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Abstract:

This paper argues that excessive financial development in combination with high levels of technological innovation or R&D activities may lead to the former being ineffective in generating economic growth. This hypothesis is examined through a dynamic panel analysis using two measures of financial development, in conjunction with R&D expenditure, for 36 OECD and non-OECD countries. Using a range of panel data estimators, our results show that the relationship between financial development and economic growth is not straightforward; rather, it is conditional upon the level of R&D. Further, we find that a high level of R&D is associated with a weak or negative effect of financial development on economic growth.

JEL Classification: E44, G21, O32, O40

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1. Introduction

Until the recent world financial crisis, the dominant view in the finance-growth literature was that more financial development results in higher levels of economic growth, mainly through its impact on productivity growth (King and Levine, 1993a, 1993b; Levine, 1997; Beck et al, 2000a; Benhabib and Spiegel, 2000; Aghion et al, 2005; Ang, 2008). Further, it was largely accepted that high levels of financial development reflect sound policies and institutions. However, recent evidence has altered our thinking by showing that countries at the heart of the financial crisis may have financial systems that are "too large" and these exist not because of good policies and institutions, but rather because of poor regulatory systems (Arcand et al, 2012). Consequently, some recent literature argues that excessive financial development is an amplifying factor behind the financial crisis and negative growth (Ductor and Grechyna, 2011; Arcand et al, 2012). To examine this, available empirical studies generally either split the sample over different time periods to show the effects of financial crises or use nonlinear methods to identify the optimal level of financial development beyond which its effect on growth changes (Rousseau and Wachtel, 2011; Arcand et al, 2012; Ductor and Grechyna, 2011).

However, "too much finance" may be associated with technological advancement that leads financial intermediaries to compete in innovations in the form of new financial instruments, new corporate structures, the formation of new financial institutions, or developing new accounting and reporting techniques or methods (Michalopoulos et al, 2009). Consequently, such innovations may alter the nature of the financial sector by expanding its operations beyond its typical domain, thus exposing it to higher risk that may result in a crisis and leaving a negative impact on growth (see Rajan, 2005; Palmerio, 2009). Related to this, empirical evidence suggests that as an economy approaches its productive capacity, adding more financial development may have a weaker or even negative effect on growth (Aghion et al, 2005; Ductor and Grechyna, 2011).

There are numerous theoretical and empirical studies which show a positive and significant relationship between R&D and economic growth, particularly expenditures on industrial R&D are considered as one of the most important determinants of total factor productivity and thus output growth (Aghion and Howitt, 1992; Coe and Helpman, 1995; Coe et al, 2009). However, technological growth has a strong positive link with financial innovation, leading to a very high correlation (around 99%) between productivity growth in the financial and manufacturing sectors (Michalopoulos et al, 2009). Nevertheless, technological innovation may proxy the role of other variables. In particular, if countries with a high level of technological innovation also have low level of financial regulation, so that the apparent role of technological innovation may result from a complex set of effects.

This paper contributes to the finance-growth literature by examining the role financial development on growth conditional on a measure of R&D. Hence, besides looking at the direct effects of financial development and R&D on growth, we address two important questions: whether the growth effect of financial development is conditional on the level of R&D; and whether a high level of R&D is associated with an apparently weak or negative effect of financial development on growth. We investigate these questions by employing a multiplicative interaction model, where the effect of interaction between technological innovation and financial development on economic growth is analysed. We use a panel data of 36 countries (26 OECD and 10 non-OECD) over the period 1980-2006 to explore this conditional effect and employ a variety of panel data techniques. Our results show technological/financial interactions to be important for growth, with financial development having negative effects on growth for high levels of R&D expenditure.

The structure of our paper is as follows: Section 2 reviews the literature related to finance, innovation and growth. Section 3 then discusses the data and econometric methods used in this study. Section 4 provides the substantive results, with concluding remarks provided in Section 5.

2. Literature Review

As already noted in the Introduction, the debate on the finance-growth relationship has recently taken a new turn by considering the roles of technological innovation, financial innovation, financial liberalization and financial crises. Moe specifically, excessive financial development or financial innovation may increase the probability of a financial crisis and weaken the effect of financial development on growth (Arcand et al, 2012; Rousseau and Wachtel, 2011). After a brief review of the literature on financial development and growth, this section discusses recent work on the role of technological innovation and then develops the testable hypotheses examined in this study.

2.1. Financial Development and Economic Growth

Following Schumpeter (1934), a substantial literature argues that well-functioning banks spur innovation in technology and products by channelizing funds to their most productive use and hence generating higher growth (McKinnon, 1973; King and Levine, 1993; Levine, 1997). In particular, the endogenous growth literature argues that finance reduces informational frictions and generates an external effect on aggregate investment efficiency which in turn offsets the notion of decreasing marginal productivity of capital (Greenwood and Jovanovic, 1990; Bencivenga and Smith, 1991). Using cross-sectional data for 80 countries over the period 1960-1989, the findings of King and Levine (1993a) re-emphasize the Schumpeterian view that finance stimulates economic growth through increasing the rate of capital accumulation and its efficiency. Further, albeit with some exceptions, most of the literature on financial structure supports the financial services view that both banks and stock markets are important to economic growth (Arestis and Demetriades, 1997; Rousseau and Wachtel, 2000; Beck *et al*, 2000b; Beck and Levine, 2002; Beck and Levine, 2004).

Recent research, however, indicates the relationship between financial development and economic growth is non-linear. For example, Rioja and Valve (2004) find that the relationship varies across the level of financial development. That is, it is positive and significant when financial development is in the middle or high regions, with the effect being larger in the former case. However, they find ambiguous results when levels of financial development are low. Similarly, Deidda and Fattouh (2002) show that a positive and significant relationship between the level of financial depth and growth holds only for countries with higher per capita income, whereas no such relationship exists for a low income group. Aghion et al (2005) finds some threshold level of financial development above which the countries converge to the growth rate of the world technology frontier, whereas all other countries have strictly lower long-run growth. Recently, Yilmazkuday (2011) finds threshold levels of inflation, government size, openness and income above and below which the finance-growth relationship changes.

Other studies explore the channels of productivity growth, physical capital accumulation, human capital accumulation, and inflation. These studies document that the main channel through which financial development affects economic growth is productivity growth rather than capital accumulation (Beck et al, 2000a; Benhabib and Spiegel, 2000; Calderon and Liu, 2003; Rousseau and Wachtel, 2002). Similarly, many studies incorporate the effects of overall legal environment and financial regulations in the discussion of finance-growth relationship (Levine et al, 2000; Beck et al, 2000b; Beck and Levine, 2002).

