suggest that accumulation might be a consequence of the growth process, ignited by the growth-based saving change. Furthermore, higher growth can enhance future growth expectations and returns on investment. Provided that saving (possibly raised by the growth process) is not a limiting factor, the accumulation of physical capital will finally take place.

While in recent years several authors have used panels of countries to study a variety of phenomena, no standard econometric methodology has been developed for the analysis of this type of data, a relative large panel of countries. The second contribution of our paper is a methodological one. We precede the empirical analysis with a discussion of alternative econometric techniques and of the related methodological issues.

In standard panel data analysis, the presence of fixed effects correlated with the variables on the right-hand side of the equations of interest constitutes an important concern. The issue is particularly serious in the analysis of dynamic systems, in which the hypothesis of strong exogeneity of the independent variables is obviously untenable. However, while these problems are certainly relevant, the analysis of a panel of countries puts the researcher in a slightly different environment than that faced by an econometrician studying large panels of individual observations. The main difference is in the fact that, unlike with household-level data, in which typically N (the number of individuals) is large and T (the number of periods) is small, in analyzing a panel of countries, N and T tend to have the same order of magnitude. Furthermore, it is more natural to think about the asymptotics of the problem as T-asymptotics rather than N-asymptotics. This will have an effect on the choice of techniques used in the analysis. Finally, if one is interested in characterizing the dynamic relationship among several variables, it is more natural to use concepts from the time-series literature and use the N dimension of the sample to allow for differences among countries that can be of independent interest.

The rest of the paper is organized as follows. In section II, we discuss some methodological issues relevant for the econometric analysis of dynamic models using panels of countries. In section III, we briefly describe the data set and present some evidence on the static correlations among the variables of interest. In section IV, we analyze the robustness of the Carroll and Weill results by using their estimators on the new data set and also considering different econometric techniques and different frequencies of the data. In section V, instead, we switch to the analysis of annual data and apply three different types of estimators. We first assume that the total number of time observations we have is large enough to allow us to use ‘‘big T’’ asymptotic approximations. We then present some results obtained using a ‘‘fixed T’’ estimator. Next, we allow for across-country heterogeneity in the dynamic effects that link the three variables of interest. Finally, we present the estimates of a trivariate model in

[2] Arguments based on the intertemporal country’s budget constraint lead to the same conclusion (Argimon and Roldan (1994)).

which we consider the variables of interests and their interactions simultaneously. We conclude the section by analyzing the effects of introducing various controls normally used in the literature. In section VI, we summarize and interpret the main results.

II. The Statistical Model and its Econometric Estimation

Preliminary to the empirical analysis, we discuss some econometric issues that are relevant to the study of the dynamic relationship between two or more variables observed over a relatively long time horizon and for a rather large number of countries.

A general representation of a dynamic model linking two variables x and y is

$$y_{i,t} = \alpha_0 + \sum_{j=1}^{q} \alpha^y_{i,t,j} y_{i,t-j} + \sum_{j=1}^{p} \beta^y_{i,t,j} x_{i,t-j} + \psi^y_t f^y_i + u^y_{i,t} \tag{1}$$

$$x_{i,t} = \beta_0 + \sum_{j=1}^{m} \alpha^x_{i,t,j} y_{i,t-j} + \sum_{j=1}^{n} \beta^x_{i,t,j} x_{i,t-j} + \psi^x_t f^x_i + u^x_{i,t} \tag{2}$$

Obviously, such a system cannot be estimated without imposing some restrictions on its parameters. This can be done either in the time series or in the cross-sectional dimension. If the time-series variability is deemed sufficient to obtain reasonably precise estimates, one could specify the model by assuming that the parameters are constant over time and might be variable across countries. On the other hand, if one wants to exploit the cross-sectional variability, one might let the parameters differ over time, while being constant across countries. Which of the two choices is feasible is often dictated by the data available. However, when the time and cross-sectional dimensions are roughly of the same order of magnitude (as it is in the case at hand), one faces a real choice whose solution should be dictated by the nature of the phenomenon one is studying.

An alternative way of thinking about the choice of estimation techniques is to consider whether the cross-sectional or the time-series dimension has to increase in order to derive the asymptotic distributions used in hypothesis testing. In the analysis of country panels, it is conceptually awkward to consider N that goes to infinity. On the other hand, the analysis that lets T go to infinity is the standard practice in time-series analysis.[3] Furthermore, if one is interested in studying the dynamic relationship between two or more variables, either by testing the existence of Granger causality or, more generally, by characterizing the dynamic relationship between the variables under study, it seems natural to consider a model that is flexible, but stable, over time. The analysis of heterogeneity in impluse-response functions across countries might be also interesting in its own right.

A. Large N (fixed T) Models

Many recent studies of data sets similar to the one we use have followed the microeconometric literature and applied estimators that rely on the cross-sectional variability to identify the model of interest. This amounts to imposing constancy of the parameters in equation (1) and (2) across countries, while, at least in principle, allowing them to vary over time. Typically, estimators with fixed effects, such as those proposed by Holtz-Eakin, Newey, and Rosen (1988) (*HNR* hereafter) and Arellano and Bond (1991) (*AB* hereafter), are used. The model is often specialized to the following expression, to impose constancy of the parameters not only across equations, but also over time:[4]

$$y_{i,t} = \alpha_0 + \sum_{j=1}^{q} \alpha^y_j y_{i,t-j} + \sum_{j=1}^{p} \beta^y_j x_{i,t-j} + f^y_i + u^y_{i,t} \tag{1a}$$

$$x_{i,t} = \beta_0 + \sum_{j=1}^{m} \alpha^x_j y_{i,t-j} + \sum_{j=1}^{n} \beta^x_j x_{i,t-j} + f^x_i + u^x_{i,t} \tag{2a}$$

The coefficients α^x_j are relevant for the Granger causality running from y to x, while the coefficients β^y_j are relevant for the Granger causality running in the opposite direction. We assume that the residuals of the two equations of the system are uncorrelated with the variables on the right side and are i.i.d. The two variables, however, are in principle correlated at a point in time; that is, the covariance between $u^x_{i,t}$ and $u^y_{i,t}$ is not necessarily zero. Notice that, because of the presence of fixed effects, none of the observable variables on the right-hand side of the two equations is strongly exogenous.

To eliminate the bias caused by the presence of fixed effects, these equations are typically estimated in first differences. As first-differencing induces MA(1) residuals, one has to use some instrumental-variable technique. HNR and AB stress that, when the cross-sectional dimension identifies the model, all the orthogonality restrictions implied by the dynamics of the system can be exploited to achieve efficiency.[5] In particular, at each point in time t, one

[3] Also, from a practical point of view, it is often not obvious that increasing the number of the included countries provides additional information, when the quality of the data decreases as more countries are considered.

[4] As such a system is typically estimated using N-asymptotics. The latter assumption can be easily relaxed. (See HNR (1988) for instance.)

[5] Notice that, in both equations, we need to instrument both the (one-period) lagged y's and the lagged x's. If one is willing to assume that the residuals of the two equations are contemporaneously uncorrelated, one can instrument the lagged y's in equation (1) and the lagged x's in equation (2).

can use as valid instruments all the variables from time 1 to time $t - s - 1$ (where $s = \max(m, n, p, q)$. [6]

While the application of the HNR or AB estimators is conceptually straightforward, a few important caveats are in order when the time dimension is not small and when the focus is on a dynamic phenomenon such as Granger causality. As T increase, the number of admissible instruments increases very quickly. In our application, for instance, with two variables whose lags are valid instruments, $m = n = p = q = 1$, $t = 35$, and $N = 50$ (as it is approximately the case in some of the results presented below), by the time we get to the end of the sample, there are close to seventy valid instruments for no more than fifty cross-sectional observations. It is obvious that one cannot use all of them. In cases like this, it is advisable to use only a limited number of lagged variables as instruments.

An alternative way to tackle the problem, which has often been employed, is to use n-year averages (with n usually equal to 5 or 10), therefore artificially reducing the time-series dimension of the sample. This filtering is meant to capture long-run relationships and abstract from fluctuations of business-cycle frequencies. We favor the use of methods that explicitly use the time-series variation and possibly explore the existence of heterogeneity across countries. Even if one wants to use the 'large N' estimators, we argue in favor of annual observations rather than n-year averages. Some of the reasons follow.[7]

1. Annual data provide information that is lost when averaging.
2. Even if one is interested in identifying long-run relationships, it is not obvious that averaging over fixed intervals will effectively eliminate business-cycle fluctuations and make easier the emergence of the relationships of interest. The length of the interval over which averages are computed is arbitrary, and there is no guarantee that business cycles are cut in the right way, as their length varies over time and across countries.
3. By averaging, one commits oneself to the use of cross-sectional variability to estimate the parameters of interest and discards the possibility of considering cross-sectional heterogeneity in the parameters. This limitation might be particularly severe when one analyzes several countries that could differ in many dimensions.
4. By averaging, an overall effect over a given time window is measured. In the case at hand, what we know about the economic relationship among the variables involved indicates that contrasting forces are often at work. The dynamic interplay of these forces could well result in significant but opposed effects, maybe acting with different lags, that might eventually cancel out once averaged. Focusing only on the long-run effect, provided averaging does that, precludes the analysis of such short-run effects.[8]

B. *Large* T *(fixed* N*) Models*

An alternative to methods based on 'large N' asymptotics is to assume that the parameters are constant over time and exploit the time-series variability to estimate them. In such a situation, we can introduce flexibility in the cross-sectional dimension and let the coefficients of interest vary across countries.

The coefficients of our model represent the lagged effects of growth, saving, and investment on the same variables. However, the underlying mechanisms linking those variables could differ across countries, possibly due to institutional reasons or differences in preferences.[9] The question, then, is to determine whether the econometric techniques that we have illustrated—all assuming constancy across countries of the underlying parameters—are still appropriate in the case in which those parameters are heterogeneous.

The answer to this question obviously depends on the nature of the variation and on the general properties of the model. As discussed by Pesaran and Smith (1995) (*PS* hereafter), if the coefficients of equation (1) and (2) are constant over time but vary across countries, techniques that impose parameter homogeneity do not yield consistent estimates. Responsible of the bias—which persists regardless of the size of N, T, and of any choice of instruments—is the dynamic nature of the model. On the other hand, a mean group estimator, obtained by averaging the individual countries estimates, is unbiased and consistent.

While wrongly assuming parameter constancy across countries implies biased estimates of the underlying average effects, a parsimoniously parameterized model yields more-precise estimates. Within this familiar tradeoff between consistency and efficiency, the choice between homogeneous ''pooled'' estimators and their heterogeneous counterparts does not reside in a formula, but boils down to a case-by-case problem of model selection.[10]

[6] By using a GLS-type transformation to account for the MA structure of the residuals, one obtains a further gain in efficiency. Arellano and Bover (1995) show that one can express the model in terms of orthogonal deviations to obtain a simple way of computing the HNR or AB estimator.

[7] The same considerations arise also in different frameworks. For example, the Feldstein-Horioka type regressions have been recently estimated on annual series rather than on the more conventional time averages. See, among others, Sinn (1992).

[8] It has also been argued that the consideration of time averages reduces the relevance of measurement error. Of course, this argument is valid only if measurement errors are not perfectly correlated over time.

[9] In such a situation, rather than in the complete characterization of the coefficients in all countries, one might be interested in the average coefficient.

[10] Baltagi and Griffin (1997) compare out-of-sample forecast performances of an array of homogeneous and heterogeneous estimators. They find that pooled estimators fare relatively well, thus showing (for the particular case at hand) that the heterogeneity inevitably characterizing different countries, and the ensuing pooled estimates' bias, should not necessarily lead to the rejection of the homogeneity assumption.

C. *Large* N *or Large* T*?*

As in our data set N and T are roughly of the same order of magnitude, the presence of a tension between flexibility in the time-series and in the cross-sectional dimension is evident. The resolution of this tension, absent in the analysis of individual data surveys in which T is typically small and inferences are conducted using 'large N' asymptotics, obviously affects the model specification and the choice of estimators.

Given these considerations, the best strategy is to estimate rich and flexible dynamic models that allow for differences in short- and long-run coefficients and use estimators that appeal to 'large T' asymptotics to achieve consistency, while efficiently exploiting all the available information. These models can and should also consider the possibilities that the (dynamic) relationships of interest are different across countries.

Obviously, the proposed approach imposes different types of constraints on the researcher. The most important is the necessity to consider coefficients that are constant over time. Obviously, it is necessary to assume that the available sample period is long enough to allow for reasonably precise estimates of time-invariant country coefficients.[11] Partly because of these reasons and partly to make our analysis comparable to a large body of the literature, we present results obtained estimating both classes of models discussed in this section.

III. The Data Set

A. *The Nature of the Data Set and its Construction*

As mentioned in the introduction, we use a new panel of countries (the World Saving Database) recently gathered at the World Bank. As the data-gathering effort is described in detail by Loayza et al. (1998), here we provide a very brief discussion of the structure of the panel, focusing in particular on those aspects that are relevant for our analysis. With the exception of total population figures, originating from the World Bank database, all the data are from National Accounts and follow their standard conventions. The database includes 150 countries and spans the years 1960 to 1995. However, not all variables are available for every country and for every year. In particular, the population data cover the period 1960 to 1994 only. As a consequence, our analysis is restricted to those years.

For each country, the variables that we use are the rate of growth of annual, real, per capita gross national product, the saving rate, and the rate of investment. All these series are measured in local currencies. The saving rates are computed as nominal gross national saving over nominal gross national income, while the investment rates are computed as nominal gross fixed investment over nominal gross national product. Growth is measured as the rate of growth in real per capita GNP (deflated with the GDP deflator).[12]

TABLE 1.—DESCRIPTION OF THE DATA SET

	Number of Countries	Of Which With Data 1961–1994 (1965–1993 for Data Set 2)	Average Number of Years Per Country
Data set 1	123	38	24
Data set 2	50	50	29
Data set 3	38	38	34
CW data set	64	64	29 (5-year average)

We use three different samples of countries. The first is as close as possible to the whole set of countries included in the World Bank database. We exclude only those countries whose annual income, saving, or investment were not recorded at all or are recorded for less than a five-year interval, and those countries for which the relevant series have missing values in the middle of the sample period. This procedure leaves us with a sample consisting of 123 countries. We call this our "whole" sample. The other two samples trade-off the T and N dimension. The second sample consists of the fifty countries for which all variables are available every year in the interval 1965–1993. Our third sample consists only of those countries whose variables are available every year from 1961 to 1994. Only 38 countries are included. We also use, for comparison purposes only, the Carroll and Weil (1994) 64-countries sample. All countries in this sample are also in our whole sample, with the exception of Tanzania and Zimbabwe, which were excluded because of the unavailability of data.[13]

In the next section, we analyze Carroll and Weil's full sample results, in addition to the analysis based on annual data. We also look at nonoverlapping, five-year averages of growth, saving, and investment rates for each country.[14] The information on the number of countries in each of the data sets we use is summarized in table 1.

