Uncertainty, investment and economic growth: evidence from a dynamic panel

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Abstract

This paper studies the interactions between uncertainty, investment and economic growth. Utilising panel data for a sample of 59 industrial and developing countries between 1966 and 1992, we estimate reduced form equations to explore the possible effects of uncertainty on economic growth and investments. Uncertainty reduces both investment and growth.

Keywords: growth, investment, uncertainty, dynamic panel

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1 Introduction

A pervading theme of recent theories of economic growth[1] is that something is excluded from the traditional list of growth factors. There are several candidates, but a

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[1]There are now several surveys of the new growth literature. Barro and Sala-i-Martin (1995) continues to serve as an excellent introduction. Temple (1999) surveys the empirical literature.

neglected one is uncertainty. In this paper, we use panel data to examine the issue by estimating reduced form specifications for investment and growth.

The approach pioneered by Solow (1956) and others was based on the assumption that growth followed from three potential sources; increasing capital stock, population and technical efficiency. There were some clear problems with this paradigm, the foremost being that while theory predicted all countries would eventually grow at the same rate, this was refuted by the evidence. Other factors must also be driving growth. This helped start a new literature, aiming to explain this phenomenon.

One explanation is that there is a missing factor of production. Labour supply and capital are important, but there is another, less easily measured factor; human capital, or knowledge. The idea was introduced by Arrow (1962). It was revisited by Romer (1986), who helped to popularise the concept, and added the idea that knowledge has spillover effects.[2] Uncertainty is relevant here because investment in knowledge is likely to be affected by risk. We examine this further below.

Of course, many previous studies have explored the determinants of economic growth. Factors examined include political, public finance, trade and other macroeconomic variables. The majority of those studies conclude that the most robust effect is the positive relationship between investment and the growth rate of output (see for example Levine and Renelt, 1992). Indeed, the new growth theory further emphasises the role of investment in the growth process (e.g. Romer 1986, 1987; Lucas, 1988).

A relatively recent theoretical literature has increased understanding of the role played by uncertainty in shaping the investment decisions (Dixit and Pindyck (1994)). It is now well known that the combination of the typically irreversible nature of investment, uncertainty about the future benefits or costs of the investment project, and some flexibility about investment timing, may have a substantial impact on the investment behaviour (Chirinko (1996)). Specifically, then there may be a gain to be achieved by waiting in an uncertain environment. The decision not to invest is equiv-

[2] Other issues, not explored here, include the role of public capital (Barro (1990)), and the conundrum of constant or increasing returns to capital and the convergence puzzle.

alent to the purchase of an option. By not investing, we forego an expected profit stream, but this enables us to make more profitable choices in the future.[3] Analysis has concentrated on physical investment but the insights apply to investment in knowledge, which is arguably still more reversible (given the absence of a market to trade information). Thus we would expect uncertainty to affect growth through the impact on physical investment and also via unobserved investment in knowledge. Additionally, although this is less emphasised, uncertainty also affects conditional factor demands, and will further require resources off-setting its effects (for example, for insurance and inventories) which will reduce output.

Contrary to common opinion, theory does not lead to any clear-cut conclusions regarding the impact on investment, so that the importance of uncertainty is clearly an empirical matter. Two empirical studies (Caballero and Pindyck (1993) and Pindyck and Solimano (1993)) found a positive correlation between the threshold value of the marginal revenue product of capital (in principle a function of uncertainty) and its variance, whilst Ferderer (1993) found a negative impact of uncertainty on investment. Three UK studies, despite different theoretical frameworks and measures of uncertainty, concluded that uncertainty reduces investment (Driver and Moreton (1991) and Price (1995, 1996)); while Asteriou and Price (2000) established a strong negative correlation between political uncertainty and UK growth.