A new wave of emerging literature incorporates the effect of financial crises. For example, Rousseau and Wachtel (2011) observe a positive and strong relationship between financial deepening and growth over 1960-1989, whereas a weak and even negative relationship is observed for more recent data (1990-2004). They argue that financial deepening has a positive effect on economic growth only if it is not excessive. Otherwise it results in credit booms that may weaken the overall banking system and increase inflation even in the developed countries, thus leading to a financial crisis. Further, they argue that the weak relationship in recent years may be the result of financial crises.

Another important study is Arcand et al (2012), who find there is a threshold level of private credit (estimated as 110% of GDP) below which the effect of financial development on growth is positive, whereas it is negative above it. This non-monotonic relationship between financial development and economic growth is consistent with their hypothesis that there can be “too much” finance.

2.2. The Role of Technological Innovation

In addition to finance-growth, the innovation-growth nexus is examined in a number of studies. Recent models (Aghion and Howitt, 1992; Howitt and Aghion, 1998) show that any subsidy to capital accumulation, whether physical or human, leaves permanent effects on the economic growth rate. Consequently, they recognize capital as an input to R&D as R&D contains a great deal of physical capital in the form of laboratories, offices, plants, computers and other scientific instruments etc. Empirical evidence (for example, Coe and Helpman, 1995; Coe et al, 2009) is consistent with this, also showing that the effects of industrial R&D expenditures are larger and positive on economic growth, especially on total factor productivity, as compared with public R&D.

A few studies emphasize the role of financial markets in promoting innovation through external-financing of innovative firms, leading to the conclusion that well-developed financial systems lower the cost of investing in productive technologies or innovative activities, and hence promote economic growth (King and Levine, 1993b; Rajan and Zingales, 1998; Ilyina and Samaniego, 2011).

Morales (2003) is the first to explicitly model the conceptual relationship between the researcher and the provider of funds in a model of endogenous technological change with moral hazard. She argues that research productivity is determined in the credit market and may be affected by financial variables as financial intermediaries use their monitoring power to force researchers to exert a higher level of effort. Hence any subsidy given to the financial sector may enhance R&D activity, thus leading the economy to a faster balanced growth path. Further, a subsidy given to the financial sector may be more effective than a direct subsidy to research. That is, a direct subsidy to research may cause a problem of moral hazard and incur higher monitoring costs and lower R&D productivity that may lead to a negative growth effect. Her finding also implies that financial sector development and innovation are substitutes in promoting economic growth.

Recognizing the importance of financial liberalization in finance-growth analysis, Ang (2011) focuses on the channel of knowledge accumulation through which financial development and financial liberalization may affect economic growth. He shows that financial deepening has a positive and significant impact on knowledge accumulation in advanced as well as developing economies, whereas financial liberalization policies have a negative impact on knowledge accumulation in developing countries. This negative effect may be due to financial crises and volatility. These findings are consistent with the view that financial development reduces monitoring costs and moral hazard problems which results in innovative production (Aghion et al, 2005).

Similarly, Michalopoulos et al (2009) highlight a positive and strong relationship between technological innovation and financial innovation, where the former increases the returns to financial innovation. That is, improved screening methodology generates monopoly rents for a financier, as for a successful innovator. However, given a technological innovation existing screening methodologies become obsolete in identifying promising entrepreneurs, thus driving financiers to invent and develop specialized investment banks, new contracts, and more detailed reporting standards for better monitoring and evaluation of high-tech firms. Therefore, economic growth eventually stagnates in the absence of financial innovation, irrespective of the initial level of financial development. Their empirical results show that a faster rate of financial innovation accelerates the rate at which an economy converges to the growth rate of the technological leader. Further, their results are consistent with the view that innovations in the real and financial sectors are strongly and positively correlated.

2.3. Building Testable Hypotheses

The above discussion suggests that interactions between the financial and innovation sectors play an important role in understanding the finance-growth relationship. It further suggests that the effect of financial development on growth is not straight-forward, but rather may be conditional on the level of technological innovation, which in turn may proxy other (missing) variables and specifically the regulation of new financial instruments. In this light, we study the interactive effect of financial development and technological innovation on growth, rather than focusing on their direct effects. For this purpose we use a measure of R&D to proxy technological innovation, together with its interactions with financial development, in order to study economic growth. This analysis sheds light on how the growth effect of financial development changes with the level of technological innovation. Further, as implied by the above discussion, a negative sign is anticipated on the coefficient of our interaction tem, so that to suggest that as innovation increases the growth effect of financial development decreases. To summarize, our testable hypotheses are as follows:

(i) the relationship between financial development and economic growth is conditional on the level of technological innovation or R&D;

(ii) a high level of technological innovation or R&D is associated with a weak or negative effect of financial development on economic growth, since technological innovation proxies the effects of complex financial innovations that are poorly regulated.

3. Data and Methodology

3.1 Data

Our dynamic panel analysis examines five year averages of growth in 36 countries (26 OECD and 10 non-OECD)[1] over 1980-2006[2], leading to period averages for t = 1, 2, …, 5. As usual, five year averages are used to control for business cycle effects. Data availability, specifically for R&D, dictates the countries selected and time period studied. Economic growth is measured by percentage per capita GDP growth (GROWTH), with the initial value of (log) real per capita GDP (Y0) included to control for convergence and average years of schooling (SCHL) and investment share of GDP (INV) included to allow for conditional convergence (Barro, 1991; Mankiw et al, 1992). Y0 is found to be significant in a wide range of specifications in the empirical growth literature, while the positive growth effect of INV is robust in the literature on growth (Levine and Renelt, 1992). Hence, in all of our specifications these three variables (Y0, SCHL and INV) are included as conditional variables. For further robustness, we also include the following control variables in our basic model: openness (OPEN), government size (GOV), and inflation (INFL). The definitions and sources of all variables used are given in Appendix A, Table A2, while the detail of financial development and R&D measures are given in the following two sub-sections.

[1] List of countries is given in Appendix Table A1.
[2] Five year averages are calculated over the period 1981-2006: 1981-1985, 1986-1990, 1991-1995, 1996-2000, and 2001-2006. The observation of 1980 is used as a proxy of initial per capita real GDP (Y0) for first average over the period 1981-1986. Although we mention five year averages, the last average is based on six years due to data availability.

3.1.1 Measures of Financial Development

To examine the conditional effects of financial development on economic growth we use combined indices of financial development rather than individual measures, for a number of reasons. First, there is no single measure that exhibits all the functions performed by a well-developed financial system. Second, according to the financial services view, overall financial development is important to promote economic growth rather than banking sector or stock market development. Third, empirical evidence supports use of these indexes (Beck et al, 2000b; Beck and Levine, 2002; and Chang et al, 2005). Four, our main objective is to investigate the conditional effects of financial development on economic growth rather than examining the relative importance of banks or stock markets.