B. *Contemporaneous Correlations and Rank Correlations between Saving, Investment, and Growth Rates*

We start the analysis of the data set computing some simple correlation and rank correlation coefficients between the three variables that constitute the main focus of this study—namely the saving rate, the investment rate, and the

[11] Another limitation is the fact that one is constrained to consider only some classes of error models. For instance, if the residuals of the model in equation (1) and (2) are of the autoregressive type and there are fixed effects, it is impossible to find instruments that identify the relationships of interest.

[12] To avoid the loss of a large number of observations, we did not perform any PPP adjustment. The same applies to the deflation of GNP by the GDP deflator.

[13] Dropping these countries from this sample does not change the results in any significant way.

[14] Given the period covered by our sample, for each country, the first observation on average growth is in fact a four-year average. If there were no missing values, we would have seven observations for each country. However, many observations are missing for the first sample considered. This implies that, for these countries, the averaged data can sometimes result from the averaging of relatively short series. Obviously, this problem does not arise when using the balanced data sets.

TABLE 2.—CORRELATION COMPUTED ON ANNUAL DATA, DATA SETS 1, 2, AND 3

Correl.		Data Set 1 Corr. Coeff.	Data Set 2 Corr. Coeff.	Data Set 3 Corr. Coeff.	Data Set 1 Rank Corr. Coeff	Data Set 2 Rank Corr. Coeff	Data Set 3 Rank Corr. Coeff
S, G	Annual	0.253	0.370	0.332	0.323	0.372	0.323
		(0.018)	(0.024)	(0.026)	(0.018)	(0.026)	(0.028)
	Country average	0.376	0.666	0.492	0.522	0.623	0.525
		(0.084)	(0.108)	(0.145)	(0.091)	(0.143)	(0.164)
I, G	Annual	0.165	0.227	0.242	0.211	0.240	0.243
		(0.018)	(0.026)	(0.027)	(0.018)	(0.026)	(0.028)
	Country average	0.319	0.601	0.652	0.409	0.585	0.650
		(0.086)	(0.126)	(0.126)	(0.091)	(0.143)	(0.164)
S, I	Annual	0.483	0.592	0.658	0.614	0.613	0.665
		(0.016)	(0.021)	(0.021)	(0.018)	(0.026)	(0.028)
	Country average	0.436	0.715	0.754	0.607	0.746	0.777
		(0.082)	(0.101)	(0.109)	(0.091)	(0.143)	(0.164)
# annual obs.		2986	1450	1292	2986	1450	1292
# countries		123	50	38	123	50	38

Notes: Spearman rank correlation coefficient; s.e. in parentheses.

growth rate. Unlike in the rest of the analysis, our interest here is merely for their static relationships.

As in any panel, our data has set two dimensions: the temporal and the cross-sectional. Therefore, even when computing simple correlations, there are several options. For each of the three pairs of variables, we first consider the whole data set; that is, we use each country-year observation. We then average for each country all the available information and therefore focus on the cross-sectional variability.[15] Finally, we compute, for each year, the correlation coefficient (in the cross section) between the two variables of interest and consider the variation of this parameter over time.

We start by comparing the coefficient of variation of the three variables of interest. In data set 1, growth rates are by far the most volatile: The coefficient of variation for this variable is 3.30, to be compared with 0.49 and 0.35 for saving and investment rates, respectively. This ranking in variability is unchanged when we consider country (time-series) averages of the variables. In this case, the three coefficients of variations are 1.73, 0.46, and 0.29. Notice that, in this case, the variability in growth rates, as measured by the coefficient of variation, is almost halved, while the reduction in the other two variables is modest. In data sets 2 and 3, whose countries are more similar, the coefficients of variation, while slightly smaller, follow the same pattern.

In table 2, we report correlation coefficients and Spearman rank correlation coefficients computed for the three pairs of variables and in the three data sets. We report both the correlations obtained with all annual observations and with country averages.

In the table, the correlation coefficients are always positive. Typically, the coefficients computed on annual data increase by 30% to 50% going from data set 1 to data set 3 (that is, going from a large group of nonhomogeneous countries to a more restricted number of more similar countries observed for longer time spans). Saving-growth correlations are somewhat higher than investment-growth correlations, but the strongest link turns out to be that between saving and investment. We get similar results for rank correlations, which should reduce the effect of outliers.

When using time-averaged observations, correlation coefficients increase in most cases. The only exception is the slight decline in the simple correlation between saving and investment rates in data set 1. Even in that case, however, the corresponding rank correlation increases, if only slightly. The largest increase is registered for the investment and growth rates pair, for which the correlations more than double.

In figure 1, we plot the contemporaneous correlation coefficients computed using all saving-growth pairs of a given year against time. In the same graph, we plot the time series obtained using only the countries in the balanced panel with fifty countries. The correlation coefficients are positive for all but four years. In the first half of the period, correlation coefficients usually fluctuate in the range of 0.2 to 0.4 for both samples. Starting in 1977, however, and until the end of the sample period, the fluctuations of the correlation coefficients for data set 1 became more marked.[16] Two effects are likely to be at play. On the one hand, several additional countries ‘‘enter’’ the data set around this period; moreover, the correlation for the preexisting countries might also be varying. In fact, if the same correlations are computed using only the countries for which data are available over the sample 1965–1993 (often middle- and high-income countries), a different picture emerges: Correlation coefficients are somewhat increasing over time, and, in the 1980s, fluctuate around 0.5. Over that period, data set 1 correlations drop with respect to the corresponding values of data set 2. Short-run linkages turn out therefore quite weak particularly for those countries that enter the sample.

In figure 2, we plot the annual correlations between growth and investment rates (across countries) against time. Again, it must be stressed that the number of countries that

[15] As data set 1 is a not balanced panel, the country averages and the annual (cross section) correlations are computed using a (possibly) different number of observations.

[16] The coefficients of variation computed for the two subsamples 1961–1976 and 1977–1994 are, respectively, 0.509 and 0.745.

FIGURE 1.—SAVING AND GROWTH CORRELATION OVER TIME

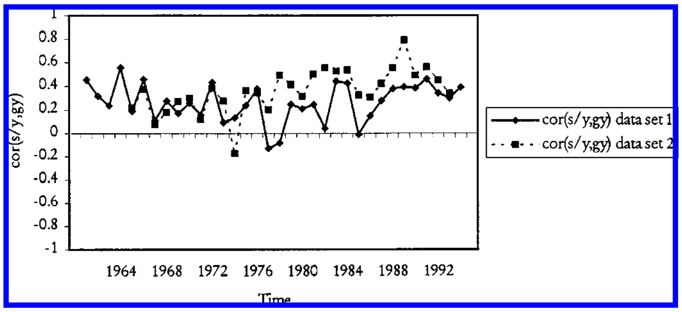
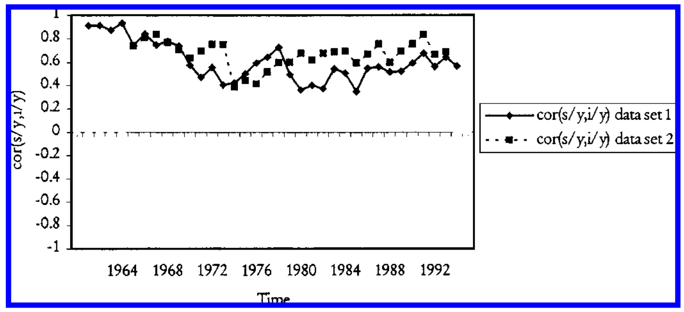


FIGURE 3.—SAVING AND INVESTMENT CORRELATION OVER TIME

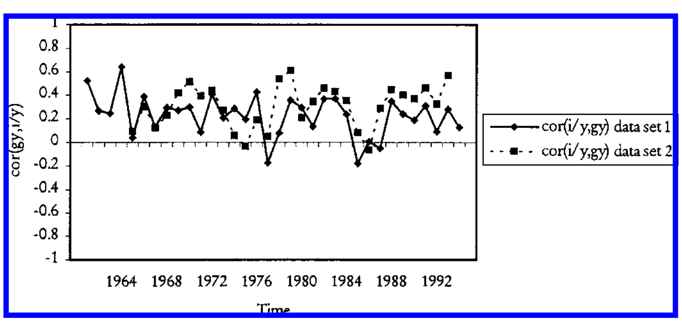


enter in the computation of the correlations changes from year to year. While short-run fluctuations are apparent, the investment-growth link does not exhibit any trend or structural break. A finding similar to figure 1 emerges: While the two series have similar cyclical patterns in the period considered, from 1977 onwards, data set 2 exhibits annual correlations higher than data set 1, thereby confirming the potential importance of country heterogeneity factors.

In figure 3, we show the contemporaneous correlation coefficients computed using all saving-investment pairs for data sets 1 and 2. The correlation coefficients are always positive, but a break in the late 1970s is apparent. During the 1960s and the early 1970s, both correlation series show a decreasing trend. All of this ended in 1974, and from that year the correlation between saving and investment rates fluctuates around a constant or possibly slightly rising trend. In fact, starting in 1979 and until the end of the sample period, the data set 2 series is always higher than the data set 1 series, an outcome we have already pointed out for the saving-growth and investment-growth links.

The simple facts we present in table 2 and in figures 1 to 3 are roughly in accordance with the existing evidence. This indicates that the data set we are using is, at least at a basic level, not too dissimilar from the object of study of previous studies. While these simple correlations do not allow for any structural interpretation, they are clearly suggestive. In the introduction, we have mentioned, for instance, that the theoretical prediction of the lifecycle model about the (long-run) correlation between saving and growth are ambiguous. The fact that the contemporaneous correlation coefficients are always positive seems to indicate a predominance of those factors within the model that make them such. In terms of the correlation between saving and investment, the evidence we present is consistent with that of Feldstein and Horioka (1980). It is somewhat surprising, however, that, as capital markets have developed in recent years, the correlation between saving and investment rates does not seem to decrease and shows, if anything, a tendency to increase.

FIGURE 2.—INVESTMENT AND GROWTH CORRELATION OVER TIME



We now consider the dynamic correlation among the variables of interest, and the instrument we use is the concept of Granger causation.

IV. Carroll and Weil's Result: How Robust Is It?

In a recent paper, Carroll and Weil (1994) (*CW* hereafter) used the Summers-Heston data set to analyze the dynamic correlation between saving and growth rates by testing for the presence of Granger causality tests between them. In this section, we analyze the robustness of their result. Besides its intrinsic interest, we also use this discussion as a methodological example to justify the choice of econometric techniques in section V.

CW perform the analysis on five-year averages to avoid picking up business-cycle fluctuations and focus, instead, on low-frequency movements. After performing the test in levels, they discuss the possible presence of fixed effects and use instrumental-variable techniques to estimate the equations in first differences. However, they instrument only the lagged dependent variables of the equations they consider. As discussed above, this procedure is valid only if the residuals of the two equations under study are assumed to be contemporaneously uncorrelated.[17] They report results obtained with and without the inclusion of a set of time dummies in their equations.

CW report that, in the larger of the two data sets they use, growth (positively) Granger-causes saving, while saving does not Granger-cause growth. In the OECD data set, growth does not Granger-cause saving, while, when time dummies are not included, saving Granger-causes growth with a negative sign. In this subsection, we study the extent to which CW's results depend on the data they use, on the

[17] CW's analysis is limited to two subsets of the countries contained in the Summers-Heston data set: the OECD countries and those countries that achieve a grade of at least C in terms of data quality.

TABLE 3.—THE ROBUSTNESS OF THE GROWTH-SAVINGS GRANGER CAUSALITY TESTS

	Five-Year Averages				Annual Data			
	(1)	(2)	(3)[a]	(4)[a]	(5)	(6)	(7)[b]	(8)[b]
$\Delta g_{i,t-1}$ in saving eq.	0.775	0.658	0.416	0.154	−0.196	0.004	0.122	0.058
	(0.292)	(0.253)	(0.231)	(0.226)	(0.021)	(0.021)	(0.037)	(0.031)
$\Delta s_{i,t-1}$ in growth eq.	−0.365	−0.220	−0.477	−0.225	−0.472	−0.253	−0.446	0.009
	(0.070)	(0.037)	(0.240)	(0.203)	(0.055)	(0.035)	(0.297)	(0.159)
# of observations in growth/sav. eq	223/243	331/383	158/158	220/221	1833/1818	1792/1795	1792/1795	2879/2897
# of countries	64	123	64	123	64	123	64	123

Notes: Standard errors in parentheses.
Columns 1, 3, 5, 7: CW data set; Columns 2, 4, 6, 8 data set 1.
Columns 1, 2, 5, 6: CW instrumenting; Columns 3, 4, 7, 8: both lags instrumented in both equations.
a) Lags two and three used as instruments.
b) Lag two used as instrument.

econometric technique they employ, and on the frequency they choose to analyze.

In table 3, we report the coefficients of lagged growth in the saving rate equation and lagged saving in the rate-of-growth equation when equation (1) and (2) are estimated with $m = n = p = q = 1$ but using different methodologies and different data sets.[18] The *t*-values on these coefficients can be interpreted as Granger causality tests. None of the columns include time dummies, whose effect is discussed in the text below.

We start in column 1 reporting the results obtained using the same procedure as CW, but on the new data set: We consider first differences of equation (1) and (2), the same countries as CW,[19] five-year averages, and we instrument only the lagged dependent variable of each equation. The results are slightly different from those in CW (1994): growth does Granger-cause saving with a positive sign, but the coefficient on lagged saving in our growth equation is negative and, unlike in CW's results, strongly significant. The introduction of time dummies does not change much these coefficients.

In column 2, we include all 123 countries of the new World Bank data set that satisfied the criteria described in section II. The results are qualitatively identical to those in column 1. Once again, they are robust to the inclusion of time dummies. In columns 3 and 4, for the two samples used in column 1 and 2, respectively, we relax the hypothesis that the residuals of the two equations are uncorrelated and proceed to instrument both lagged variables in both equations. Unlike CW, who estimate a just-identified model, we use the second and third lag of growth and saving rates to instrument the first lag of these variables.[20] While the signs of the coefficients do not change relative to columns 1 and 2, the hypothesis of no Granger causality in either direction is not rejected in either of the data sets at usual confidence levels. This different result is explained by a large reduction in the point estimated of the coefficients on lagged growth in the saving equation (that go from 0.775 and 0.658 to 0.42 and 0.15) and a considerable increase in the standard errors of the coefficients on lagged saving in the growth equation. These results, as for the other columns, are unaffected by the introduction of time dummies.

The experiments in columns 3 and 4 indicate that the assumption about the lack of contemporaneous correlation in the residuals of equation (1) and (2) is potentially quite important and might substantially affect our inferences. It remains to be seen if this is due to a substantive change in the size of the estimated coefficients or to a reduction in the precision of our estimates.

In columns 5 through 8, we reestimate the specifications in the first four columns, but on annual data rather than five-year averages. Once again, the results are obtained without time dummies, but are robust to their inclusion.

The results on annual data are quite different from those obtained using five-year averages. First of all, using the CW instrumenting procedure results in saving Granger-causing growth with a strong negative sign, both in the subset of countries used by CW and in the entire sample (columns 5 and 6). On the other hand, growth does not seem to Granger-cause saving in the larger sample, while it takes a significant negative sign in the data set containing the CW countries. When one uses the more robust instrumenting procedure in columns 7 and 8, one finds significant causation in both directions when the reduced sample is used—and marginally significant causation in the growth to saving direction when the larger sample is used. Increasing the number of instruments does not significantly change the results.