Cross-sectional studies examining the role of uncertainty on investment and growth rates include those of Alesina and Perotti (1993) which found social and political instability affects investment negatively. Negative effects of uncertainty on economic growth have been found by Aizenman and Marion (1993), and Todd (1996). However, none of these studies uses the dynamic panel techniques we employ. Much of the growth literature emphasises political instability as a source of uncertainty. For example, in a recent paper Brunetti (1998) provides a comparative test of different measures of policy volatility in cross-country growth regressions and concludes that

[3] However, Abel *et al* (1996) emphasise that investment also has a value as a *call* option, as there may be limits on 'expandability' in the future.

these measures are negatively related to economic growth.[4] Some studies exist that look at volatility and investment, but only a limited number examine growth. Bleaney (1994) looks at aggregate South African investment, as does Fielding (1997). Other authors have explored political events and financial market measures: for example, Gemmill (1992) and Clarke (1997).

There are also methodological issues. Use of a country panel of the type we use raises some important econometric methodological issues that are not always fully appreciated. There has been an increasing interest in the use of panel data in macroeconomics, removed from the micro and labour based areas in which panels have traditionally been analysed. Country panels tend to have dimensions in T and N of roughly equal orders. As static models are rarely adequate for typical time series, dynamic models are usually appropriate. The small T problems with dynamic panels[5] are not relevant here as the fixed-effects problem from the initial conditions declines rapidly as T rises. But instead, there are profound problems that result from heterogeneity in the model parameters that emerge as soon as a lagged dependent variable is introduced.[6] This problem was forcefully addressed by Pesaran and Smith (1995). Unlike in static models, estimates are inconsistent even in large samples. Happily, in typical data sets (including our own) T is sufficiently large to allow individual country estimation. Pesaran and Smith observe that while it is implausible that the dynamic specification is common to all countries, it is at least conceivable that the long-run parameters of the model may be common. We can then exploit the cross-sectional dimension to gain more precise estimates of these average long-run parameters. They then propose estimation by either averaging the individual country estimates,[7] or by pooling the long-run parameters,[8] if the data allows; this is the method we adopt, although we compare the results with those from (inconsistent) conventional estimators.

In this paper, then, we examine the effects of uncertainty on investment and economic

[4] See also Barro (1996) and Easterly and Rebelo (1993).

[5] Arellano and Bond (1991).

[6] See Hall and Urga (1998) for a recent survey and analysis of some panel estimation issues that are relevant to the case we consider here.

[7] The 'mean group' (MG) method.

[8] The 'pooled mean group' (PMG) method.

growth using a panel of 59 industrial and developing countries. We measure uncertainty as the conditional variance of output and we explicitly examine its effects on investment and growth rates, both for all countries and for different sub-sets of countries with similar characteristics. The plan of the paper is as follows. Section 2 specifies the model and presents the econometric methodology. The results are presented in Section 3. Some conclusions are drawn in the final section.

2 Specification and methodology

2.1 A simple econometric model

We employ a standard log-linear production function. Temporarily suppressing time and cross-country indices,

$$Y = AK^{\alpha}L^{\beta} \tag{1}$$

where Y is output, K is capital, L is labour and A denotes the level of 'technology', total factor productivity. Taking logarithms of (1) and assuming constant returns to scale,

$$(y - l) = a + \alpha(k - l) \tag{2}$$

where lower case letters denote logs. Total factor productivity growth is assumed to have a deterministic component, a_0, but is also affected by the level of uncertainty (h) which affects the level of investment in 'knowledge'. Thus in growth rates,

$$\Delta(y - l) = a_0 + a_1 h + \alpha\Delta(k - l). \tag{3}$$

Denoting per capita variables as $\hat{y}$ and $\hat{k}$ and introducing an error term,

$$\Delta\hat{y}_{i,t} = a_{0,i} + a_{1,i}h_{i,t} + \alpha_i\Delta\hat{k}_{i,t} + \epsilon_{i,t}. \tag{4}$$

We first estimate (4) using the traditional but inappropriate pooled methods. We then use the Mean Group (MG) and Pooled Mean Group (PMG) estimators,[9]) with a dynamic ECM equation that has (4) as a long-run solution.

[9] Described below.