Following Beck et al (2000b), Beck and Levine (2002), and Chang et al (2005), we use two indices, Finance Activity and Finance Size. Finance Activity (FA) measures the overall activity in the financial sector and is constructed as the log of the product of Private Credit (value of private credit by deposit money banks as a percentage of GDP) and Trading Value (value of the total shares traded at stock exchanges as a percentage of GDP). Private Credit has certain advantages over other monetary aggregates, as it excludes credit allocation to the public sector, thus representing more accurately the role of financial intermediaries in channelling funds to private market participants. This is the most comprehensive measure of activity of financial intermediaries which is closely related to investment efficiency and economic growth. However, it can be a poor indicator of financial development, especially in industrial countries which have experienced substantial non-bank financial innovation. Nevertheless, bank-based and non-bank-based measures are positively correlated, with the impact of size being variable (Gregorio and Guidotti, 1995). Trading Value represents the activity of stock market trading volume as a share of GDP and indicates the degree of liquidity provided by stock markets to economic agents rather than its size. Despite some demerits, theoretical and empirical studies on finance-growth analysis consider it an important measure of stock market development (Levine and Zervos, 1998; Beck et al, 2000b; Rousseau and Wachtel, 2000).

Finance Size (FS) measures the overall size of the financial sector and is constructed as the log of the sum of Private Credit and Market Capitalization (value of listed shares, as a percentage of GDP). Although Market Capitalization indicates the size of the stock market relative to the economy, past studies show that it is not a good predictor of economic growth when used as a single measure (Levine and Zervos 1998; Beck et al, 2000b; Rousseau and Wachtel, 2000).

3.1.2 Measuring Technological Innovation

Innovation may be defined as novelty or the creation of something qualitatively new using the processes of learning and knowledge accumulation. Although inherently difficult to measure, it is often proxied by R&D expenditure (Helpman, 2004; Greenhalgh and Rogers, 2010).

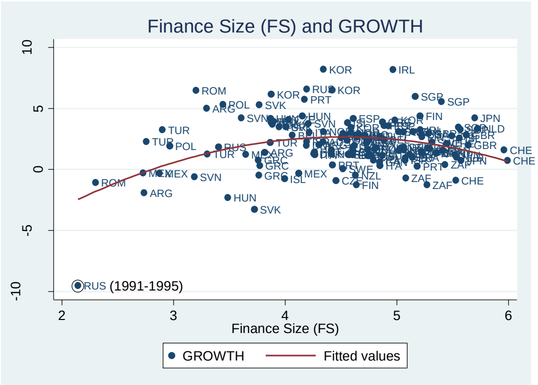
More precisely, our measure of technological innovation is business enterprise expenditures on R&D financed by industry as percentage of GDP (denoted simply as R&D), which measures both innovation and imitating activities. Further, industrial R&D is most closely related to the creation of new products, production techniques, and country‘s innovation efforts as compared to government and higher education R&D. Past empirical studies recognize the importance of R&D in explaining total factor productivity, being an important determinant of economic growth (Coe and Helpman, 1995; Coe et al, 2009).

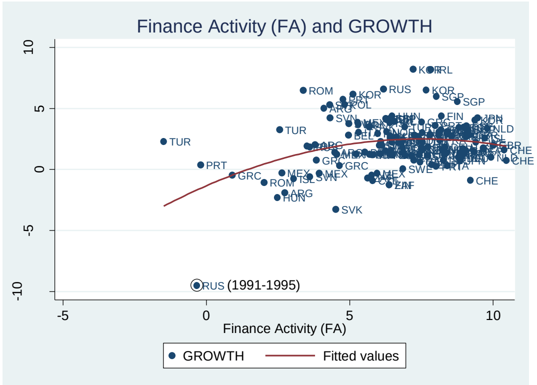
3.1.3 Preliminary Analysis

Simple correlations (Appendix Table A3) show that both measures of financial development are positively related to growth. However, their scatter plots imply that the relationship is not linear, with a positive slope for initial levels of financial development, whereas is flat or possibly has negative slope at higher levels; see Figure 1(a) and 1(b). Further, R&D intensity is positively related to growth, but with apparently weak relationships; see Figure 1(c). The scatter plots in panels (a) to (c) of Figure 1 also indicate the presence of outlier observations, which may hinder understanding of these relationships. For example, the observation with lowest GROWTH in all these plots relates to the Russian Federation over the period 1991-1995 and may be due to Russia’s transition from a planned economy to market economy that resulted in a sharp contraction of real per capita GDP growth during this period (Beck et al, 2007). Although outliers in multiple regressions cannot be identified through simple scatter plots like Figure 1, our analysis guards against them having an undue role in the results; see subsection 3.2.5.

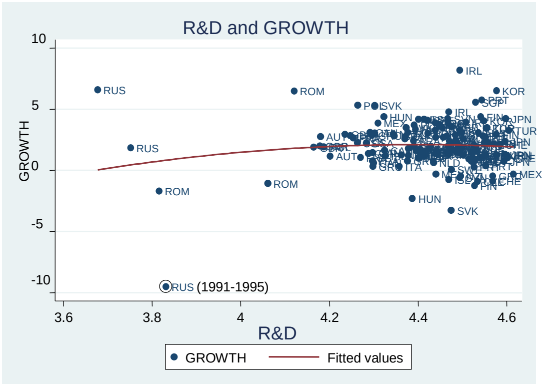
Figure 1: Scatter plots of Finance Size (FS), Finance Activity (FA), BERDIND and NPATA against Economic Growth (GROWTH)

(a) Finance Size (FS) and GROWTH (b) Finance Activity (FA) and GROWTH





(c) R&D and GROWTH



Note: GROWTH is real per capita GDP growth, FS is finance size, FA is finance activity, R&D is the percentage of R&D activity financed by industry, All variables are used in log form. The fitted line is based on the calculation of prediction for GROWTH from a linear regression of GROWTH on each of FS, FA and R&D together with their squared values.

3.2. Methodology

To analyse the impact of financial sector development on economic growth via R&D, we use an econometric model of the form employed by Levine et al (2000), Beck et al (2000a), Beck and Levine (2004), and others. More specifically, the model has the form:

$$y_{it} - y_{it-1} = (\alpha - 1)y_{it-1} + \gamma' X_{it} + \eta_i + \varepsilon_{it} \qquad (1)$$

where y is the logarithm of real per capita GDP, X represents a vector of explanatory variables (other than lagged real per capita GDP), η is an unobserved non-stochastic country specific effect, while the stochastic error term ε varies with individual countries and time and is assumed to be distributed as ε_{it} ~ *iid* (0, σ^2). The country-specific effect captures the characteristics of individual countries that are not picked up by the regressors but which are assumed to be time invariant. The subscripts i and t represent country and time period respectively.