We are now in a position to evaluate the evidence presented by Carroll and Weil (1994) and, in particular, its robustness. First, when we use the same procedure followed by CW, we obtain roughly similar results, even though the negative causation running from saving to growth is larger and significant in our data sets.

The second feature that emerges, perhaps not surprisingly, from the table is that the results are not neutral to the instrumenting scheme used. When we allow for the possibility that the residuals of the two equations are correlated, the results change considerably. This indicates that the assump-

[18] The complete set of results is available upon request.

[19] Zimbabwe is excluded because several observations are missing in the World Bank data set.

[20] When we estimated a just-identified model, as, for instance, in column 7 and 8, we obtain very noisy estimates due to the low explanatory power of the first-stage regressions.

tion of uncorrelated residuals in the two equations might be too strong.

Finally, and in a sense most importantly, by far the most dramatic changes are obtained when we move from five-year averages to annual data. Not only are the coefficients estimated with much more precision (even using a relatively inefficient estimator), producing more-significant results, but the point estimates (and therefore the pattern of causation) occasionally change sign relative to the results obtained on five-year averages.

The considerations above suggest that the results presented in table 3 can be extended in various directions. First of all, given the importance that proper instrumenting has on the results and the fact that the estimates in columns 3 and 4 are relatively imprecise, it is worth investigating the use of more-efficient estimators, such as those proposed by HNR, especially in analyzing five-year averages. On the other hand, as mentioned in the previous paragraph and discussed in section III, the use of annual data can be more informative than that of five-year averages in uncovering both long- and short-run relationships between the variable of interest. The analysis of annual data, however, calls for the use of more-flexible and richer dynamic specification models that allow for more-flexible effects and, especially, longer lags. It is to this that we now turn.

V. Analysis of Annual Data

In this section, we estimate a flexible dynamic model of the variables of interest that allows us to identify both long- and short-run effects. As stressed in the introduction and in section II, we believe that the most profitable way of identifying the dynamic relationships between two or more variables in a panel of countries is the analysis of annual data and not time-averaged data. In section IV, we showed that the results using five-year averages can be dramatically different from those obtained with annual data. In this section, therefore, we focus on the analysis of the relationship between saving, growth, and investment rates using annual data.

As discussed in section II, the technique to be used depends on the type of phenomena one wants to study, the data available, and the restrictions on parameters and residuals of the model one feels comfortable with and on the size of the T and N dimension relative to the variability present in the data. Because of this, we report several sets of results, obtained using different techniques and assumptions.

We start by assuming that the coefficients of interest are constant across countries and that the time dimension of our sample is large enough for OLS to provide meaningful estimates even in the presence of fixed effects.[21] We then relax the latter assumption and use GMM-IV estimators of first-differenced models. In the third set of results, we relax instead the assumption that the coefficients are homogeneous across countries. In such a situation, we have to assume that T is ‘‘large enough.’’

We next estimate a trivariate version of our model, simultaneously considering the three variables of interest. Finally, we check whether the results we report are robust to the introduction of a number of controls that are typically used in the literature.

To present the complete set of results in detail would test the endurance of the most interested reader. We therefore present a summary of the main results and relegate the detailed tables to the appendix. In particular, we present in this section mostly the long-run effects and (implicitly) the persistence of each of the variables of interest. We summarize the short-run dynamics of the system we have estimated by plotting impulse-response functions. For the sake of brevity, however, we report only the impulse-response functions for our favorite models.

A. *A Dynamic Model with No Country Heterogeneity*

In this subsection, we present a dynamic model for each of the three pairs of variables considered above, estimated with annual data and allowing for four lags of each of the two variables considered. As discussed above, we estimate the model by OLS with country-specific intercepts. In doing this, we are implicitly assuming that T is large enough.

We estimate the model in equation (1) and (2) for each of the three pairs of variables considered in section V and on three data sets: the unbalanced panel of 123 countries and the two balanced panels (of 50 and 38 countries, respectively) discussed in section II.

Rather than exploring for each equation the most-appropriate dynamic specification, we opt for a common number of lags for all the models we estimate. After some experimentation, we settled for a specification with four lags for each of the variables considered.[22] The dynamic behavior of the model we consider can therefore be quite complex. We can separately identify short- and long-run effects, and we can consider short- and long-run Granger causation.

While the complete set of estimates can be found in the appendix, in table 4 we report a summary of our results. In particular, for each pair of variables y and x, we report the sum of the coefficients on the lagged x's in the regression for y, along with the p-value corresponding to the test that such a sum is zero. Moreover, we report the long-run effect of x on y and the p-value of the hypothesis that all the coefficients on the lagged x's are zero. This last test corresponds, strictly speaking, to a test of Granger causality running from x to y. The difference between the sum of the lagged coefficients

[21] It should be stressed once more that the OLS estimator in section V(A) (a within estimator) also exploits the cross-sectional dimension, as it assumes that the coefficients are identical for all countries except for the constant. However, as the constants are estimated, asymptotics are done by keeping N fixed and letting T go to infinity. As is well known, the OLS fixed-effects estimator is biased when applied to a dynamic panel model, but the size of the bias tends to zero as T grows (Nickell (1981)).

[22] As suggested by a referee, in order to consider a longer time span for the detection of dynamic effects, we also experimented with eight lags. The main results of the analysis, which are available on request, were unchanged. Obviously, the point estimates became much less precise.

TABLE 4.—ANNUAL DATA—OLS ESTIMATES

	Saving and Growth					
	Data Set 1 (123 Countries)		Data Set 2 (50 Countries)		Data Set 3 (38 Countries)	
Dependent Variable	Saving (1)	Growth (2)	Saving (3)	Growth (4)	Saving (5)	Growth (6)
Sum[a]	0.1335	0.0081	0.1057	0.0434	0.0950	−0.0203
(p-value)	(0.000)	(0.719)	(0.011)	(0.239)	(0.027)	(0.548)
Long-run[b]	0.4965	0.0074	0.5337	0.0463	0.4174	−0.0258
(p-value)[c]	(0.000)	(0.000)	(0.000)	(0.623)	(0.000)	(0.028)
Number of obs.	2766	2757	1250	1250	1140	1140
	Saving and Investment					
Dependent Variable	Saving (1)	Investment (2)	Saving (3)	Investment (4)	Saving (5)	Investment (6)
Sum[a]	0.0326	0.1174	0.0120	0.1105	0.0607	0.1179
(p-value)	(0.167)	(0.000)	(0.719)	(0.000)	(0.113)	(0.000)
Long-run[b]	0.1194	0.3837	0.0614	0.4040	0.2259	0.5494
(p-value)[c]	(0.000)	(0.000)	(0.013)	(0.000)	(0.000)	(0.000)
Number of obs.	2649	2638	1250	1250	1140	1140
	Growth and Investment					
Dependent Variable	Growth (1)	Investment (2)	Growth (3)	Investment (4)	Growth (5)	Investment (6)
Sum[a]	−0.0959	0.1678	−0.0916	0.1606	−0.0783	0.2062
(p-value)	(0.001)	(0.000)	(0.025)	(0.000)	(0.0112)	(0.000)
Long-run[b]	−0.0918	0.6381	−0.1003	0.7521	−0.0947	1.2871
(p-value)[c]	(0.000)	(0.000)	(0.004)	(0.000)	(0.000)	(0.000)
Number of obs.	2517	2516	1250	1250	1140	1140

Notes: Standard errors in parentheses. The estimated equations also included country-specific intercepts not reported here. The equation estimated in each column is of the form

$$y_{i,t} = \alpha_{0,i} + \sum_{j=1}^{4} \alpha_j y_{i,t-j} + \sum_{j=1}^{4} \beta_j x_{i,t-j},$$

where y is the variable in the heading of each column in each panel and x is the other variable in each panel. For instance, in the saving-growth panel, saving is the y variable and growth the x one in columns 1, 3, and 5, while growth is the y variable and saving the x one in columns 2, 4, and 6.

Notes:

a) Sum of the β coefficients and p-value of a chi-square test of the hypotheses that such a sum is zero.

b) The long-run coefficient is obtained as

$$\sum_j \beta_j \Big/ \left(1 - \sum_j x_j\right).$$

c) The p-value refers to the hypotheses that the β coefficients are jointly zero.

and the long-run effects indicates the importance of the persistence in y.

In each of the three panels of table 4, we consider a pair of variables. In the first panel, we report the results for the regressions for saving and growth rates; in the second, those for the saving and investment regressions; and, in the third, for growth on investment. So, for instance, the columns labeled ‘‘saving’’ in the Saving and Growth panel contains the sum of the coefficient on lagged growth rates (and the corresponding long-run effect) in a regression for saving rates that includes lagged saving and growth rates as well as fixed effects.

The first important feature of the table is that the results seem to be quite robust across data sets (at least in their qualitative nature). Starting with the saving/growth pair, it seems that growth Granger-causes saving, with a positive sign, while there is no significant effect running from saving to growth. The long-run effect of growth on saving is in general considerably larger than the sum of the lagged coefficients, reflecting a certain amount of persistence of saving rates: The sum of the coefficients on the lagged dependent variable is between 0.7 and 0.8 in the saving rate equations. Growth rates, on the other hand, do not show much persistence. The sum of lagged coefficient is very close to zero in the three samples. This is consistent with the evidence presented by Easterly et al. (1993).

The negative relation running from saving to growth found in table 3 disappears and is probably due to the arbitrary truncation of the dynamics to the first lag. While the sum of the coefficients (and the long-run effect) is not significantly different (either economically or statistically) from zero, individual lagged coefficients are significant, as it can be verified in the appendix. Finally, growth rates do not exhibit much persistence, even though some of the individual coefficients are significantly different from zero.

Turning now to the relationship between investment and saving rates, we find a strong relationship running from lagged saving to investment, while we do not find any long-run relationship running from investment to saving. The long-run effect of lagged saving rates on investment rates turns out to be quite large (0.38 in the unbalanced panel and 0.40 and 0.55 in the two balanced panels) as a consequence of the persistence in the investment rate equations. The sum of coefficients on the lagged dependent variable is close to 0.7 in the first two data sets and 0.8 in the third one.[23]

Even though the sum of the coefficients on lagged investment is not significant in the saving equation, some of the individual coefficients are strongly significant. However, different lags are typically equal in size and opposite in sign, so that the long-run effect is close to zero. As in the equations summarized in table 4, saving rates show a considerable amount of persistence.

The results in the third panel show a strong and positive effect of lagged growth on investment. Once again, the long-run effect of growth on investment is much larger than the sum of the coefficients, due to the multiplier effects induced by the strong persistence in the investment equation. The most surprising result in the third panel of the table, however, is the negative relationship between lagged investment rates and growth rates. This result is in line with other empirical evidence, based on different data sets and methods of estimation, such as Blomstrom et al. (1996) and Podrecca and Carmeci (1998).

The long-run effect is very similar to the sum of the coefficients on lagged investment rates, due to the very small autocorrelation in growth rates. While there is almost no dynamics in the growth in terms of the lagged dependent-variable equation (as in the results for the growth/saving equation), the coefficient on lagged investment rates vary considerably. The coefficient on the first lag is significantly positive in all data sets, but the overall long-run effect turns out to be negative because of the effect of the additional lags.

In figure 4, we summarize the short-run behavior of the systems of equations that we have estimated by using some impulse-response function. These plot the reaction of each of the variables in a bivariate system to a permanent shock to one of the two variables. In each of the three columns, we plot the impulse-response function to a shock to each of the three variables. As each variable appears in two systems, there are two responses to the ‘‘own’’ shocks. For instance, the change of growth rates to shock to growth can be computed looking at the growth-investment or the growth-saving systems. Each column of the figure has four panels for this reason.

Two elements of the figure are of particular interest. First, the graphs summarize synthetically the short-run dynamics implied by our estimates. In some cases, such as the reaction of growth to its own shocks or the reaction of I to shocks on G, this can be quite involved. Second, the long-run effects that emerge from the graphs are different from the long-run multipliers computed in table 4 as the latter take into account one equation at a time, while the impulse-response functions compute the effects on each pair of equations simultaneously. In some cases, the simultaneous effects can be substantially larger than the single equation ones. For instance, the effect of a permanent shock to saving rates on growth rates is very small if one takes the estimates of the growth equation (which includes lagged growth and saving rates). However, this effect is greatly amplified by considering the growth and saving equation simultaneously.

B. *Fixed* T *Estimator with Annual Data*

As discussed above, it is possible that the properties of the estimators we use in section V(A), given the size of T in the available sample, do not approximate well enough those of the asymptotic distribution. In such a situation, one can consider estimators based on fixed T (and large N) asymptotics.

With fixed T, the within group estimator used above is no longer appropriate. A first obvious choice is to consider the model in first differences to eliminate fixed effects and use instrumental variables to take into account the correlation of the lagged dependent variables with the MA(1) residuals induced by the differencing.

In table 5, we report a summary of the results obtained using a GMM estimator to estimate a model analogous to that studied in section V(A). (A complete set of results is available in the appendix.) As above, we consider four lags for each of the two variables. As far as the orthogonality conditions are concerned, given the length of the time period covered, we cannot use all of them. We use four lags (additional to those necessary to just-identify the model) for each of the two variables in the system.

The most noteworthy feature of table 5 is that, with few exceptions, the results are similar to those described in section V(A). The similarity is greater for the balanced panels and in particular for data set 3, which comprises a group of relatively homogeneous countries over a long interval. This comes as no surprise, given that T is probably large enough to pull the OLS bias close to zero. The main difference, however, is that the estimates obtained with this GMM estimator are not as precise as those discussed in section V(A). If we consider the relationship between saving and growth, for instance, while we obtain point estimates that are not miles apart (especially in the two balanced panels), in table 5 we always fail to reject the hypothesis of no Granger causation.

This does not mean, however, that no effect is picked up by this procedure. For instance, we find again the result that saving Granger-causes investment. Furthermore, both the short- and the long-run effects are quite similar to those in table 4. Analogously, we find that growth strongly and positively Granger-causes investment, while we do not find any evidence of causation going from investment to growth.

C. *Growth and Investment Dynamic Model with Country Heterogeneity*

One of the main advantages of using data that have a reasonably large time dimension is that one can investigate

[23] Moreover, the first two lagged investment rates take very large coefficients: close to 1 in the first and close to −0.3 in the second.