2.2 Econometric methodology: Dynamic hetereogeneous panels

The data set we are examining covers 59 countries ($N = 59$) over 28 ($T = 28$) years. Such data sets[10] raise special problems in estimation. Pesaran and Smith (1995) show that, unlike in static models, pooled dynamic heterogeneous models generate estimates that are inconsistent even in large samples.[11] In the type of data set we are considering T is sufficiently large to allow individual country estimation. Nevertheless, we may still be able to exploit the cross-section dimension of the data to some extent. Pesaran and Smith observe that while it is implausible that the dynamic specification is common to all countries, it is at least conceivable that the long-run parameters of the model may be common. They propose estimation by either averaging the individual country estimates,[12] or by pooling the long-run parameters, if the data allows, and estimating the model as a system.[13] The latter combines the efficiency of pooled estimation while avoiding the inconsistency problem flowing from pooling heterogeneous dynamic relationships. It is the latter method we apply.

The unrestricted specification for the system of ARDL equations for $t = 1, 2, \ldots, T$ and $i = 1, 2, \ldots, N$ is

$$y_{it} = \sum_{j=1}^{p} \lambda_{ij} y_{i,t-j} + \sum_{j=1}^{q} \delta'_{ij} x_{i,t-j} + \mu_i + \varepsilon_{it} \tag{5}$$

where $x_{i,t-j}$ is the $(k \times 1)$ vector of explanatory variables for group i and μ_i are the fixed effects. In principle the panel can be unbalanced and p and q may vary across

[10] Termed 'data fields'; Quah (1993).

[11] The problem cannot be solved by extending the sample, as it flows from heterogeneity: extending the dimension of the cross-section increases the problem. Baltagi and Griffin (1997) argue that the efficiency gains of pooling the data outweigh the losses from the bias induced by heterogeneity. They support this argument in two ways. Firstly, they informally assess the plausibility of the estimates they obtain for a model of gasoline demand using different methods including the mean group method discussed below. This is hard to evaluate as it relies upon a judgement about what is 'plausible'. Monte Carlo simulations would make the comparison clearer. Secondly, they compare forecast performance. However, this is a weak test to apply to the averaging technique, which is designed only to estimate long-run parameters and not the short-run dynamics. Baltagi and Griffin do not consider the other method introduced by PSS, the PMG.

[12] Pesaran, Shin and Smith (1998) (PSS) refer to this as the mean group estimator (MG).

[13] The pooled mean group estimator (PMG).

countries. (5) can be reparameterised as a VECM system.

$$\Delta y_{it} = \theta_i(y_{i,t-1} - \beta_i' x_{i,t-1}) + \sum_{j=1}^{p-1} \gamma_{ij} \Delta y_{i,t-j} + \sum_{j=1}^{q-1} \gamma_{ij}' \Delta x_{i,t-j} + \mu_i + \varepsilon_{it} \tag{6}$$

where the β_i are the long-run parameters and θ_i are the equilibrium (or error) correction parameters. The pooled mean group restriction is that the elements of β are common across countries:

$$\Delta y_{it} = \theta_i(y_{i,t-1} - \beta' x_{i,t-1}) + \sum_{j=1}^{p-1} \gamma_{ij} \Delta y_{i,t-j} + \sum_{j=1}^{q-1} \gamma_{ij}' \Delta x_{i,t-j} + \mu_i + \varepsilon_{i,t}. \tag{7}$$

Estimation could proceed by OLS, imposing and testing the cross-country restrictions on β. However, this will be inefficient as it ignores the contemporaneous residual covariance. A natural estimator is Zellner's SUR method, which is a form of feasible GLS. However, SUR estimation is only possible if N is smaller than T. Thus PSS suggest a maximum likelihood estimator.[14]