Our hypotheses of subsection 2.3 state that the effect of financial development (FD) on growth is conditional on the level of R&D or technological innovations. These hypotheses are tested using a multiplicative interaction model as suggested by Aitken and West (1991), Brambor et al (2006), and more recently used by Ahlin and Pang (2008) in growth literature, resulting in the baseline specification:

$$GROWTH_{it} = \beta_1(Y0)_{it} + \beta_2 SCHL_{it} + \beta_3 FIN_{it} + \beta_4 R\&D_{it} + \beta_5(FIN \times R\&D)_{it} + \eta_i + \varepsilon_{it} \qquad (2)$$

In particular, if (as hypothesised) a high level of R&D leads to financial development having a weak or negative effect on economic growth, then β_5 in (2) will be negative.

A number of panel data techniques are used in the growth literature to estimate econometric models like (2). Following Islam (1995), Caselli et al (1996) and Arellano and Bover (1995), we use a range of estimators, namely fixed effects, difference GMM and system GMM methods. These are briefly explained in the following subsections.

3.2.1. Fixed Effects Estimation

Representing the fixed effects of (2) using a dummy variable for each country *i*, estimation by OLS leads to the least squares dummy variable or fixed effects (FE) estimator. In practice, the country specific fixed effects (η_i) can be eliminated by expressing the variables (including the interaction term, treated as a single variable) as deviations from individual country means, with estimates of the country-specific η_i then recovered.

Consistency of an estimator is usually achieved by requiring the disturbances to be uncorrelated with the (transformed) regressors. However, the presence of the dynamic term *Y0*, or any other variable that depends upon the history of dependent variable (*GROWTH*), will violate this assumption because the country-specific mean $\overline{Y0}_{i.}$ is correlated with ε_{it} by construction. This correlation becomes negligible only for sizeable *T*, which does not apply in our case of time-averaged data and hence we anticipate biased regression coefficient estimates (Nickell, 1981; Judson and Owen, 1999; Eberhardt and Teal, 2011). Further, fixed-effects estimation does not permit any of the other regressors of (2) to be endogenous.

The model can be extended by the addition of a non-stochastic time effect, λ_t, leading to the two-way fixed effects model. In this case, the estimates of β_1, $\beta_2, \ldots,$ β_5 are obtained by performing the within transformation two times: first, over time to eliminate country-specific effects (η_i) and second, over countries to eliminate time-specific effects (λ_t); see Baltagi (2005). If time-specific effects (λ_t) are significant then the one-way fixed-effects estimator will suffer from omitted variables bias. We use the *xtreg* command in Stata 9.2 for estimation, with standard errors robust to cross-sectional heterosckedasticity and within-panel serial correlation.

3.2.2. GMM Estimation

In addition to issues arising from dynamics, the other explanatory variables of the model are potentially endogenous due to the possible feedback effects from growth to these variables. As usual in dynamic panel regressions, we employ lagged values as instruments. The difference GMM estimator suggested by Arellano and Bond (1991) differences (2) over time to eliminate the country specific effects, resulting in the MA(1) disturbance term $\Delta\varepsilon_{it} = \varepsilon_{it} - \varepsilon_{i,t-1}$. Due to this MA(1), one period lagged endogenous regressors are not valid instruments and Arellano and Bond (1991) suggest that lags of at least two periods should be used as instruments for current differences of the endogenous variables. Hence, treating all regressors of (2) as potentially endogenous and assuming that the original error terms ε_{it} are serially uncorrelated, the following moment conditions must be satisfied in our case:

$$\begin{aligned} &E[Y0_{i,t-s}\Delta\varepsilon_{it}] = 0, \qquad \forall\ s \geq 2; t = 3,4,5 \\ &E[X_{i,t-s}\Delta\varepsilon_{it}] = 0, \qquad \forall\ s \geq 2; t = 3,4,5 \end{aligned} \tag{3}$$

where $X_{it} = (SCHL_{it}, FIN_{it}, R\&D_{it}, (FIN \times R\&D)_{it})'$.

Using these moment conditions, Arellano and Bond (1991) propose a difference GMM estimator which can be applied in two steps. In the first step the error terms ε_{it} are assumed to be *i.i.d.* across countries and time, while the second step relaxes the *i.i.d.* assumption over countries and a consistent estimate of the cross-country variance-covariance matrix is obtained using the residuals from the first step. Although this estimator is consistent, it can exhibit large biases in the reported standard errors in samples with a small number of time series observations (Windmeijer, 2005). Hence, following Bond *et al* (2001), we prefer to apply only first step of the difference GMM estimator.

In addition to problems with standard errors, Arellano and Bover (1995) discuss how the information contained in levels can be exploited in estimation by using valid instruments for the level equation (2) in addition to the moment conditions of (3); see also Blundell and Bond (1998). In this case, the country-specific effects (η_i) are controlled by the use of suitable instruments rather than eliminated. Using one period lagged differences as instruments and assuming stationarity over time results in the additional moment conditions for our system

$$\begin{aligned} &E[\Delta Y0_{i,t-1}(\eta_i + \varepsilon_{it})] = 0 \qquad \text{for t} = 3,4,5 \\ &E[\Delta X_{i,t-1}(\eta_i + \varepsilon_{it})] = 0 \qquad \text{for t} = 3,4,5 \end{aligned} \tag{4}$$

Given the moment conditions in (3) and (4), the system GMM estimator generates efficient and consistent estimates of the parameters of (2). However, this can result in over-fitting of instrumented variables, especially in small samples like 5 periods and 36 countries, and hence may fail to wipe out the endogeneity. Moreover, it may bias the Sargan/Hansen test towards over-accepting the null hypothesis (Beck, 2008; Roodman, 2006, 2009). To correct for these problems, we use a collapsed matrix of instruments as suggested by Roodman (2006, 2009), which creates one instrument for each variable and lag distance, rather than one for each time period, variable, and lag distance.

We use one-step difference and system GMM estimators for the estimation of equation (2) with the addition of time dummies as strictly exogenous regressors. For estimation purpose, we use the *xtabond2* command in Stata 9.2 written by Roodman (2003), which implements difference and system GMM with standard errors that are asymptotically robust to heteroskedasticity.