FIGURE 4.—IMPULSE-RESPONSE IN THE BIVARIATE SYSTEMS

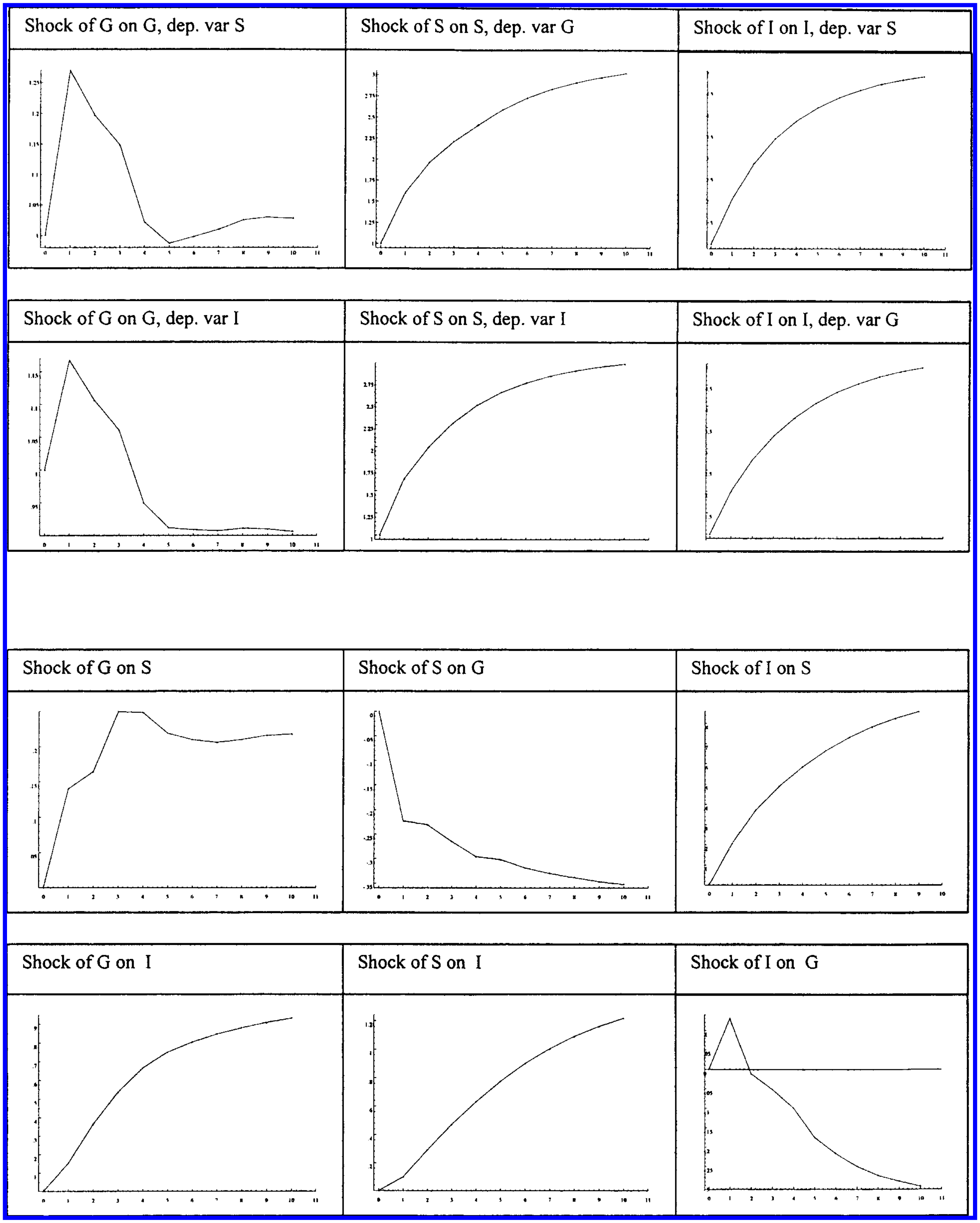


TABLE 5.—IV-GMM ESTIMATES ANNUAL DATA

	Data Set 1 (123 Countries)		Data Set 2 (50 Countries)		Data Set 3 (38 Countries)	
	Saving and Growth					
Dependent variable	Saving (1)	Growth (2)	Saving (3)	Growth (4)	Saving (5)	Growth (6)
Sum[a]	0.0699	−0.0283	0.213	0.1086	0.0891	−0.050
(*p*-value)	(0.7861)	(0.5269)	(0.8105)	(0.4275)	(0.5604)	(0.6593)
Long-run[b]	0.4353	−0.0313	0.8120	0.1143	0.4163	−0.0647
(*p*-value)[c]	(0.9804)	(0.8301)	(0.3481)	(0.7014)	(0.5135)	(0.6720)
	Saving and Investment					
Dependent variable	Saving (1)	Investment (2)	Saving (3)	Investment (4)	Saving (5)	Investment (6)
Sum[a]	0.1100	0.3449	−0.1550	0.2445	−0.0126	0.1997
(*p*-value)	(0.6145)	(0.4254)	(0.2538)	(0.024)	(0.9141)	(0.0036)
Long-run[b]	0.1371	0.3449	−0.4427	0.5959	−0.0396	0.6793
(*p*-value)[c]	(0.0969)	(0.8789)	(0.5089)	(0.080)	(0.5778)	(0.0573)
	Growth and Investment					
Dependent variable	Growth (1)	Investment (2)	Growth (3)	Investment (4)	Growth (5)	Investment (6)
Sum[a]	−0.0337	0.0585	−0.2171	0.3309	−0.1169	0.2878
(*p*-value)	(0.2661)	(0.8234)	(0.1171)	(0.0071)	(0.1135)	(0.006)
Long-run[b]	−0.0346	0.5006	−0.2687	1.0648	−0.1152	1.7442
(*p*-value)[c]	(0.7175)	(0.9845)	(0.4649)	(0.0526)	(0.4399)	(0.0075)

Notes: See table 4. The estimates reported here are equivalent to those in table 4. Estimates are obtained by GMM using the HNR (1988) and AB (1991) estimators. Four additional lags are used as instruments in all columns.

the possibility that the coefficients of the dynamic model differ in the cross-sectional dimension. We now estimate the same dynamic relationships of the previous two sections, relaxing the assumption that their coefficients are equal across countries.[24]

To summarize the information from the estimated country-specific parameters, we focus on ''mean group'' estimates of the coefficients of interest, as proposed by Pesaran and Smith (1995), but also report the three quartiles of the distribution of each coefficient. We also compute, as before, the short- and long-run multipliers for the (possibly) causing variable.[25]

This framework is suitable for the analysis of heterogeneity among countries. A detailed analysis of the nature of cross-sectional heterogeneity would be particularly relevant whenever relaxing the homogeneity assumption leads to qualitatively different results.[26]

[24] A series of F-tests of the null hypothesis that the coefficients are indeed homogeneous across countries led to the rejection of the hypothesis in all cases for significance levels below 1%.

[25] Their significance is assessed using a simple test based on the observed relative frequency of the estimated multipliers taking positive values, which is approximately normally distributed. For individual coefficient estimates, for which standard errors are available, we notice that this simple ''count test'' yields results similar to those obtained using standard parametric techniques. Note that, because of the presence of outliers, sometimes the mean group estimator is signed differently than the median individual estimate. Rejecting the null hypothesis, in this case, would be evidence in favor of an effect signed as the median estimate.

[26] This is not our case. However, an informal analysis to identify those countries having the sign of the estimated relationships different from the sign of the mean effect, did not show the presence of any clearly identifiable pattern. Details are available from the authors.

Because the procedure we use in this subsection requires a large T for each country, we limit ourselves to the use of the balanced panel of 38 countries.[27] We report the estimates of the sum of lagged coefficients and of the long-run effects in table 6.[28]

Qualitatively, the results do not differ sensibly from what was found imposing the homogeneity assumption. Compared to the OLS estimates, we note that, on average, the short-run multipliers are approximately halved.

Long-run multipliers are often influenced by the presence of outliers, and sometimes their mean estimate diverges considerably from the median individual estimate. In the saving-on-growth equation, in which the quantiles' information shows the presence of considerable heterogeneity, the long-run multiplier looses significance once we go from OLS to mean estimates. In the investment-on-growth equation, the long-run multiplier changes sign and becomes insignificantly different from zero. In all other cases, the results obtained with the mean estimator are qualitatively identical to those obtained with the OLS estimator.

We conclude that, even if in our data set there is evidence of parameter heterogeneity across country, appropriately taking it into account does not modify the general picture obtained using estimators that erroneously impose homogeneity.

[27] We have also carried out the analysis with the fifty-country balanced data set. The results (available upon request) are not significantly different from the ones that we report.

[28] A complete set of results is in the appendix, where the standard errors of individual coefficients are computed using a simple extension to the present context of the White's robust variance-covariance estimator.

TABLE 6.—A DYNAMIC MODEL OF SAVING AND GROWTH WITH HETEROGENEOUS COEFFICIENTS: ANNUAL DATA

	Dependent variable: Saving rates Independent variable: Growth rates		Dependent variable: Growth rates Independent variable: Saving rates	
	Avg. Coeff	1st, 2nd, and 3rd Quantile	Avg. Coeff	1st, 2nd, and 3rd Quantile
Sum[a]	0.0463	−0.00964, 0.0390, 0.0993	−0.0022	−0.0455, 0.0012, 0.0618
(*p*-value)[b]	(0.003)		(1.000)	
Long-run[c]	−1.428	−0.4550, 0.6613, 1.8027	−0.3274	−0.1859, 0.0519, 0.9897
(*p*-value)[d]	(0.004)*		(0.194)*	
	Dependent variable: Saving rates Independent variable: Investment rates		Dependent variable: Investment rates Independent variable: Saving rates	
Sum[a]	−0.0077	−0.0642, −0.0189, 0.0444	0.0656	0.0234, 0.0620, 0.1237
(*p*-value)	(1.000)		(0.000)	
Long-run[b]	−8.1049	−0.1700, 0.4949, 1.7086	0.5789	0.2893, 0.6417, 0.9289
(*p*-value)[c]	(0.009)*		(0.000)	
	Dependent variable: Growth rates Independent variable: Investment rates		Dependent variable: Investment rates Independent variable: Growth rates	
Sum[a]	−0.0440	−0.1062, −0.0644, 0.0106	0.0857	0.0279, 0.0815, 0.1271
(*p*-value)[b]	(0.023)		(0.023)	
Long-run[c]	0.1411	−0.3588, 0.0115, 0.3230	3.6307	0.5731, 1.3355, 2.8268
(*p*-value)[d]	(1.000)		(0.000)	
# of observations: 1292				
# of countries: 38				

Notes: The model is equivalent to that estimated in table 4 but with country-specific coefficients. *p*-values from ‘‘count tests’’ are in parentheses.
a) Average of the sum of the lagged coefficients on the ‘‘causing’’ variable.
b) *p*-value of a ‘‘count test’’ of the hypotheses that the fraction of countries for which the sum of the lagged coefficients on the ‘‘causing’’ variable is greater than zero is equal to ½.
c) The long-run coefficient is the average of the country-specific long-run effects.
d) The *p*-value of a ‘‘count test’’ of the hypothesis that the fraction of countries for which the long-run coefficient is greater than zero is equal to ½.
*An asterisk next to the *p*-values of the short- and long-run coefficients indicates that, because of the presence of extreme values, the estimated coefficients’ most frequent sign is different from the sign of their mean.

D. *Three-Equation System*

So far, we have been considering pair-wise tests of Granger causation. However, in studying our three variables, there is no reason not to consider them jointly. In order to do so, we return to the methodology used in section V(A)—OLS regression with country-specific intercepts. Once again, we consider four lags of the variables under study. That is, we regress each of our three variables on four of its lags, four lags of the other two variables and country dummies. The results of this procedure are summarized in table 7. The table has nine columns: one for each of the three variables in each of the three data sets. Rather than showing all estimates, we report the sum of the coefficients on the four lags considered and, in the case of the variables other than the dependent variable, the long-run effects. In addition, we report the *p*-value of the test that each of the four lags (on a given variable) has a zero coefficient and of the hypothesis that the sum of the coefficient is zero.

The results, once more, are reasonably homogeneous across samples. This is particularly true for the investment equation. Investment seems to be affected significantly and positively by both lagged growth and saving rates. Saving rates, on the other hand, do not seem to be affected by either lagged growth rates or lagged investment rates. The only exception is the positive effect of lagged growth rates in the unbalanced panel. Finally, in the growth equation, we find in all samples a negative effect of lagged investment (already noticed in Section V(A)). Saving rates, on the other hand, significantly affect growth rates only in the balanced sample with fifty countries.

If we consider the persistence of the three equations as measured by the sum of the coefficients on the lags of the dependent variable, we find that, as before, growth shows very little of it, while investment and saving rates are very persistent.[29]

As with the bivariate systems, we summarize the short-run dynamics by plotting, in figure 5, the impulse-response functions of each of the variables under study to each of the three shocks. Once again, as we consider the three variables simultaneously, the cumulate impulse response does not coincide with the long-run multipliers of table 7 computed using a single equation’s coefficient, because they take into account the dynamics of all the variables simultaneously. In general, this magnifies the size of the effects. In the case of the effect of a shock to the saving rate regression on growth, the effect is first negative and then mildly positive, which stands in contrast with the pattern shown in figure 4.

E. *An Overall Evaluation and Some Extensions*

We have already noticed that our results are, within the framework we have used, quite stable and robust. In particular, as mentioned above, we have experimented with changing samples and increasing the number of lags in-

[29] The only odd finding in this respect is the sum of the coefficients on lag investment in the unbalanced panel that equals −1.22.

TABLE 7.—A DYNAMIC TRIVARIATE MODEL OF SAVING, INVESTMENT, AND GROWTH: ANNUAL DATA

	OLS Estimates								
	Data Set 1 (123 Countries)			Data Set 2 (50 Countries)			Data Set 3 (38 Countries)		
Dependent Variable	Saving (1)	Invest. (2)	Grow. (3)	Saving (1)	Invest. (2)	Grow. (3)	Saving (1)	Invest. (2)	Grow. (3)
Saving coeffs.									
Sum	0.7206	0.1051	0.0690	0.7985	0.0928	0.1264	0.7364	0.0854	0.0627
(*p*-value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.003)	(0.000)	(0.000)	(0.137)
Long-run	—	0.3313	0.0614	—	0.3508	0.1277	—	0.4164	0.0770
(*p*-value)		(0.000)	(0.000)		(0.000)	(0.049)		(0.000)	(0.000)
Investment coeffs.									
Sum	0.0229	−1.2246	−0.1205	0.0183	0.7354	−0.1625	0.0627	0.7948	−0.1226
(*p*-value)	(0.347)	(0.000)	(0.000)	(0.582)	(0.000)	(0.001)	(0.026)	(0.000)	(0.001)
Long-run	0.0820	—	−1.0730	0.0909	—	−0.1642	0.2379	—	−0.1506
(*p*-value)	(0.000)		(0.000)	(0.111)		(0.000)	(0.000)		(0.000)
Growth coeffs.									
Sum	0.1391	0.1111	0.6829	0.0641	0.0976	0.0109	0.0496	0.1544	0.1858
(*p*-value)	(0.000)	(0.000)	(0.000)	(0.152)	(0.000)	(0.865)	(0.299)	(0.000)	(0.000)
Long-run	0.4977	0.3313	—	0.3182	0.3689	—	0.1882	0.7526	—
(*p*-value)	(0.000)	(0.000)		(0.000)	(0.000)		(0.000)	(0.000)	
# of observations	2527	2516	2517	1250	1250	1250	1140	1140	1140

Notes: See table 4.

cluded in our regressions. Both experiments did not change the basic nature of our results.