There are also issues of inference. PSS argue that in panels omitted group specific factors or measurement errors are likely to severely bias the country estimates. It is a commonplace in empirical panel to report a failure of the 'poolability' tests based on the group parameter restrictions.[15] So PSS propose a Hausman test. This is based on the result that an estimate of the long-run parameters in the model can be derived from the average (mean group) of the country regressions. This is consistent even under heterogeneity. However, if the parameters are in fact homogeneous, the PMG estimates are more efficient. Thus we can form the test statistic

$$H = \hat{q}'[var(\hat{q})]^{-1}\hat{q} \sim \chi_k^2$$

where $\hat{q}$ is a $(k \times 1)$ vector of the difference between the mean group and PMG estimates and $var(\hat{q})$ is the corresponding covariance matrix. Under the null that the two estimators are consistent but one is efficient, $var(\hat{q})$ is calculated as the difference

[14] This is implemented in a GAUSS procedure, downloadable as JASA.EXE, made available at Hashem Pesaran's website. We use this software in estimation, and are grateful to the authors for making it available.

[15] For example, Baltagi and Griffin (1997, p 308) states that although the poolability test is massively failed (F(102,396) = 10.99; critical value about 1.3), 'like most researchers we proceed to estimate pooled models.'

between the covariance matrices for the two underlying parameter vectors. If the poolability assumption is invalid then the PMG estimates are no longer consistent and we fail the test.

3 Empirical results

We use data for GDP per capita (worker) and capital per capita taken from the Penn World Tables.Prior to estimation of the main model, we estimate GARCH(1,1) models for GDP per capita growth in order to obtain the variance series, used as uncertainty proxies in the subsequent analysis.

3.1 Traditional panel data estimation

We begin with traditional panel data techniques, fixed effects and random effects. We know these to be inappropriate, but they are nevertheless widely used in the literature. We report them partly to illustrate how misleading they may be. The results are presented in Table 1. We present estimates of equation (4) for three alternative cases: first, assuming that the constant in the model is common and homogeneous for all countries, which is a rather restrictive assumption; second, assuming fixed effects; and third, assuming the existence of random effects.[16] In all cases (see panels A, C and D of Table 1) the reported coefficients are similar and apparently significant. Where capital growth is included, the uncertainty proxy enters the equation negatively, so that higher levels of uncertainty are associated with lower levels of growth. Capital growth has the expected positive sign. However, when we exclude the growth rate of capital per capita term from the equation, the uncertainty proxy coefficients obtained are positive and highly significant (see panels B, D and F of Table 1). This implies investment is increasing in uncertainty. But regressions of the growth rate of capital on uncertainty[17] reveal that uncertainty has a significant negative impact. These results are therefore hard to interpret.

[16] The country specific constants have been omitted from Table 1.
[17] Not reported.

Table 1: Traditional Panel Data Estimation

	Common Constant		Fixed Effects		Random Effects	
Variable	**A**	**B**	**C**	**D**	**E**	**F**
constant	0.01 (12.6)	0.01 (5.13)			0.01 (8.5)	0.02 (9.7)
$h_{i,t}$	-0.10 (-5.7)	0.63 (13.5)	-0.06 (-2.6)	0.92 (13.5)	-0.08 (-4.1)	0.48 (14.0)
$\Delta\hat{k}_{i,t}$	0.12 (7.2)		0.10 (6.4)		0.11 (6.7)	
R^2	0.05	0.08	0.14	0.11	0.13	0.05

t-statistics in parentheses in this and subsequent tables.

3.2 Mean Group and Pooled Mean Group estimates

In this section we report the results of the MG and PMG methodology. Table 2 shows the effects of uncertainty on GDP per capita growth in three cases. These are: pooling only the effect of uncertainty; pooling only capital; pooling both uncertainty and capital. The results show that the Hausman test rejects pooling of the long-run variance term, but accepts pooling of the capital stock effect. The joint test in Panel C accepts, but the individual test rejects. Thus the key results are in panel B.[18] The PMG coefficient on Δk is on the small side but correctly signed and significant.[19] The impact of uncertainty is apparently large, but the variance terms are small. The (average) error correction coefficients reported show adjustment is rapid, 93% occurring within one year. Compared to the traditional pooled estimates, the variance effect is larger by two orders of magnitude. Thus the standard panel estimators are highly misleading.