3.2.3. Diagnostic Tests

The consistency of the GMM estimator depends upon the validity of the instruments and the assumption of no serial correlation in the error terms $(\varepsilon_{i,t})$. As suggested by Arellano and Bond (1991), we employ Hansen's *J*-test for over-identified restrictions. Under the null hypothesis that the instruments are uncorrelated with disturbances, this follows a χ^2 distribution with *(J-K)* degrees of freedom, where *J* is the number of instruments and *K* is the number of endogenous variables.

Our second test examines the assumption of no second order serial correlation in the first differenced error term ($\Delta\varepsilon_{it}$). By construction this is MA(1), but no second-order serial correlation of the differenced residuals supports the assumption that the original error term is serially uncorrelated and hence that the corresponding moment conditions are valid (Calderon et al 2002).

3.2.4. Discussion

Panel analyses of growth are preferable to cross-sections as they allow for unobservable country-specific differences in technology and preferences. However, it is unclear which panel data estimator should be preferred for a dynamic growth regression even when no endogeneity problem arises in relation to the regressors X_{it}. Although the FE estimator allows for country specific effects, it is not an ideal candidate as the lagged dependent variable implies the estimator is not consistent when the asymptotics are considered in the direction $N \rightarrow \infty$ with T fixed (Islam, 1995).

On the other hand, the FE estimator is consistent in the absence of other endogenous regressors if the asymptotics are considered as $T \rightarrow \infty$, in which case it is asymptotically equivalent to maximum likelihood and performs quite well in Monte Carlo studies (Islam, 1995). However, other Monte Carlo studies for N=20 or 100 and T=5, 10, 20 and 30 find that the FE estimator can result in sizeable biases (Judson and Owen, 1999; Baltagi, 2005). In sum, although FE estimation wipes out the country specific fixed effects, it largely ignores dynamics. Further, it takes no account that regressors, other than the lagged dependent variable, may be endogenous.

Caselli et al (1996) address both problems of country specific effects and endogeneity in their growth regressions by implementing the difference GMM estimator of Arellano and Bond (1991). However, the difference GMM estimator performs poorly when the time series are persistent with small T because under these conditions lagged levels are weak instruments for corresponding first-differences. Consequently, Bond et al (2001) recommend using the system GMM estimator of Arellano and Bover (1995). However, it is also important to appreciate that the validity of system GMM estimation relies on the validity of the additional moment restrictions of (4). That is, lagged changes in the explanatory variables must be uncorrelated with the country fixed effects, which (although Bond et al, 2001, argue to the contrary) could be a contentious assumption in our context.

The above discussion indicates that the choice of estimator for a panel growth model is not entirely clear-cut. However, in the presence of substantial dynamics and when the assumptions of (4) are valid, then preference should be given to the system GMM estimator (especially in short panels) that takes care of country specific fixed effects as well as endogeneity. For our sample of 36 countries and five time periods, system GMM is therefore our preferred estimator. However, doubts over the possible validity of the additional conditions of system GMM compared with difference GMM indicates that the latter could be more appropriate, while FE remains the best choice in the absence of strong dynamics when exogeneity can be assumed. Our strategy, therefore, is to check the robustness of the results from system GMM to the choice of estimator.

3.2.5. Treatment of Outliers

Our results also take account of influential outliers in the data, which is potentially important for our group of heterogeneous countries as shown in Figure 1. For this purpose, outliers are detected using the Hampel Identifier as given in Wilcox (2005), where an outlier is defined by

$$HI = \frac{|R_i - M|}{MAD/0.6745} > c \qquad (5)$$

where M is the median of the observations R_1, R_2, …, R_n, MAD is the median of the centred absolute values $|R_1 - M|,...,|R_n - M|$, 0.6745 is the 75th quantile of the standard normal distribution and c is a cut-off. In practice, we use c = 2.24 except for difference GMM estimation, where 2.24 is the 97.5th quantile of a chi-square distribution with one degree of freedom. Its efficiency remains high even when samples are drawn from heavy tailed distributions (Wilcox, 2003). For difference GMM estimation we use c = 3.5, as used by Hampel (Wilcox, 2005), because the smaller value results in a large number of identified outliers.

Our approach is to estimate each model using the full data set and apply the Hampel Identifier to the regression residuals stacked over time and individual countries (R_i). The observation is then discarded when the residual is identified as an outlier and the model re-estimated.

4. Results

In this section, we use both finance size and finance activity as measures of financial development and examine their conditional effects on economic growth using R&D intensity as the primary measure of innovation. Each model includes initial real per capita GDP (Y0), a measure of human capital (SCHL), and the investment to GDP ratio (INV) as conditional variables, whereas the other control variables are openness (OPEN), government size (GOV) and inflation (INFL); all of these are standard explanatory variables in growth regressions. Section 4.1 considers results obtained using the preferred system GMM estimator in conjunction with financial development measured by finance size and finance activity; section

4.2 then presents difference GMM and fixed effects results, with a comparison analysis using all three estimators in section 4.3.

4.1. GMM Results

Tables 1 and 2 present system GMM estimation results for the model of (2), with control variables and time dummies added; financial development is represented by finance size in Table 1 and by finance activity in Table 2. Due to limitations of available data and the number of instruments employed, only one of openness (OPEN), government size (GOV) and inflation (INFL) is considered in each regression, although the other control variables (Y0, SCHL and INV) are always included[3]. The estimation results for each model are initially shown using all observations and after removal of observations giving rise to outlier residuals (see subsection 3.2.5).

Across all models of both tables, and temporarily ignoring interactions, financial development has a positive effect on economic growth. Similarly, and also as anticipated, R&D activity is good for growth. Of most interest for our study, however, is the negative interaction between these, indicating that the growth effect of financial development is, as hypothesised in Section 2, conditional on the level of R&D. With the exception of specification (5) in each table, which includes inflation and makes no allowance for outliers (whose effects are considered further below), the coefficients for finance size, R&D and their interaction are all significant at 10% and typically with marginal significance levels of 2% or less.

Using model (2) of Table 1 as representative of these results after the exclusion of outliers, the partial derivative of GROWTH with respect to a unit increase in finance size is given by:

$$\frac{\partial GROWTH}{\partial FIN} = 35.361 - 7.748 \times R\&D \qquad (6)$$

[3] A rule of thumb often applied is that the number of instruments should not exceed the number of groups or countries. Following this, we include the maximum number of variables for which the number of instruments is less than the number of countries.