In an attempt to control for important differences among countries that could affect the relationships of interest, many of the papers that study multicountry data sets, such as the growth regressions of Barro (1991) and many others, have considered a number of variables ranging from measures of human capital to government consumption to measures of political instability.[30] While this is certainly important in cross-sectional studies, it is less so in our case, as our focus is on the time dimension. Moreover, at least the variables that do not vary over time are taken care of by the presence of fixed effects. However, in this subsection, we explore whether the results we obtain are robust to the introduction of a number of control variables that are typical in cross-sectional studies.

The control variables we consider are chosen on the basis of two criteria. First, we want to consider variables that are likely to be important and have been typically used in the macro (and especially growth) literature. Second, we do not want to lose from our data set too many countries because of data availability. This is an important issue, because the controls usually included in the growth (cross-sectional) regressions are usually available only at very low frequencies.

We included four additional controls in data sets 2 and 3: the public consumption rate, computed as (central) government consumption over GNP, the share of population aged between 15 and 65 years, a human capital proxy (years of schooling), and life expectancy at birth. As we need annual controls, these series (except public consumption) required the imputation of some missing values. To fill the gaps, we performed linear interpolations and/or extrapolations based on the tendency of the nearest six observations of the series.

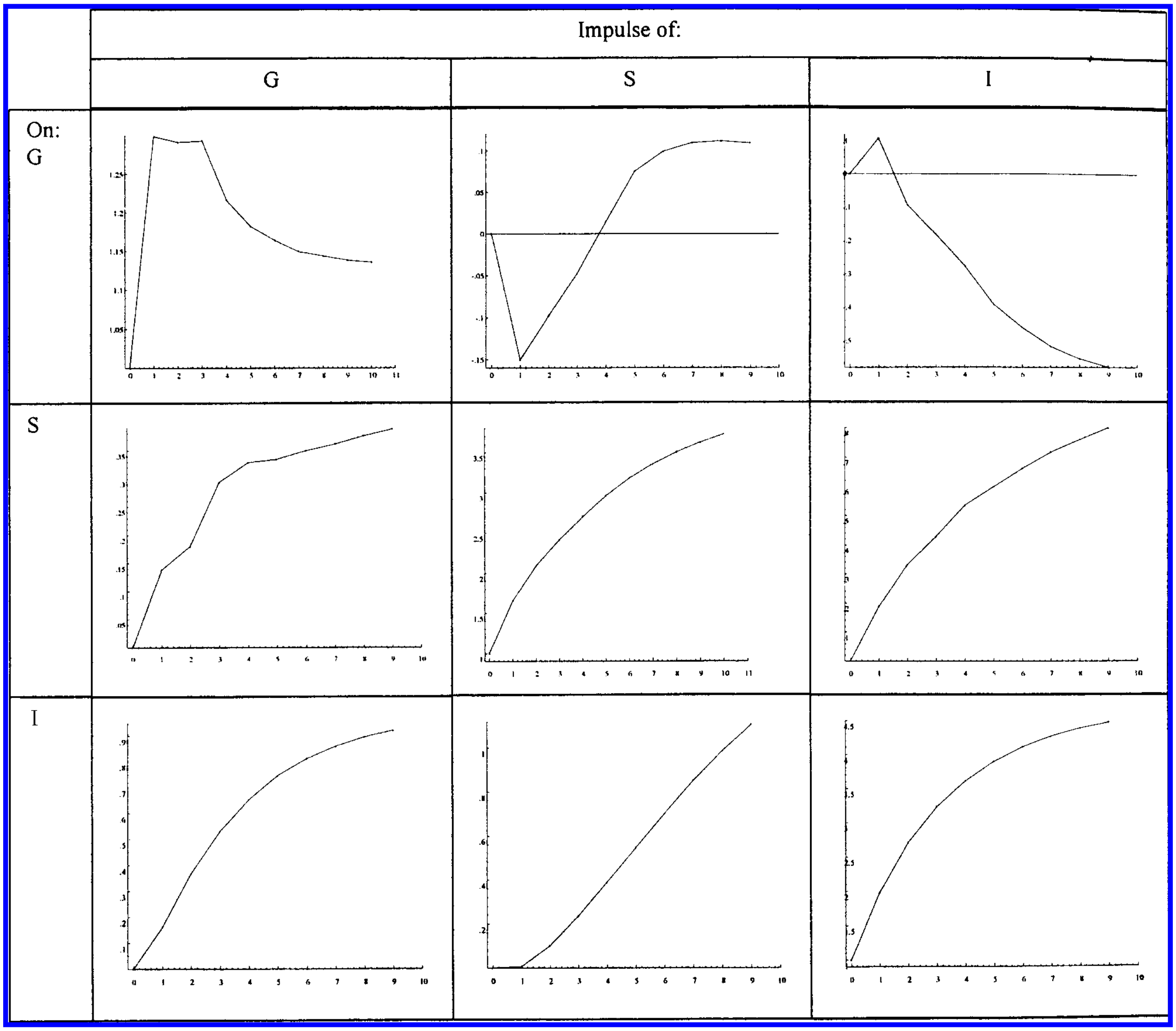
Most of the control variables we consider are strongly significant in most of the specifications we consider. In particular, the public consumption coefficient is negative and significant in all two- and three-equation systems (with the exclusion of the regression of investment against lagged saving using data set 2). This is an unsurprising conclusion in light of previous cross-sectional studies.[31] The estimated coefficient of the share of population aged between 15 and 65 is almost always positive and significant, with the exception of the investment equation in the three-equation systems and in the investment-growth equation in the two-equation systems, irrespective of the data set considered. In both the two- and three-equation systems, the human capital control is often imprecisely estimated. This is true especially for the data set of 38 mostly developed countries, in which none of the human capital coefficients are significant, perhaps because of the low variability in the sample. The effect of the life expectancy is significant in most of the regressions, the exception being the investment equations in the three-equation system and the investment on lagged growth rates in the case of two equations. However, the sign of the point estimates are different in different equations.

The introduction of the control variables, however, does not affect most of our results about the dynamic relationship among saving investment and growth. For the bivariate systems (which we do not report but which are available upon request), this is true for the saving-investment and growth-investment cases. The short- and long-run effects always retain sign and significance (or lack of) and are

[30] Typically, in growth regressions, the average growth rate of a country is explained by means of a set of (supposedly exogenous) controls concerning geographical, institutional, political, and more traditional demographic factors and economic variables—the investment rate among them—evaluated at the beginning of the period or in terms of sample averages. These controls might also affect the relationships that we analyze.

[31] The complete set of results is shown in the appendix.

FIGURE 5.—IMPULSE-RESPONSE IN THE TRIVARIATE SYSTEM



remarkably close in size. The only important exception is the saving-growth system. While the results for data set 3 are again unaffected, in the case of data set 2, the effect of lagged growth rates on saving changes from positive without controls to insignificant (and negative) when controls are introduced. Furthermore, when we consider the effect of lagged saving rates on growth, we now find a negative and (marginally significant) coefficient.

Table 8 summarizes the results of the introduction of controls in the three-equation system considered in the previous section. Let us consider first the saving equation. The introduction of controls leaves almost unaffected the degree of persistence of the dependent variable estimated in the three-equation system without controls. Also, the estimated effect of the lagged investment rates on saving is very similar to the corresponding case of table 7, with a long-run multiplier always positive, significant, and not far from 0.20 for both data sets. However, the effect of growth is somewhat different, especially in data set 2. In this case, consistently with the ‘‘saving for a rainy day’’ argument, or with a more traditional IS-LM model, the long-run coefficient is negative and marginally significant. In the data set including 38 of the most-industrialized countries, however, the effect is insignificantly different from zero. This seems to confirm Deaton’s (1995) statement that ‘‘the reverse mechanism from growth to saving is at best relatively unimportant.’’

As for the growth equation, to the short- and long-run effects of lagged investment are again quite precisely estimated and similar to the estimates of the no-controls, three-equation system of table 7 for both data sets. Therefore, the negative short- and long-run investment effects are robust also to the inclusion of these controls. However, the saving effect is less stable than the investment one. While in table 7 the short- and the long-run multipliers are positive and usually significant, the introduction of controls reduces

TABLE 8.—A DYNAMIC TRIVARIATE MODEL OF SAVING, INVESTMENT, AND GROWTH AND CONTROLS: ANNUAL DATA

	OLS Estimates					
	Data Set 2 (50 Countries)			Data Set 3 (38 Countries)		
Dependent variable	Saving (1)	Invest. (2)	Grow. (3)	Saving (1)	Invest. (2)	Grow. (3)
Saving coeffs.						
Sum	0.6847	0.1054	0.0305	0.6584	0.0706	−0.0151
(*p*-value)	(0.000)	(0.000)	(0.500)	(0.000)	(0.001)	(0.072)
Long-run	—	0.3802	0.0244	—	0.3354	−0.0154
(*p*-value)		(0.000)	(0.893)		(0.000)	(0.000)
Investment coeffs.						
Sum	0.0639	0.7227	−0.1142	0.0697	0.7896	−0.0796
(*p*-value)	(0.050)	(0.000)	(0.016)	(0.012)	(0.000)	(0.039)
Long-run	0.2028	—	−0.0913	0.2041	—	−0.0816
(*p*-value)	(0.000)		(0.000)	(0.000)		(0.000)
Growth coefficients						
Sum	−0.0911	0.0821	−0.2519	0.0009	0.1625	0.0242
(*p*-value)	(0.046)	(0.010)	(0.000)	(0.985)	(0.000)	(0.723)
Long-run	−0.2891	0.2958	—	0.0027	0.7724	—
(*p*-value)	(0.000)	(0.000)		(0.000)	(0.000)	
# of observations	1250	1250	1250	1140	1140	1140

Notes: See table 4.

size and precision of the estimates in data set 2, and changes the signs in the case of data set 3.

The investment equation is unaffected by the inclusion of controls. The degree of persistence of the dependent variable is only slightly lower than the one estimated in table 7. Investment and growth coefficients, both in the short-run and long-run cases are always positive, significant, and very close to the corresponding values of the no-control case.

In conclusion, the results might be consistent with a framework in which the saving-investment and investment-growth relationships are direct and therefore relatively easy to detect. On the contrary, the (possibly indirect) relationship from saving to growth is influenced by other factors and is therefore less stable, while in the growth-to-saving relationship enter opposing (and perhaps offsetting) forces that reflect different and not completely understood theoretical mechanisms of consumer behavior.

VI. Interpretation of the Results and Conclusions

In this section, we summarize and interpret our results. Across data sets, estimation methods and specifications, saving rates, and investment rates show a substantial amount of persistence, with the sum of the coefficients on the lagged dependent variable ranging between 0.6 and 0.8. On the contrary, growth rates are much less persistent. This has obvious implications on the way in which the shocks are propagated and on the speed of adjustment. The evidence on growth rates is consistent with that presented by Easterly et al. (1993).

Table 9 provides a simple and selective summary of the implications of our estimates. A plus or a minus sign indicates the sign of the long-run coefficients (and therefore of the long-run effect) in the equation listed in the first column. One asterisk following the sign indicates significance at the 10% level; two asterisks indicate significance at the 5% level. Within each column are more subcolumns when a given estimation technique was used on more than one sample of countries. The number at the head of each subcolumn identifies the relevant sample size.[32]

Some clear patterns emerge from the table. Three results are extremely robust across data sets and estimation methods. Lagged saving rates are positively related to investment rates. Investment rates Granger-cause growth rates with a negative sign, and growth rates Granger-cause investment rates with a positive sign. These results emerge in all columns, with the only exceptions being the unbalanced sample with the GMM estimator (which typically yields the less precise estimates), and, in one case, the heterogeneous coefficient estimator. Also, lagged investment positively Granger-causes saving in all cases, with the exclusion of the two smaller samples in GMM estimation, in which the relation has a negative and nonsignificant sign. Growth and saving seem to be mutually and positively related, but an important exception arises once we include additional controls in the three-variable system.

In the introduction, while discussing the link between saving and investment, we mentioned the Feldstein and Horioka (1980) and the Feldstein and Bacchetta (1991) papers as relating the positive correlation between saving and investment to the limited mobility of international capital. We also mentioned other papers, such as that by Baxter and Crucini (1992) who construct a two-country equilibrium model with perfectly open capital markets that is able to generate the type of correlation observed in the data. Baxter and Crucini's story seems to be supported by the evidence on the contemporaneous correlation in section

[32] For example, the ''Growth on Sav''—''OLS'' cell of the table shows that the long-run coefficient of growth on saving, in the OLS estimates and using the sample with 123 countries, is positive and significantly different from zero at the 5%-significance level.

TABLE 9.—SUMMARY OF RESULTS

Number of Countries in the Sample:	OLS (table 4)			HNR GMM (table 5)			P-S (table 6)	Three Variables (table 7)			Three Variables and Controls (table 8)	
	123	50	38	123	50	38	38	123	50	38	50	38
Growth on Saving	+**	+**	+**	+	+	+	+**	+**	+**	+**	−**	+**
Saving on Growth	+**	+	−*	−	+	−	+	+**	+**	+**	+	−**
Investment on Saving	+**	+**	+**	+*	−	−	+**	+**	+	+**	+**	+**
Saving on Investment	+**	+**	+**	+	+*	+*	+**	+**	+**	+**	+**	+**
Investment on Growth	−**	−**	−**	−	−	−	+	−**	−**	−**	−**	−**
Growth on Investment	+**	+**	+**	+	+*	+**	+**	+**	+**	+**	+**	+**

Notes: A +/− sign indicates a positive/negative long-run estimated coefficient. One/two asterisk(s) indicate(s) significance at the 10% (5%) level.

III (and especially that in figure 3), which shows that such correlation has been relatively constant in the last thirty years, while capital markets have been developing and becoming more integrated. However, the fact that lagged saving seems to be strongly related to current investment poses a more difficult challenge to the type of models that Baxter and Crucini have been constructing.

Turning to the Granger causation running from growth to investment, one could probably construct models in which growth might create incentives to new investment by making future growth more likely. This is the mechanism stressed by Blomstrom et al. (1996). Such a story, however, contrasts with the low persistence that growth shows in the data.

By far the most difficult piece of evidence to interpret is the negative Granger causation running from investment to growth rates. This result is extremely robust to changes in the sample, econometric technique, model specification, and inclusion of controls. Moreover, as already mentioned, this evidence—which contrasts sharply with the positive correlation coefficient typically obtained in growth regressions such as those of Barro (1991) and Barro and Lee (1993)—is not inconsistent with that recently presented by Bolstrom et al. This negative correlation has been interpreted in terms of the adjustment process towards the steady state within the Solow model, following a shock on saving (Vanhoudt (1998)). A different possible story might be that saving decreases anticipating future growth, and this constitutes a limiting factor for investment, given the limited mobility of international markets. This story, however, is inconsistent with the fact that, in the trivariate system, lagged saving is negatively related to growth only in the smallest data set when controls are introduced in the equation. Another possibility is that investment is less costly or more productive when growth is high; anticipating a decline in growth, firms will tend to anticipate investment projects and vice versa.