Table 2 shows the effect of uncertainty over and above that working through investment, while Table 3 reports the direct impact on investment. The PMG specification is easily accepted by the Hausman test. As discussed above, the impact of uncertainty is ambiguous, but we expect a negative coefficient; this is the case.

[18] The inefficient MG results are given for comparison. In these, the Δk term is incorrectly signed but insignificant.

[19] As usual in growth studies, one has a potential difficulty interpreting these results, as the equation is specified in first differences. These are marginal effects we are observing.

Table 2: MG and PMG Estimates: Dependent Variable Output Growth

A. Common parameter on h					
	PMG Estimates		**MG Estimates**		
variable	**coef.**	**t-ratio**	**coef.**	**t-ratio**	**h-test**
Common Long-run Coefficients					
h	-0.061	-1.891	-26.618	-1.967	3.85[0.05]
Unrestricted Long-Run Coefficients					
Δk	0.086	1.323	-0.214	-0.487	–
Error Correction Coefficients					
ϕ	-0.952	-32.988	-0.926	-22.300	–
B. Common parameter on Δk					
	PMG Estimates		**MG Estimates**		
variable	**coef.**	**t-ratio**	**coef.**	**t-ratio**	**h-test**
Common Long-run Coefficients					
Δk	0.061	3.324	-0.214	-0.487	1.19[0.27]
Unrestricted Long-Run Coefficients					
h	-10.325	-1.762	-26.618	-1.967	–
Error Correction Coefficients					
ϕ	-0.929	-25.798	-0.926	-22.300	–
C. Common parameter on Δk and h					
	PMG Estimates		**MG Estimates**		
variable	**coef.**	**t-ratio**	**coef.**	**t-ratio**	**h-test**
Common Long-run Coefficients					
Δk	0.160	7.949	-0.214	-0.487	2.21[0.14]
h	-0.027	-1.019	-26.618	-1.967	3.86[0.05]
Joint Hausman test : 3.89[0.14]					
Error Correction Coefficients					
ϕ	-0.945	-35.920	-0.926	-22.300	–

Table 3: MG and PMG Estimates: Dependent Variable Capital Growth

	PMG Estimates		**MG Estimates**		
variable	**coef.**	**t-ratio**	**coef.**	**t-ratio**	**h-test**
h	-5.956	-4.310	-316.0	-1.003	0.97[0.33]
Error Correction Coefficients					
ϕ	-0.345	-5.972	-0.414	-7.409	–

3.3 Results for industrialised and developing countries

The Hausman tests above support (restricted) pooling across all countries. However, it is highly plausible that developing and developed countries differ structurally, even if our test is insufficiently powerful to pick this up. Recall that in the previous section we found that the long-run capital coefficient could be pooled but not the variance term. This is consistent with the existence of a common production structure between countries, but differing financial systems (which affect the impact of uncertainty on agents). [20] We therefore split the sample into 37 developing and 22 industrial countries.[21]

The results are presented in Table 4. We report the PMG results suggested by the Hausman test. For industrial countries, once again only the pooling Δk restriction is accepted. Perhaps surprisingly but consistent with the tests for poolability from the previous section, the point estimates are very similar to those reported for the whole sample. The main difference is that the precision of the estimates falls. For developing countries we cannot reject poolability for both coefficients but this may be due to the less well- determined coefficients on uncertainty for developed countries. Pooling only the Δk terms produces estimates for both parameters similar to the developing results. We conclude from this that it is indeed appropriate to pool the capital stock terms for all countries, but not the uncertainty terms.

3.4 Reduced forms and robustness

As a further check for robustness, we estimated equations for both sub-samples which included either only the uncertainty measure or only the growth rate of capital.[22] As expected, given the negative impact of uncertainty on growth conditional on capital

[20]Theoretical and empirical research tends to support the idea that growth is determined by financial development.