Table 1: Growth Effect of Finance Size: System GMM Estimation Results

Coefficient	All Obs. (1)	Outliers Excluded (2)	All Obs. (3)	Outliers Excluded (4)	All Obs. (5)	Outliers Excluded (6)
FIN	34.054***	35.361***	34.749***	35.655***	25.977	33.510***
	(0.006)	(0.000)	(0.006)	(0.003)	(0.144)	(0.001)
R&D	31.199**	30.075***	30.018**	29.735***	24.448	33.174***
	(0.016)	(0.000)	(0.019)	(0.009)	(0.199)	(0.004)
FIN × R&D	-7.051**	-7.748***	-7.194**	-7.584***	-5.252	-7.319***
	(0.019)	(0.000)	(0.018)	(0.009)	(0.205)	(0.002)
Control Variables						
Y0	-2.749	-1.446	-2.395	-1.539	-3.431**	-2.904**
	(0.131)	(0.174)	(0.206)	(0.333)	(0.037)	(0.021)
SCHL	-0.869	-0.595	1.570	0.656	-2.419	-2.553
	(0.829)	(0.760)	(0.677)	(0.835)	(0.554)	(0.313)
INV	-1.892	-2.589	-0.326	-1.271	-2.210	-1.314
	(0.406)	(0.378)	(0.858)	(0.639)	(0.389)	(0.503)
OPEN	-0.368	1.634				
	(0.798)	(0.209)				
GOV			-3.047	-4.487*		
			(0.322)	(0.077)		
INFL					-0.658	-0.800
					(0.369)	(0.197)
Time Dummies						
1986-1990	3.097*	2.288**	3.068**	3.412***	2.990*	3.519**
	(0.060)	(0.047)	(0.021)	(0.007)	(0.086)	(0.017)
1991-1995	1.603	0.331	1.706	2.051	1.481	2.272
	(0.398)	(0.806)	(0.210)	(0.125)	(0.437)	(0.159)
1996-2000	3.005	2.026	2.604*	2.605*	2.513	3.432*
	(0.120)	(0.139)	(0.064)	(0.085)	(0.268)	(0.056)
2001-2006	2.008	1.051	1.630	1.901	1.479	2.881*
	(0.345)	(0.489)	(0.255)	(0.219)	(0.493)	(0.098)
Constant	-115.792*	-120.821***	-117.133**	-111.095**	-74.722	-114.005**
	(0.051)	(0.001)	(0.042)	(0.033)	(0.412)	(0.040)
Number of Observations	124	118	126	119	123	117
Number of Countries	36	35	36	35	36	35
Number of Instruments	33	33	33	33	33	33
Diagnostic tests (*p*-values)						
J-test	0.28	0.27	0.12	0.11	0.24	0.26
AC(2)	0.43	0.33	0.41	0.53	0.41	0.92

Notes: The dependent variable is real per capita GDP growth. FIN is measured by finance size, while R&D is measured as the percentage financed by industry, with FIN×R&D being their interaction; the control variables are described in Section 4. Values in parentheses are *p*-values for individual coefficients, with ***, **, * indicating significance at 1%, 5% and 10% respectively. All regressions allow for country-specific fixed effects, and employ heteroscedasticity robust standard errors with one-step GMM estimation. Outliers are removed from models (2), (4) and (6) based on the Hampel Identifier applied to the residuals of (1), (3) and (5) respectively. Diagnostic test results are reported as *p*-values, with AC(2) being the Arellano-Bond tests for second-order serial correlation.

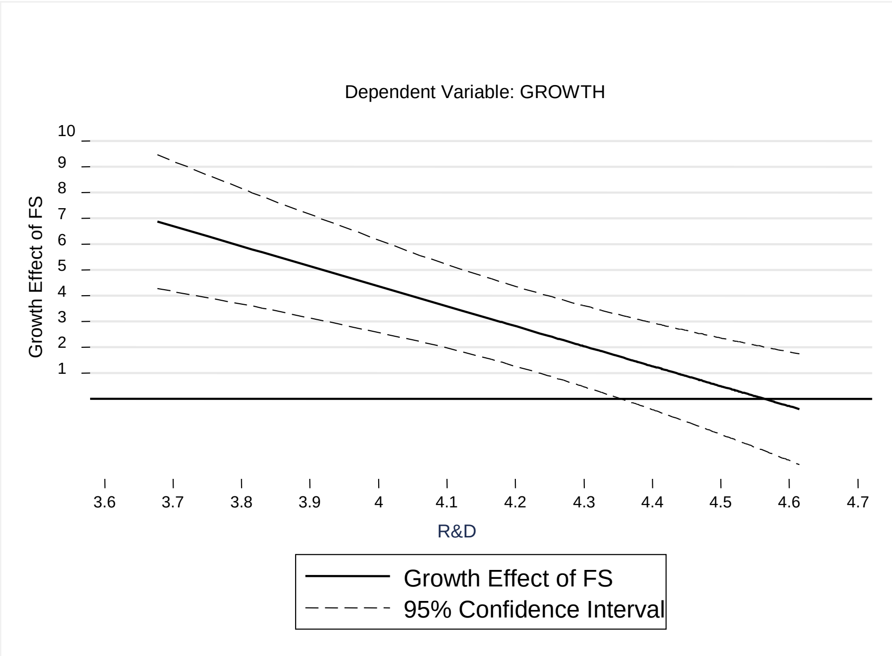
Table 2: Growth Effect of Finance Activity: System GMM Estimation Results

Coefficient	All Obs. (1)	Outliers Excluded (2)	All Obs. (3)	Outliers Excluded (4)	All Obs. (5)	Outliers Excluded (6)
FIN	12.094***	11.857***	11.832***	13.320***	7.050	8.541**
	(0.001)	(0.000)	(0.001)	(0.000)	(0.176)	(0.020)
R&D	16.739***	13.858***	14.057**	14.997***	10.645	11.486*
	(0.004)	(0.000)	(0.019)	(0.000)	(0.246)	(0.058)
FIN × R&D	-2.625***	-2.582***	-2.550***	-2.874***	-1.514	-1.857**
	(0.002)	(0.000)	(0.003)	(0.000)	(0.204)	(0.028)
Control Variables						
Y0	-1.478	-1.336**	-0.990	-0.858	-2.797**	-2.748**
	(0.227)	(0.047)	(0.474)	(0.271)	(0.047)	(0.032)
SCHL	-1.326	-1.356	0.071	-0.024	-3.883	-2.038
	(0.551)	(0.310)	(0.975)	(0.990)	(0.116)	(0.249)
INV	0.466	-1.004	1.702	0.839	-0.208	0.926
	(0.847)	(0.647)	(0.363)	(0.702)	(0.924)	(0.690)
OPEN	-0.252	1.010				
	(0.872)	(0.236)				
GOV			-3.039	-2.562		
			(0.282)	(0.196)		
INFL					-1.473*	-1.323*
					(0.090)	(0.077)
Time Dummies						
1986-1990	2.858	2.675*	2.655	2.301	2.411	2.747
	(0.351)	(0.057)	(0.145)	(0.172)	(0.329)	(0.159)
1991-1995	1.599	1.073	1.486	1.166	1.059	1.584
	(0.622)	(0.462)	(0.409)	(0.535)	(0.693)	(0.449)
1996-2000	3.218	2.360	2.596	1.880	2.052	2.220
	(0.426)	(0.144)	(0.234)	(0.391)	(0.535)	(0.383)
2001-2006	2.580	1.697	1.969	1.000	1.430	1.920
	(0.561)	(0.347)	(0.400)	(0.668)	(0.653)	(0.439)
Constant	-60.993**	-49.148***	-53.107**	-56.735**	-10.911	-23.107
	(0.021)	(0.009)	(0.027)	(0.029)	(0.822)	(0.514)
Number of Observations	123	107	125	119	122	118
Number of Countries	36	35	36	36	36	35
Number of Instruments	33	33	33	33	33	33
Diagnostic tests (*p*-values)						
J-test	0.24	0.14	0.15	0.24	0.40	0.31
AC(2)	0.70	0.26	0.67	0.31	0.83	0.81