Before turning to the discussion of the relationship between growth and saving, a small digression on the relevance of our evidence for the growth regressions initiated by the work of Barro (1991), Mankiw, Romer, and Weil (1992), and others is called for. While the evidence on the relationship between growth and investment is relevant for that literature, we should stress that the relation with the debate on relative convergence is only marginal. The main reason for this is that the convergence regressions are typically identified by cross-sectional variation that, in our regressions that focus mainly on the time series dynamic is, to a large extent, absorbed by the fixed effects.

The relationship between saving and growth that constituted the main theme of the Carroll and Weil (1994) work is not very stable. Growth seems to be (positively) Granger-causing saving in many specifications and data sets, but often the effect is quite weak. More importantly, the introduction of controls causes such a correlation to disappear. In the introduction, we mentioned that both the long-run and short-run implications of the lifecycle model for the relationship between growth and aggregate saving are ambiguous and depend on a number of aggregation effects. It is therefore interesting to note that—controlling for some additional variables such as the share of the population in working age—the relationship between lagged growth and saving changes from positive to negative. This piece of evidence is consistent with the importance of demographic variables for aggregate saving recently stressed by Behrman, Duryea, and Szekely (1999).

While there is some evidence of a positive relationship between lagged saving rates and current growth rates, it is interesting to note that a negative and significant effect is obtained in the trivariate system when additional controls are present. To identify such a micro effect as the ''saving for a rainy day'' implication of the lifecycle model, it is necessary to control for several determinants of heterogeneity across countries.

The long-run coefficients are only a part of the story, however, because they do not capture short-run dynamic effects that can be quite complex and relatively long lasting. For instance, most of the relationships that exhibit no significant long-run effects are characterized by some significant coefficient on some of the lagged causing variable. That is, even in those cases in which there seems to be no long-run Granger causation, we find significant short-run effects. These results are compatible with the presence of the contrasting economic forces that are the likely determinants of the relationships that we have studied and that we have described in the introduction to this work. If the timing of the effects of these forces is different so that they are empirically distinguishable (but these effects also tend to cancel out after time) then we would exactly expect to find individually significant coefficients, but a nonsignificant average effect.

In this paper, we have experimented with different econometric techniques with the purpose of properly treating a panel of data in which both *N* and *T* are relatively large. We have argued that the novelty of using pooled data of this kind presents the researcher both with new opportunities and with new problems. We have made the point that, in our case, it is more meaningful to think about *T*, rather than *N*, asymptotics. We have also argued that, because Granger causality is an intrinsically dynamic concept, the dynamics of the data is where this relation has to be sought. Obviously, the estimators that one chooses under the assumption that *T* is large enough are subject to possible small-sample bias if *T* turns out to be not large enough given the variability in the data. Finally, we have argued for the use of annual rather than time-averaged data and for the construction of flexible dynamic models that would allow one to separately model and identify short- and long-run effects.

The comparison of our results, obtained using different estimation techniques, also calls for conclusions of a methodological type. First, the instrumental-variables GMM method led to less-precise estimates compared to the other methods. The bias of an OLS estimator of a dynamic panel model is very small for most data-generating processes, because it follows a correlation of single observations with their time average. The lack of precision of our GMM estimates seems to indicate that, when *T* is big enough, the bias that comes with an OLS estimator of a dynamic model is to be preferred to the loss of precision that follows the implementation of an instrumental-variable procedure.

Another issue regards the use of heterogeneous coefficients estimates. Even though, in all cases, we were able to reject the hypothesis of parameter homogeneity, when we allowed parameters to vary across countries we ended up with results that are qualitatively very similar to the ones obtained assuming homogeneity. In other words, the lack of parameter homogeneity did not seem to be enough for the ensuing bias to invalidate our previous results. This result seems to be further proof of the reliability of pooled estimation techniques, and, through different means and in a different context, it adds to the evidence presented by Baltagi and Griffin (1997).

Last, a general comment on the issue of large *N*-large *T* panel data: Advocating the use of dynamic models is a different way of saying that, as the time-series dimension of the panel data used in economics tends to grow, it becomes increasingly important to apply the lessons learned from time-series econometrics. This point has also been forcefully made by Granger and Ling-Ling (1997).

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Appendix A

This appendix reports the tables with the complete results of the regressions we referred to in the main text. In order to facilitate comparisons, the numeration of the tables of this appendix is the same used in the text.

TABLE A4A.—A DYNAMIC MODEL OF SAVING AND GROWTH: ANNUAL DATA

	OLS Estimates					
	Data Set 1 123 Countries		Data Set 2 50 Countries		Data Set 3 38 Countries	
Dependent variable	Saving (1)	Growth (2)	Saving (3)	Growth (4)	Saving (5)	Growth (6)
$g_{i,t-1}$	0.115499	0.640135	0.645385	0.052755	0.660285	−0.18019
	(0.02605)	(0.0204)	(0.031244)	(0.045098)	(0.034705)	(0.047698)
$g_{i,t-2}$	0.005523	0.090427	0.030299	0.012158	0.040342	0.196364
	(0.03044)	(0.02376)	(0.03825)	(0.05521)	(0.042787)	(0.058807)
$g_{i,t-3}$	−0.08889	−0.04794	0.026327	−0.02583	−0.00541	−0.05283
	(0.0305)	(0.0243)	(0.040361)	(0.058257)	(0.041903)	(0.057592)
$g_{i,t-4}$	−0.02402	0.048511	0.099913	0.004369	0.077242	0.016326
	(0.02608)	(0.02082)	(0.032765)	(0.047292)	(0.03239)	(0.044517)
$s_{i,t-1}$	0.025317	0.082779	0.088442	0.08095	0.161202	0.328445
	(0.02062)	(0.01614)	(0.021725)	(0.031358)	(0.025508)	(0.035058)
$s_{i,t-2}$	−0.04337	0.013104	−0.00425	0.027619	−0.10203	−0.09027
	(0.02054)	(0.01606)	(0.021898)	(0.031607)	(0.02646)	(0.036366)
$s_{i,t-3}$	−0.00905	0.058171	0.071663	−0.00693	0.113586	0.024084
	(0.01997)	(0.01577)	(0.021856)	(0.031547)	(0.026427)	(0.036321)
$s_{i,t-4}$	−0.06747	−0.02057	−0.05013	−0.04076	−0.07778	−0.05446
	(0.01937)	(0.01519)	(0.021069)	(0.030411)	(0.023594)	(0.032428)
Growth coeffs.						
Sum	0.1335	—	0.1057	—	0.0950	—
(p-value)	(0.000)		(0.011)		(0.027)	
Long-run	0.4965	—	0.5337	—	0.4174	—
(p-value)	(0.000)		(0.000)		(0.000)	
Saving coeffs.						
Sum	—	0.0081	—	0.0434	—	−0.0203
(p-value)		(0.719)		(0.239)		(0.548)
Long-run	—	0.0074	—	0.0463	—	−0.0258
(p-value)		(0.000)		(0.623)		(0.028)
# of observations	2766	2757	1250	1250	1140	1140

Notes: See table 4.

TABLE A4B.—A DYNAMIC MODEL OF SAVING AND GROWTH WITH CONTROL VARIABLES: ANNUAL DATA

	OLS Estimates			
	Data Set 2 50 Countries		Data Set 3 38 Countries	
Dependent Variable	Saving (3)	Growth (4)	Saving (5)	Growth (6)
$g_{i,t-1}$	0.047613	0.010327	0.140069	0.268921
	(0.021081)	(0.030619)	(0.025084)	(0.034404)
$g_{i,t-2}$	−0.03614	−0.03222	−0.0973	−0.11381
	(0.021145)	(0.030712)	(0.025777)	(0.035355)
$g_{i,t-3}$	0.039265	−0.06678	0.101913	−0.01866
	(0.021105)	(0.030654)	(0.025754)	(0.035323)
$g_{i,t-4}$	−0.07212	−0.09146	−0.07862	−0.08936
	(0.020419)	(0.029657)	(0.02319)	(0.031806)
$s_{i,t-1}$	0.57426	−0.02382	0.601141	−0.22324
	(0.030251)	(0.043938)	(0.034146)	(0.046833)
$s_{i,t-2}$	0.023446	0.012066	0.031099	0.18663
	(0.036238)	(0.052634)	(0.041145)	(0.056432)
$s_{i,t-3}$	0.027372	−0.0194	−0.01019	−0.04556
	(0.038251)	(0.055557)	(0.040337)	(0.055323)
$s_{i,t-4}$	0.089872	−0.00505	0.071941	0.014844
	(0.031141)	(0.045231)	(0.03115)	(0.042728)
Publ. Cons.	−0.3807	−0.46931	−0.34213	−0.40405
	(0.036969)	(0.053695)	(0.036191)	(0.049638)
Pop. 15–65	0.003344	0.002721	0.001447	0.002091
	(0.000606)	(0.000881)	(0.000493)	(0.000677)
Hum. Cap.	−0.00307	−0.0042	−0.00105	−0.0016
	(0.002007)	(0.002915)	(0.001451)	(0.001991)
Life Exp.	−0.00156	−0.00294	0.000388	−0.00158
	(0.000708)	(0.001029)	(0.000504)	(0.000691)
Growth coeffs.				
Sum	−0.0213	—	0.0661	—
(*p*-value)	(0.618)		(0.142)	
Long-run	−0.075	—	0.2159	—
(*p*-value)	(0.000)		(0.000)	
Saving coeffs.				
Sum	—	−0.0362	—	−0.0673
(*p*-value)		(0.341)		(0.059)
Long-run	—	−0.0307	—	−0.0707
(*p*-value)		(0.903)		(0.000)
# of observations	1250	1250	1140	1140

Notes: See table 4.

TABLE A4C.—A DYNAMIC MODEL OF SAVING AND INVESTMENT: ANNUAL DATA

	OLS Estimates					
	Data Set 1 123 Countries		Data Set 2 50 Countries		Data Set 3 38 Countries	
Dependent variable	Saving (1)	Investment (2)	Saving (3)	Investment (4)	Saving (5)	Investment (6)
$s_{i,t-1}$	0.701393	0.107546	0.67805	0.107411	0.709031	0.114401
	(0.02088)	(0.01543)	(0.029003)	(0.019293)	(0.030694)	(0.021413)
$s_{i,t-2}$	0.044949	0.03632	0.011118	0.011691	−0.06379	0.023198
	(0.02482)	(0.01848)	(0.036611)	(0.024354)	(0.037283)	(0.026009)
$s_{i,t-3}$	−0.03292	−0.04567	0.049335	−0.01365	0.082546	−0.03513
	(0.02493)	(0.01874)	(0.038359)	(0.025517)	(0.036837)	(0.025698)
$s_{i,t-4}$	0.013751	0.019238	0.065447	0.005032	0.003615	0.015448
	(0.02124)	(0.01577)	(0.032306)	(0.02149)	(0.03115)	(0.02173)
$i_{i,t-1}$	−0.0026	0.742666	0.073664	0.964113	0.221524	1.05534
	(0.02696)	(0.01999)	(0.043308)	(0.028809)	(0.043888)	(0.030616)
$i_{i,t-2}$	0.139342	−0.00021	0.041234	−0.24634	−0.21374	−0.31872
	(0.0333)	(0.02507)	(0.059812)	(0.039788)	(0.063564)	(0.044343)
$i_{i,t-3}$	−0.13577	−0.09184	−0.0579	0.049144	0.061728	0.037378
	(0.03297)	(0.02507)	(0.060084)	(0.039969)	(0.063652)	(0.044404)
$i_{i,t-4}$	0.031594	0.044129	−0.04496	−0.04039	−0.00884	0.011379
	(0.0242)	(0.01811)	(0.043101)	(0.028672)	(0.043008)	(0.030003)
Inv. coeffs.						
Sum	0.0326	—	0.0120	—	0.0607	—
(p-value)	(0.167)		(0.719)		(0.036)	
Long-run	0.1194	—	0.0614	—	0.2259	—
(p-value)	(0.000)		(0.013)		(0.000)	
Saving coeffs.						
Sum	—	0.1174	—	0.1105	—	0.1179
(p-value)		(0.000)		(0.000)		(0.000)
Long-run	—	0.3837	—	0.4040	—	0.5494
(p-value)		(0.000)		(0.000)		(0.000)
# of observations	2649	2638	1250	1250	1140	1140

Notes: See table 4.

TABLE A4D.—A DYNAMIC MODEL OF SAVING AND INVESTMENT WITH CONTROL VARIABLES: ANNUAL DATA

	OLS Estimates			
	Data Set 2 50 Countries		Data Set 3 38 Countries	
Dependent variable	Saving (3)	Investment (4)	Saving (5)	Investment (6)
$i_{i,t-1}$	0.075511	0.954479	0.207073	1.052369
	(0.04101)	(0.028904)	(0.042079)	(0.030578)
$i_{i,t-2}$	0.074149	−0.24334	−0.18473	−0.3127
	(0.05634)	(0.039708)	(0.060976)	(0.04431)
$i_{i,t-3}$	−0.04674	0.046259	0.051483	0.035082
	(0.05659)	(0.039884)	(0.061011)	(0.044336)
$i_{i,t-4}$	−0.04176	−0.04	−0.00551	0.013272
	(0.040787)	(0.028746)	(0.041816)	(0.030387)
$s_{i,t-1}$	0.570555	0.099757	0.63258	0.098927
	(0.028612)	(0.020165)	(0.030372)	(0.022071)
$s_{i,t-2}$	−0.00873	0.012924	−0.06314	0.023208
	(0.034516)	(0.024326)	(0.035725)	(0.02596)
$s_{i,t-3}$	0.035564	−0.01202	0.066837	−0.03852
	(0.036162)	(0.025487)	(0.035335)	(0.025677)
$s_{i,t-4}$	0.05856	0.011538	0.003586	0.015635
	(0.030701)	(0.021638)	(0.02987)	(0.021706)
Publ. Cons.	−0.39472	−0.03267	−0.35887	−0.069
	(0.036573)	(0.025776)	(0.036649)	(0.026632)
Pop 15–65	0.003595	0.000103	0.001542	0.000414
	(0.000613)	(0.000432)	(0.0005)	(0.000364)
Hum. Cap.	−0.00156	−0.00401	−0.00081	−0.00074
	(0.002046)	(0.001442)	(0.001478)	(0.001074)
Life Exp.	−0.00196	0.000806	0.000163	0.00082
	(0.000736)	(0.000519)	(0.000513)	(0.000373)
Inv. coeffs.				
Sum	0.0611	—	0.0683	—
(p-value)	(0.064)		(0.0169)	
Long-run	0.1777	—	0.1897	—
(p-value)	(0.001)		(0.000)	
Saving coeffs.				
Sum	—	0.1122	—	0.0992
(p-value)		(0.000)		(0.000)
Long-run	—	0.3970	—	0.4682
(p-value)		(0.000)		(0.000)
# of observations	1250	1250	1178	1178

Notes: See table 4.