[21]**Industrial Countries:** Austria, Australia, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Iceland, Italy, Japan, Luxembourg, Netherlands, Norway, New Zealand, Portugal, Spain, Sweden, UK, USA. **Developing Countries:** Argentina, Bolivia, Botswana, Chile, Colombia, Czechoslovakia, Dominican Republic, Ecuador, Guatemala, Hong Kong, Honduras, India, Iran, Israel, Ivory Coast, Jamaica, Kenya, Korea, Madagascar, Malawi, Mauritania, Mauritius, Mexico, Nigeria, Oman, Panama, Paraguay, Peru, Philippines, Sri Lanka, Sierra Leone, Syria, Thailand, Turkey, Yugoslavia, Zambia, Zimbabwe.

[22]Detailed results not presented.

Table 4: Sub-Samples; Dependent Variable Output Growth

A. Common parameter on h						
	Industrial			**Developing**		
variable	**coef.**	**t-ratio**	**h-test**	**coef.**	**t-ratio**	**h-test**
Common Long-run Coefficients						
h	-28.39	-1.954	5.74[0.02]*	-0.063	-1.944	1.61[0.20]
Unrestricted Long-Run Coefficients						
Δk	0.003	0.027	–	0.180	2.555	–
Error Correction Coefficients						
ϕ	-0.981	-24.241	–	-0.934	-24.599	–
B. Common parameter on Δk						
variable	**coef.**	**t-ratio**	**h-test**	**coef.**	**t-ratio**	**h-test**
Common Long-run Coefficients						
Δk	0.060	1.571	0.29[0.59]	0.104	4.706	1.25[0.26]
Unrestricted Long-Run Coefficients						
h	-11.491	-0.899	–	-9.936	-1.620	–
Error Correction Coefficients						
ϕ	-0.938	-25.478	–	-0.921	-17.806	–
C. Common parameter on Δk and h						
variable	**coef.**	**t-ratio**	**h-test**	**coef.**	**t-ratio**	**h-test**
Common Long-run Coefficients						
Δk	0.013	0.360	0.01[0.93]	0.187	7.878	1.76[0.18]
h	-7.630	-3.558	6.23[0.01]	-0.023	-0.855	1.61[0.20]
Error Correction Coefficients						
ϕ	-0.952	-28.247	–	-0.933	-25.300	–

growth and the negative impact on capital growth itself, there is a negative relationship between growth and uncertainty in both cases. The estimated coefficients were -0.360 for the industrial and -0.053 for the developing countries, although only the latter was significant (t-statistics -0.217 and -1.985). In both cases the PMG estimates were accepted. For the effect of capital growth on output, we found PMG coefficients of 0.193 (insignificant) for industrial countries and 0.051 (significant) for developing. For the effect of uncertainty on investment, the PMG results revealed a significant negative relationship for both sub-groups, with higher negative magnitudes for the industrial countries (-3.280) comparing to the the developing countries (-0.081) (t -1.931 and -2.065). Finally, we also estimated the aggregated relationships using the (inefficient) OLS estimator. The ML estimator is clearly to be preferred, but we would have been concerned had the OLS results radically differed. In fact, they did not.

4 Conclusions

A neglected aspect of cross country growth studies is uncertainty, modelled here as the conditional variance of output. In theory, this may have indirect effects via investment and other effects working through unobservable investments in knowledge and possibly other factors. We use panel date with a dynamic specification, which raises methodological issues that are often neglected. We use the Pooled Mean Group estimator developed by Pesaran, Shin and Smith (1998), testing for the degree to which we can pool the long-run coefficients with a Hausman-type test. Utilising data for a sample of 59 industrial and developing countries between 1966 and 1992, we estimate reduced form equations to explore the possible effects of uncertainty on investment and economic growth. We find that uncertainty reduces both investment and growth. Countries possess a common production structure, but there is a heterogeneity in the impact of uncertainty on growth. The results also show that the use of conventional panel techniques in dynamic models characterised by heterogeneity can be highly misleading; the results on the effect of uncertainty differ by an order of magnitude.

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