Notes: As for Table 1, except that financial development is measured as finance activity.

Figure 2 illustrates this graphically, using the observed range of values for R&D and including 95% confidence intervals computed assuming a normal distribution. At low levels of R&D, financial development has a strong effect, but this declines as the level of R&D rises. Indeed the effect becomes negative for sufficiently large levels of the latter, being -0.40 at the observed maximum sample R&D value of 4.6151 (see Appendix Table A3)[4]. This marginal effect compares with estimates of 1.09 at the mean R&D value and 6.87 at its observed minimum. Similar implications apply also to the other models of both tables.

Figure 2: Growth Effect of Finance Size (FS) as R&D Increases



There are a number of other points of interest in these tables. Among these, it is notable that outliers play an important role. This is particularly the case in specification (5) of both tables in which inflation is employed as a control variable and where no coefficient is individually significant at 5%, except for initial GDP. However, removal of six or four outliers, as appropriate (detailed in Appendix Table A4), has a substantial impact on the significance of the variables in this specification that are our focus of interest.

In contrast to the generally strong significance of the finance and R&D variables in Tables 1 and 2, the control variables are individually less significant. However, the coefficient of Y0 is always negative, as anticipated, although often not statistically

[4] Noting that R&D is measured as the log of the ratio of a percentage variable, it is not simple to interpret the meaning of a unit increase is this variable. Since the range of observed values is approximately one unit (Appendix Table A3), then, *ceteris paribus*, a unit increase would approximate a switch from the lowest to highest observed level of R&D.

significant. The human capital measure (SCHL) has an estimated positive or negative coefficient, depending on the specification, which is in line with other empirical literature that provides mixed evidence on the sign and significance of such a variable for growth (Temple, 1999; Benhabib and Spiegel, 2000; Beck and Levine, 2004; Rogers, 2008). Although the negative sign obtained in some cases for the investment variable does not accord with the general finding of the literature (Barro, 1991; Levine and Renelt, 1992; Caselli et al 1996), it is not close to being significant in any specification.

When openness is used as an additional control variable, it does not appear to play a significant role, with a positive coefficient obtained only after the removal of outliers in model (2) of both tables. Government size (GOV) has a negative coefficient, although significant only at 10% in Table 1 after removal of outliers. Finally, inflation bears a negative sign, and is also significant at 10% in Table 2, which is consistent with the literature on inflation and growth (Fischer, 1993).

Also note that the diagnostic tests confirm that the instruments used in the analysis of both Tables are valid. In particular, neither Hansen's *J*-test nor the Arellano-Bond test for second order serial correlation indicates any instrument problem.

4.2. Difference GMM and Fixed Effects Results

As argued in Section 3, the most appropriate estimator for a panel growth regression depends on the nature of the underlying relationships and hence Table 3 checks the robustness of the results from Tables 1 and 2 (measuring financial development by finance size and finance activity, respectively) using both difference GMM and the standard two-way fixed effects estimator. The use of fewer instruments for difference as compared with system GMM allows a less parsimonious general model to be considered here than in the earlier tables, with all control variables included. For each estimator, a general to specific modelling strategy is then used, whereby any insignificant variable from the set OPEN, GOV and INFL is dropped to obtain the specific model. Each (general or specific) model was initially estimated using all observations[5] and outlier observations were then deleted, yielding the results shown in the table.

[5] Detailed estimation results for these, and other models referred to in the paper, can be obtained from the authors on request.

Table 3: Growth Effect of Finance Size and Finance Activity:
Difference GMM and Fixed Effects Estimation Results

	Finance Size				Finance Activity			
	Difference GMM		Fixed Effects		Difference GMM		Fixed Effects	
Coefficient	General Model (1)	Specific Model (2)	General Model (3)	Specific Model (4)	General Model (5)	Specific Model (6)	General Model (7)	Specific Model (8)
FIN	20.720**	29.764***	24.058***	24.247***	7.180**	10.087***	6.276***	6.801***
	(0.017)	(0.000)	(0.000)	(0.000)	(0.035)	(0.000)	(0.000)	(0.000)
R&D	14.287	23.233***	22.756***	23.794***	3.535	8.571*	7.941**	9.274***
	(0.138)	(0.006)	(0.000)	(0.000)	(0.589)	(0.098)	(0.011)	(0.002)
FIN × R&D	-4.599**	-6.760***	-5.236***	-5.357***	-1.673**	-2.380***	-1.368***	-1.476***
	(0.021)	(0.000)	(0.000)	(0.000)	(0.038)	(0.000)	(0.001)	(0.000)
Control Variables								
Y0	-12.686***	-12.031***	-13.094***	-14.527***	-11.341***	-12.330***	-14.759***	-14.002***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
SCHL	-3.488	-9.324*	-0.343	-0.686	-2.651	-9.780	-2.567	-3.941*
	(0.738)	(0.088)	(0.926)	(0.803)	(0.816)	(0.113)	(0.421)	(0.087)
INV	4.546***	5.264***	5.886***	5.660***	6.158***	7.117***	5.154***	5.389***
	(0.004)	(0.003)	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)
OPEN	3.052	4.881*	2.818**	2.769**	1.314	4.402*	2.110*	2.487**
	(0.143)	(0.082)	(0.010)	(0.010)	(0.589)	(0.080)	(0.065)	(0.019)
GOV	-4.686		-1.630		-5.976		-1.895	
	(0.483)		(0.457)		(0.437)		(0.386)	
INFL	-0.757**	-0.712	-0.686**	-0.644**	-1.062***	-0.915***	-0.750***	-0.766***
	(0.040)	(0.100)	(0.019)	(0.026)	(0.003)	(0.006)	(0.004)	(0.005)
Time Dummies								
1986-1990	3.069	3.428**	4.137***	4.150***	5.179*	7.248***	2.191**	3.904***
	(0.123)	(0.043)	(0.002)	(0.001)	(0.067)	(0.006)	(0.033)	(0.004)
1991-1995	3.604*	4.207**	4.421***	4.642***	5.891*	8.460***	2.841**	4.455***
	(0.094)	(0.021)	(0.001)	(0.000)	(0.066)	(0.003)	(0.016)	(0.002)
1996-2000	4.879**	5.664***	5.518***	5.946***	7.468**	10.345***	4.096***	5.654***
	(0.049)	(0.005)	(0.000)	(0.000)	(0.046)	(0.001)	(0.003)	(0.000)
2001-2006	5.942**	6.603***	6.377***	7.064***	8.700**	11.657***	5.448***	6.784***
	(0.014)	(0.002)	(0.000)	(0.000)	(0.022)	(0.001)	(0.000)	(0.000)
Constant			-6.880	0.263			89.417***	69.804***
			(0.857)	(0.994)			(0.001)	(0.006)
Observations	84	85	117	116	83	84	114	115
Outliers Removed	1	0	4	5	1	0	6	5
Countries	32	33	36	36	32	33	36	36
R^2			0.886	0.897			0.908	0.899
Instruments	31	28			31	28		
Diagnostic Tests (*p*-values)								
J-test	0.21	0.24			0.33	0.36		
AC(2)	0.82	0.59			0.72	0.43		