TABLE A4E.—A DYNAMIC MODEL OF GROWTH AND INVESTMENT: ANNUAL DATA

	OLS Estimates					
	Data Set 1 123 Countries		Data Set 2 50 Countries		Data Set 3 38 Countries	
Dependent variable	Growth (1)	Investment (2)	Growth (3)	Investment (4)	Growth (5)	Investment (6)
$g_{i,t-1}$	0.063251	0.092051	0.078638	0.12196	0.237738	0.156059
	(0.02122)	(0.01181)	(0.029607)	(0.013695)	(0.031691)	(0.01607)
$g_{i,t-2}$	−0.02297	0.059429	0.032296	0.028082	−0.06335	0.039476
	(0.02126)	(0.01183)	(0.030451)	(0.014085)	(0.033211)	(0.016841)
$g_{i,t-3}$	−0.01722	0.001627	0.002171	0.012899	0.051549	0.00233
	(0.02051)	(0.01141)	(0.030237)	(0.013986)	(0.033164)	(0.016817)
$g_{i,t-4}$	−0.06709	0.014667	−0.02604	−0.00234	−0.05319	0.008317
	(0.01962)	(0.01096)	(0.029562)	(0.013674)	(0.031447)	(0.015946)
$i_{i,t-1}$	0.066977	0.719835	0.132254	0.937334	0.121781	0.999271
	(0.03645)	(0.02044)	(0.063501)	(0.029373)	(0.06187)	(0.031373)
$i_{i,t-2}$	−0.07657	0.014941	−0.24183	−0.20945	−0.32159	−0.24987
	(0.04461)	(0.02552)	(0.086259)	(0.0399)	(0.087388)	(0.044314)
$i_{i,t-3}$	−0.02304	−0.0622	0.139193	0.082148	0.210645	0.070734
	(0.04378)	(0.02555)	(0.086845)	(0.040171)	(0.087391)	(0.044315)
$i_{i,t-4}$	−0.06324	0.064476	−0.12121	−0.02357	−0.08918	0.019673
	(0.03269)	(0.0184)	(0.062402)	(0.028865)	(0.060396)	(0.030626)
Inv. Coeffs.						
Sum	−0.0959	—	−0.0916	—	−0.0783	—
(p-value)	(0.001)		(0.025)		(0.0112)	
Long-run	−0.0918	—	−0.1003	—	−0.0947	—
(p-value)	(0.000)		(0.004)		(0.000)	
Growth coeffs.						
Sum	—	0.1678	—	0.1606	—	0.2062
(p-value)		(0.000)		(0.000)		(0.000)
Long-run	—	0.6381	—	0.7521	—	1.2871
(p-value)		(0.000)		(0.000)		(0.000)
# of observations	2517	2516	1250	1250	1140	1140

Notes: See table 4.

TABLE A4F.—A DYNAMIC MODEL OF GROWTH AND INVESTMENT WITH CONTROL VARIABLES: ANNUAL DATA

	OLS Estimates			
	Data Set 2 50 Countries		Data Set 3 38 Countries	
Dependent variable	Growth (3)	Investment (4)	Growth (5)	Investment (6)
$g_{i,t-1}$	−0.01731	0.113569	0.167132	0.150496
	(0.02934)	(0.014264)	(0.031502)	(0.01651)
$g_{i,t-2}$	−0.05582	0.020776	−0.10837	0.039546
	(0.029942)	(0.014557)	(0.032582)	(0.017076)
$g_{i,t-3}$	−0.07868	0.006057	−0.00145	0.000674
	(0.029609)	(0.014395)	(0.032607)	(0.017089)
$g_{i,t-4}$	−0.09617	−0.00797	−0.09818	0.009741
	(0.028922)	(0.014061)	(0.031017)	(0.016256)
$i_{i,t-1}$	0.150473	0.935643	0.130386	0.989416
	(0.060469)	(0.029398)	(0.06005)	(0.031472)
$i_{i,t-2}$	−0.20543	−0.20583	−0.29236	−0.24637
	(0.081994)	(0.039863)	(0.084259)	(0.04416)
$i_{i,t-3}$	0.136142	0.081233	0.189131	0.068423
	(0.082518)	(0.040118)	(0.084238)	(0.044149)
$i_{i,t-4}$	−0.17482	−0.0301	−0.09668	0.011245
	(0.059575)	(0.028963)	(0.05848)	(0.03065)
Publ. Cons.	−0.48055	−0.04368	−0.37454	−0.07831
	(0.052234)	(0.025395)	(0.047771)	(0.025037)
Pop 15–65	0.00267	0.000659	0.001967	0.000415
	(0.000839)	(0.000408)	(0.000675)	(0.000354)
Hum. Cap.	−0.00489	−0.00274	−0.00195	−0.00055
	(0.002888)	(0.001404)	(0.002005)	(0.001051)
Life Exp.	−0.00257	0.000287	−0.00144	0.000388
	(0.001009)	(0.000491)	(0.000705)	(0.000369)
Inv. coeffs.				
Sum	−0.0936	—	−0.0695	—
(*p*-value)	(0.0175)		(0.031)	
Long-run	−0.075	—	−0.067	—
(*p*-value)	(0.000)		(0.002)	
Growth coeffs.				
Sum	—	0.1324	—	0.2005
(*p*-value)		(0.000)		(0.000)
Long-run	—	0.6046	—	1.1306
(*p*-value)		(0.000)		(0.000)
# of observations	1250	1250	1140	1140

Notes: See table 4.

TABLE A5A.—A DYNAMIC MODEL OF SAVING AND GROWTH: ANNUAL DATA

	IV-GMM Estimates					
	Data Set 1 123 Countries		Data Set 2 50 Countries		Data Set 3 38 Countries	
Dependent variable	Saving (1)	Growth (2)	Saving (3)	Growth (4)	Saving (5)	Growth (6)
$s_{i,t-1}$	0.7848	0.0612	0.5158	−0.0483	0.5220	−0.3999
	(0.213)	(0.240)	(0.209)	(0.305)	(0.172)	(0.313)
$s_{i,t-2}$	0.0315	0.0606	−0.0004	0.2558	0.1000	0.3216
	(0.249)	(0.335)	(0.136)	(0.272)	(0.134)	(0.222)
$s_{i,t-3}$	−0.1231	−0.0679	0.0870	−0.1975	0.0004	0.0011
	(0.279)	(0.327)	(0.121)	(0.283)	(0.138)	(0.184)
$s_{i,t-4}$	0.1462	−0.0822	0.1276	0.0986	0.1636	0.0272
	(0.190)	(0.197)	(0.119)	(0.187)	(0.090)	(0.140)
$g_{i,t-1}$	0.0140	0.1036	0.2159	0.1878	0.2687	0.4206
	(0.213)	(0.240)	(0.209)	(0.305)	(0.172)	(0.313)
$g_{i,t-2}$	−0.0850	0.0200	−0.0468	−0.1536	−0.1756	−0.0795
	(0.249)	(0.335)	(0.136)	(0.272)	(0.134)	(0.222)
$g_{i,t-3}$	0.1631	−0.0658	0.1081	0.1226	0.1280	−0.0125
	(0.279)	(0.327)	(0.121)	(0.283)	(0.138)	(0.184)
$g_{i,t-4}$	−0.0222	0.0399	−0.0579	−0.1067	−0.1320	−0.1021
	(0.190)	(0.197)	(0.119)	(0.187)	(0.090)	(0.140)
Sum	0.0699	−0.0283	0.213	0.1086	0.0891	−0.050
(p-value)	(0.7861)	(0.5269)	(0.8105)	(0.4275)	(0.5604)	(0.6593)
Long-run	0.4353	−0.0313	0.8120	0.1143	0.4163	−0.0647
(p-value)	(0.9804)	(0.8301)	(0.3481)	(0.7014)	(0.5135)	(0.6720)
# of observations						

Notes: See table 4. The estimates reported here are equivalent to those in table 4, but they are obtained by GMM using the HNR (1988) and AB (1991) estimators. Four additional lags are used as instruments in all columns.

TABLE A5B.—A DYNAMIC MODEL OF SAVING AND INVESTMENT: ANNUAL DATA

	IV-GMM Estimates					
	Data Set 1 123 Countries		Data Set 2 50 Countries		Data Set 3 38 Countries	
Dependent variable	Saving (1)	Investment (2)	Saving (3)	Investment (4)	Saving (5)	Investment (6)
$s_{i,t-1}$	0.7844	0.0587	0.5653	0.1254	0.6576	0.1643
	(0.195)	(0.211)	(0.310)	(0.113)	(0.315)	(0.108)
$s_{i,t-2}$	0.0139	0.0043	−0.1142	0.1167	−0.1627	0.0084
	(0.297)	(0.297)	(0.375)	(0.148)	(0.322)	(0.088)
$s_{i,t-3}$	−0.0472	−0.0642	0.1787	−0.0495	0.1411	0.0016
	(0.342)	(0.295)	(0.423)	(0.140)	(0.294)	(0.064)
$s_{i,t-4}$	0.0778	0.0485	0.0200	0.0519	0.0441	0.0254
	(0.202)	(0.180)	(0.317)	(0.101)	(0.167)	(0.072)
$i_{i,t-1}$	−0.0238	0.9156	−0.0019	0.8938	0.3372	1.0742
	(0.195)	(0.211)	(0.310)	(0.113)	(0.315)	(0.108)
$i_{i,t-2}$	0.0401	0.0077	0.0632	−0.3130	−0.4367	−0.4216
	(0.297)	(0.297)	(0.375)	(0.148)	(0.322)	(0.088)
$i_{i,t-3}$	0.0567	−0.0901	−0.0692	0.0741	0.1827	0.1277
	(0.342)	(0.295)	(0.423)	(0.140)	(0.294)	(0.064)
$i_{i,t-4}$	−0.0496	0.0296	−0.1471	−0.0653	−0.0958	−0.0743
	(0.202)	(0.180)	(0.317)	(0.101)	(0.167)	(0.072)
Sum	0.1100	0.3449	−0.1550	0.2445	−0.0126	0.1997
(p-value)	(0.6145)	(0.4254)	(0.2538)	(0.024)	(0.9141)	(0.0036)
Long-run	0.1371	0.3449	−0.4427	0.5959	−0.0396	0.6793
(p-value)	(0.0969)	(0.8789)	(0.5089)	(0.080)	(0.5778)	(0.0573)
# of observations						

Notes: See table 4. The estimates reported here are equivalent to those in table 4, but they are obtained by GMM using the HNR (1988) and AB (1991) estimators. Four additional lags are used as instruments in all columns.

TABLE A5C.—A DYNAMIC MODEL OF GROWTH AND INVESTMENT: ANNUAL DATA

	IV-GMM Estimates					
	Data Set 1 123 Countries		Data Set 2 50 Countries		Data Set 3 38 Countries	
Dependent variable	Growth (1)	Investment (2)	Growth (3)	Investment (4)	Growth (5)	Investment (6)
$g_{i,t-1}$	0.1804	0.0320	0.1737	0.2128	0.1994	0.1963
	(0.220)	(0.199)	(0.393)	(0.098)	(0.330)	(0.083)
$g_{i,t-2}$	0.0115	0.0856	−0.0593	0.0651	−0.1648	0.0386
	(0.357)	(0.193)	(0.520)	(0.074)	(0.489)	(0.054)
$g_{i,t-3}$	−0.1672	−0.0754	0.1481	0.0430	0.0195	0.0226
	(0.281)	(0.163)	(0.452)	(0.079)	(0.433)	(0.055)
$g_{i,t-4}$	0.0009	0.0165	−0.0703	0.0100	−0.0684	0.0303
	(0.148)	(0.116)	(0.283)	(0.064)	(0.266)	(0.049)
$i_{i,t-1}$	0.0744	0.9648	0.1026	0.9113	0.3981	1.0847
	(0.220)	(0.199)	(0.393)	(0.098)	(0.330)	(0.083)
$i_{i,t-2}$	−0.1271	−0.0938	−0.5318	−0.3398	−0.6626	−0.3717
	(0.357)	(0.193)	(0.520)	(0.074)	(0.489)	(0.054)
$i_{i,t-3}$	−0.0083	−0.0462	0.3504	0.1212	0.2583	0.0771
	(0.281)	(0.163)	(0.452)	(0.079)	(0.433)	(0.055)
$i_{i,t-4}$	0.0273	0.0580	−0.1383	−0.0035	−0.1107	0.0449
	(0.148)	(0.116)	(0.283)	(0.064)	(0.266)	(0.049)
Sum	−0.0337	0.0585	−0.2171	0.3309	−0.1169	0.2878
(p-value)	(0.2661)	(0.8234)	(0.1171)	(0.0071)	(0.1135)	(0.006)
Long-run	−0.0346	0.5006	−0.2687	1.0648	−0.1152	1.7442
(p-value)	(0.7175)	(0.9845)	(0.4649)	(0.0526)	(0.4399)	(0.0075)
# of observations						

Notes: See table 4. The estimates reported here are equivalent to those in table 4, but they are obtained by GMM using the HNR (1988) and AB (1991) estimators. Four additional lags are used as instruments in all columns.

TABLE A6A.—A DYNAMIC MODEL OF SAVING AND GROWTH WITH HETEROGENEOUS COEFFICIENTS: ANNUAL DATA

	Data Set 3 38 Countries			
	Saving Rates		Growth Rates	
Dependent variable	Avg. Coeff. (s.e.)	1st, 2nd, and 3rd Quartile	Avg. Coeff. (s.e.)	1st, 2nd, and 3rd Quartile
$s_{i,t-1}$	0.7078	0.4758, 0.7454, 0.8979	−0.0854	−0.3959, 0.0437, 0.1590
	(0.061)		(0.097)	
$s_{i,t-2}$	0.0073	−0.2130, 0.0658, 0.2249	0.1264	−0.1458, 0.1692, 0.5683
	(0.065)		(0.104)	
$s_{i,t-3}$	−0.0030	−0.1909, 0.0127, 0.1863	−0.0900	−0.5703, −0.1269, 0.1673
	(0.051)		(0.089)	
$s_{i,t-4}$	0.0276	−0.1963, 0.0118, 0.2165	0.0398	−0.5210, −0.0365, 0.3000
	(0.039)		(0.073)	
$g_{i,t-1}$	0.1547	−0.0529, 0.1855, 0.3216	0.3429	0.1134, 0.4221, 0.5967
	(0.042)		(0.065)	
$g_{i,t-2}$	−0.0274	−0.1674, −0.0026, 0.0881	−0.1280	−0.3575, −0.1509, 0.0642
	(0.036)		(0.047)	
$g_{i,t-3}$	0.0551	−0.0802, 0.1055, 0.1585	0.0456	−0.1999, 0.1074, 0.3163
	(0.038)		(0.061)	
$g_{i,t-4}$	0.0030	−0.0906, −0.0105, 0.0421	−0.0891	−0.2233, −0.1001, 0.0804
	(0.026)		(0.050)	
Sum	0.0463	−0.00964, 0.0390, 0.0993	−0.0022	−0.0455, 0.0012, 0.0618
(p-value)	(0.003)		(1.000)	
Long-run	0.2204	−0.2568, 0.2576, 0.8875	1.3507	−0.1859, 0.0519, 0.9897
(p-value)	(0.105)		(0.746)	
# of observations	1292		1292	

Notes: See table 6.

TABLE A6B.—A DYNAMIC MODEL OF SAVING AND INVESTMENT WITH HETEROGENEOUS COEFFICIENTS: ANNUAL DATA

	Data Set 3 38 Countries			
	Saving Rate		Investment Rate	
Dependent variable	Avg. Coeff. (s.e.)	1st, 2nd, and 3rd Quantile	Avg. Coeff. (s.e.)	1st, 2nd, and 3rd Quantile
$s_{i,t-1}$	0.7685 (0.051)	0.5219, 0.6685, 1.0673	0.1713 (0.027)	0.0057, 0.2174, 0.3505
$s_{i,t-2}$	−0.0727 (0.060)	−0.2058, −0.0558, 0.1367	0.0548 (0.051)	−0.0863, −0.0051, 0.2231
$s_{i,t-3}$	0.0975 (0.065)	−0.0361, 0.1150, 0.2894	−0.0119 (0.051)	−0.1426, 0.0220, 0.1243
$s_{i,t-4}$	−0.0391 (0.035)	−0.2006, −0.0478, 0.0346	0.0483 (0.034)	−0.0373, 0.0540, 0.1167
$i_{i,t-1}$	0.0947 (0.059)	−0.1758, 0.0876, 0.2055	0.9599 (0.040)	0.7766, 0.9783, 1.2263
$i_{i,t-2}$	−0.1653 (0.079)	−0.5240, −0.1951, −0.0488	−0.3550 (0.060)	−0.6684, −0.3229, −0.0094
$i_{i,t-3}$	−0.0888 (0.079)	−0.1846, 0.0371, 0.3786	0.0530 (0.050)	−0.1864, 0.0297, 0.2309
$i_{i,t-4}$	−0.0488 (0.055)	−0.2800, −0.0977, 0.0646	−0.0643 (0.035)	−0.1839, −0.00561, 0.1423
Sum (p-value)	−0.0077 (1.000)	−0.0642, −0.0189, 0.0444	0.0656 (0.000)	0.0234, 0.0620, 0.1237
Long-run (p-value)	0.2549 (0.746)*	−0.4242, −0.0330, 0.5477	0.1962 (0.105)*	−0.8175, −0.1808, 0.2976
# of observations	1292	1292	1292	1292

Notes: See table 6.

TABLE A6C.—A DYNAMIC MODEL OF GROWTH AND INVESTMENT WITH HETEROGENEOUS COEFFICIENTS: ANNUAL DATA

	Data Set 3 38 Countries			
	Growth Rates		Investment Rates	
Dependent variable	Avg. Coeff. (s.e.)	1st, 2nd, and 3rd Quantile	Avg. Coeff. (s.e.)	1st, 2nd, and 3rd Quantile
$g_{i,t-1}$	0.3144 (0.075)	0.1131, 0.2770, 0.4421	0.2124 (0.026)	0.1186, 0.2066, 0.2916
$g_{i,t-2}$	−0.141 (0.045)	−0.3822, −0.2205, 0.0095	0.0483 (0.024)	−0.0295, 0.0636, 0.1324
$g_{i,t-3}$	0.1258 (0.045)	−0.0917, 0.0799, 0.2454	0.0636 (0.024)	−0.0284, 0.0624, 0.1568
$g_{i,t-4}$	−0.0707 (0.046)	−0.1924, −0.486, 0.0473	0.0186 (0.019)	−0.0377, 0.0088, 0.1051
$i_{i,t-1}$	−0.1990 (0.104)	−0.6818, −0.0884, 0.2332	0.9184 (0.040)	0.7625, 0.9365, 1.0775
$i_{i,t-2}$	0.0487 (0.122)	−0.6855, −0.0111, 0.6472	−0.2230 (0.061)	−0.4556, −0.2571, 0.0218
$i_{i,t-3}$	−0.0376 (0.145)	−0.6079, −0.0474, 0.3587	0.0462 (0.055)	−0.1676, 0.0363, 0.3305
$i_{i,t-4}$	0.0119 (0.099)	−0.33480, −0.0280, 0.4008	−0.0271 (0.040)	−0.1416, 0.0492, 0.1897
Sum (p-value)	−0.0440 (0.023)	−0.1062, −0.0644, 0.0106	0.0857 (0.023)	0.0279, 0.0815, 0.1271
Long-run (p-value)	−0.1246 (0.105)	−0.7449, −0.1929, 0.1373	1.1631 (1.000)	−0.7372, 0.0293, 1.316
# of observations	1292	1292	1292	1292

Notes: See table 6.

TABLE A7.—A DYNAMIC MODEL OF SAVING, INVESTMENT, AND GROWTH: ANNUAL DATA

	OLS Estimates								
	Data Set 1 123 Countries			Data Set 2 50 Countries			Data Set 3 38 Countries		
Dependent variable	Saving (1)	Invest. (2)	Growth (2)	Saving (1)	Invest. (2)	Growth (2)	Saving (1)	Invest. (2)	Growth (2)
$g_{i,t-1}$	0.090474	0.076143	0.024328	0.082773	0.104546	0.05635	0.138821	0.160769	0.298668
	(0.01694)	(0.01247)	(0.02238)	(0.022407)	(0.014766)	(0.032145)	(0.026493)	(0.018342)	(0.03635)
$g_{i,t-2}$	0.015148	0.040646	−0.05226	−0.02062	0.006291	0.007989	−0.12033	−0.00052	−0.09342
	(0.01688)	(0.01238)	(0.02233)	(0.022942)	(0.015118)	(0.032912)	(0.027723)	(0.019194)	(0.038038)
$g_{i,t-3}$	0.062673	−0.00626	−0.0209	0.056428	0.001256	−0.00774	0.108908	−0.01142	0.038924
	(0.01619)	(0.01184)	(0.02138)	(0.022719)	(0.014972)	(0.032592)	(0.027629)	(0.019128)	(0.037909)
$g_{i,t-4}$	−0.02922	0.000540	−0.07362	−0.05446	−0.01446	−0.04567	−0.07782	0.005581	−0.05836
	(0.01518)	(0.1117)	(0.02002)	(0.021468)	(0.014147)	(0.030797)	(0.024174)	(0.016736)	(0.033168)
$s_{i,t-1}$	0.671058	0.056744	0.144853	0.642471	0.051247	0.065979	0.651686	0.006416	−0.15066
	(0.02271)	(0.01674)	(0.03005)	(0.031418)	(0.020704)	(0.045071)	(0.034915)	(0.024173)	(0.047906)
$s_{i,t-2}$	0.041783	0.042053	−0.00248	0.031228	0.036887	0.032961	0.032633	0.108095	0.195221
	(0.02619)	(0.01942)	(0.03473)	(0.03849)	(0.025364)	(0.055217)	(0.042666)	(0.029539)	(0.058541)
$s_{i,t-3}$	−0.04564	−0.02381	−0.06429	0.023042	−0.0086	−0.01997	−0.02157	−0.03789	−0.04892
	(0.02627)	(0.01964)	(0.03477)	(0.040375)	(0.026607)	(0.057922)	(0.041877)	(0.028993)	(0.057458)
$s_{i,t-4}$	0.053365	0.030083	−0.00912	0.101759	0.013313	0.047388	0.073736	0.008791	0.067014
	(0.02251)	(0.01665)	(0.02982)	(0.03346)	(0.02205)	(0.048002)	(0.033464)	(0.023168)	(0.045915)
$i_{i,t-1}$	−0.04347	0.694041	0.039478	0.048991	0.92218	0.113994	0.188093	0.97931	0.107368
	(0.02798)	(0.02063)	(0.03703)	(0.044497)	(0.029323)	(0.063834)	(0.045429)	(0.031452)	(0.062333)
$i_{i,t-2}$	0.153297	0.009941	−0.0569	0.046829	−0.2146	−0.2517	−0.1781	−0.24669	−0.31001
	(0.03395)	(0.02545)	(0.04474)	(0.060102)	(0.039606)	(0.086221)	(0.063656)	(0.044071)	(0.087341)
$i_{i,t-3}$	−0.13416	−0.06981	−0.04103	−0.02721	0.073794	0.128405	0.074803	0.055635	0.191633
	(0.03374)	(0.0255)	(0.04399)	(0.060516)	(0.039879)	(0.086815)	(0.063465)	(0.043939)	(0.087079)
$i_{i,t-4}$	0.04725	0.048684	−0.06203	−0.0503	−0.04601	−0.15315	−0.02211	0.006589	−0.11158
	(0.02485)	(0.01849)	(0.03295)	(0.04442)	(0.029272)	(0.063724)	(0.04461)	(0.030885)	(0.061209)
Saving coeffs.									
Sum	0.7206	0.1051	0.0690	0.7985	0.0928	0.1264	0.7364	0.0854	0.0627
(*p*-value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.003)	(0.000)	(0.000)	(0.137)
Long-run	—	0.3313	0.0614	—	0.3508	0.1277	—	0.4164	0.0770
(*p*-value)		(0.000)	(0.000)		(0.000)	(0.049)		(0.000)	(0.000)
Inv. Coeffs.									
Sum	0.0229	−1.2246	−0.1205	0.0183	0.7354	−0.1625	0.0627	0.7948	−0.1226
(*p*-value)	(0.347)	(0.000)	(0.000)	(0.582)	(0.000)	(0.001)	(0.026)	(0.000)	(0.001)
Long-run	0.0820	—	−1.0730	0.0909	—	−0.1642	0.2379	—	−0.1506
(*p*-value)	(0.000)		(0.000)	(0.111)		(0.000)	(0.000)		(0.000)
Growth coeffs									
Sum	0.1391	0.1111	0.6829	0.0641	0.0976	0.0109	0.0496	0.1544	0.1858
(*p*-value)	(0.000)	(0.000)	(0.000)	(0.152)	(0.000)	(0.865)	(0.299)	(0.000)	(0.000)
Long-run	0.4977	0.3313	—	0.3182	0.3689	—	0.1882	0.7526	—
(*p*-value)	(0.000)	(0.000)		(0.000)	(0.000)		(0.000)	(0.000)	
# of observations	2527	2516	2517	1250	1250	1250	1140	1140	1140

Notes: See table 4.

TABLE A8.—A DYNAMIC MODEL OF SAVING, INVESTMENT, AND GROWTH WITH CONTROLS: ANNUAL DATA

	OLS Estimates					
	Data Set 2 50 Countries			Data Set 3 38 Countries		
Dependent variable	Saving (1)	Investment (2)	Growth (2)	Saving (1)	Investment (2)	Growth (2)
$g_{i,t-1}$	0.0395	0.10118	−0.0129	0.115431	0.161159	0.244499
	(0.021561)	(0.015078)	(0.031343)	(0.025982)	(0.01871)	(0.03571)
$g_{i,t-2}$	−0.0615	0.003244	−0.05894	−0.12116	0.003105	−0.11978
	(0.022037)	(0.015411)	(0.032035)	(0.027033)	(0.019467)	(0.037155)
$g_{i,t-3}$	0.0125	−0.0028	−0.07862	0.090021	−0.01048	−0.00893
	(0.021872)	(0.015296)	(0.031795)	(0.026989)	(0.019436)	(0.037095)
$g_{i,t-4}$	−0.0816	−0.01957	−0.10144	−0.08338	0.008722	−0.09158
	(0.020683)	(0.014464)	(0.030066)	(0.023726)	(0.017085)	(0.032609)
$s_{i,t-1}$	0.5609	0.051292	−0.01682	0.592706	−0.0055	−0.20505
	(0.030341)	(0.021219)	(0.044106)	(0.034228)	(0.024648)	(0.047044)
$s_{i,t-2}$	0.0207	0.039225	0.029692	0.023903	0.106822	0.183714
	(0.036254)	(0.025354)	(0.052701)	(0.040991)	(0.029518)	(0.056338)
$s_{i,t-3}$	0.0198	−0.00459	−0.01589	−0.02496	−0.03958	−0.04701
	(0.038048)	(0.026608)	(0.05531)	(0.040247)	(0.028983)	(0.055316)
$s_{i,t-4}$	0.0834	0.019516	0.033528	0.066769	0.008833	0.053282
	(0.031796)	(0.022236)	(0.046221)	(0.032189)	(0.02318)	(0.044241)
$i_{i,t-1}$	0.0796	0.915611	0.145244	0.186539	0.975393	0.128329
	(0.042122)	(0.029457)	(0.061231)	(0.043837)	(0.031568)	(0.060251)
$i_{i,t-2}$	0.0804	−0.21331	−0.20919	−0.15349	−0.24368	−0.27482
	(0.056594)	(0.039578)	(0.082269)	(0.0612)	(0.044072)	(0.084115)
$i_{i,t-3}$	−0.0183	0.071711	0.136593	0.06485	0.055111	0.174084
	(0.05696)	(0.039834)	(0.082801)	(0.060977)	(0.043911)	(0.083808)
$i_{i,t-4}$	−0.0777	−0.05136	−0.18688	−0.0282	0.002792	−0.10717
	(0.04194)	(0.02933)	(0.060966)	(0.043007)	(0.03097)	(0.059109)
Publ. Cons.	−0.4036	−0.01541	−0.47864	−0.34153	−0.05409	−0.39928
	(0.037001)	(0.025876)	(0.053787)	(0.035962)	(0.025897)	(0.049427)
Pop 15–65	0.0036	0.000018	0.002508	0.001498	0.000288	0.002026
	(0.000607)	(0.000425)	(0.000883)	(0.00049)	(0.000353)	(0.000674)
Hum. Cap.	−0.0021	−0.00394	−0.00538	−0.00097	−0.00054	−0.00203
	(0.002034)	(0.001422)	(0.002956)	(0.001448)	(0.001042)	(0.00199)
Life Exp.	−0.0020	0.000991	−0.00231	0.000148	0.00033	−0.00127
	(0.000732)	(0.000512)	(0.001065)	(0.000511)	(0.000368)	(0.000702)
Saving coeffs.						
Sum	0.6847	0.1054	0.0305	0.6584	0.0706	−0.0151
(*p*-value)	(0.000)	(0.000)	(0.500)	(0.000)	(0.001)	(0.072)
Long-run	—	0.3802	0.0244	—	0.3354	−0.0154
(*p*-value)		(0.000)	(0.893)		(0.000)	(0.000)
Inv. Coeffs.						
Sum	0.0639	0.7227	−0.1142	0.0697	0.7896	−0.0796
(*p*-value)	(0.050)	(0.000)	(0.016)	(0.012)	(0.000)	(0.039)
Long-run	0.2028	—	−0.0913	0.2041	—	−0.0816
(*p*-value)	(0.000)		(0.000)	(0.000)		(0.000)
Growth coeffs.						
Sum	−0.0911	0.0821	−0.2519	0.0009	0.1625	0.0242
(*p*-value)	(0.046)	(0.010)	(0.000)	(0.985)	(0.000)	(0.723)
Long-run	−0.2891	0.2958	—	0.0027	0.7724	—
(*p*-value)	(0.000)	(0.000)		(0.000)	(0.000)	
# of observations	1250	1250	1250	1140	1140	1140

Notes: See table 4.

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