Notes: As for Table 1, except financial development is measured by finance size or finance activity and estimation is by one-step difference GMM or standard two-way fixed effects estimation, as indicated, with outliers removed from all specifications. Each specific model is obtained from the general model by dropping any of OPEN, GOV or INFL whose individual coefficient is not significantly different from zero at the 10% level.

Table 3 shows that our principal results from Tables 1 and 2 are robust to the estimator employed and also to the measure of financial development used. In particular, although R&D is not significant for the general model when estimated using difference GMM, that is in models (1) or (5), the interaction term with the financial development measure has a negative coefficient in all cases and is significant at 5%. Although the relevant estimated coefficients are often smaller in magnitude in Table 3 compared with those tables, the qualitative implications of the latter carry over. That is, the marginal effects of financial development on growth decline as the level of R&D increases such that, at a sufficiently high level of R&D, increasing finance size has a negative effect on growth. Indeed, an analysis as in (6) and Figure 2 for each set of the estimates in Table 3 again implies negative growth effects for additional financial development at the observed sample maximum level of R&D.

The superficial implication of Table 3 is that exogeneity of the control variables may not be a substantial issue in our case, as the difference GMM and fixed effects coefficient estimates are generally similar. On the other hand, in comparison with Tables 1 and 2, the results of Table 3 suggest that the choice of estimator may be important in relation to the control variables, but this is difficult to assess as the specifications differ across the two tables. The next subsection considers this further.

4.3. Comparison of Estimators

To allow a comparison of results, all three estimators are applied to a single model in Table 4, which also employs each of finance size and finance activity as the measure of financial development. The model is specification (6) of Tables 1 and 2, namely including inflation as the single additional control variable, as it is generally significant when included across all specifications and estimators. Further, the outliers identified and removed for the difference GMM estimation are also removed when the other estimators are employed. Although the system GMM results are identical to those presented in these earlier tables, they are reproduced in Table 4 to facilitate comparison.

Table 4: Comparison of Estimators

	Finance Size			Finance Activity		
	System GMM	Difference GMM	Fixed Effects	System GMM	Difference GMM	Fixed Effects
Coefficient	(1)	(2)	(3)	(4)	(5)	(6)
FIN	33.510***	19.111**	19.840***	8.541**	5.457	6.404***
	(0.001)	(0.039)	(0.001)	(0.020)	(0.104)	(0.001)
R&D	33.174***	14.739	18.444***	11.486*	0.877	8.116**
	(0.004)	(0.232)	(0.005)	(0.058)	(0.911)	(0.014)
FIN × R&D	-7.319***	-4.432**	-4.356***	-1.857**	-1.279*	-1.403***
	(0.002)	(0.042)	(0.002)	(0.028)	(0.100)	(0.001)
Control Variables						
Y0	-2.904**	-11.521***	-12.496***	-2.748**	-11.125***	-12.325***
	(0.021)	(0.000)	(0.000)	(0.032)	(0.001)	(0.000)
SCHL	-2.553	-7.894	1.911	-2.038	-10.090	0.417
	(0.313)	(0.195)	(0.582)	(0.249)	(0.126)	(0.907)
INV	-1.314	2.671	4.298***	0.926	4.322**	4.370***
	(0.503)	(0.104)	(0.002)	(0.690)	(0.017)	(0.002)
INFL	-0.800	-1.242***	-0.681**	-1.323*	-1.502***	-0.817***
	(0.197)	(0.002)	(0.019)	(0.077)	(0.001)	(0.004)
Number of Observations	117	80	117	118	82	118
Number of Countries	35	32	35	35	33	35
R^2			0.807			0.814
Number of Instruments	33	25		33	25	
Diagnostic tests (*p*-values)						
J-test	0.26	0.23		0.31	0.30	
AC(2)	0.92	0.26		0.81	0.42	

Notes: Financial development is measured as finance size or finance activity, as indicated, and all models allow for country-specific effects and include time dummies. The system GMM estimates of (1) and (4) are reproduced from model (6) of Tables 1 and 2, respectively; outliers removed from these models are also removed for difference GMM and two-way fixed effects estimation. For other notes, see Table 1.

Across all models of Table 4, the coefficients of the two measures of financial development are positive and significant, except for model (5) where it has a *p*-value of 0.104. Similarly, R&D is positive and significant, except when the difference GMM estimator is used in models (2) and (5). However, the interaction between the financial development variables and R&D is negative and significant in all cases. Note that, as suggested by a comparison of Tables 1 and 2 with 3, these three coefficients obtained from difference GMM and two-way fixed effects estimation are smaller in magnitude compared to those obtained from system GMM estimation. We also note that the coefficients of principal interest (FIN, R&D and FIN×R&D) obtained from system GMM and fixed effects estimation methods are close in significance, especially when finance size is used to measure financial development, whereas difference GMM estimation results in lower significance levels for these coefficients.

On the other hand, the coefficient on starting GDP (Y0) is less strong when estimation is by system GMM, in line with results obtained by Bond el al (2001), and which may be due to the biases of the other methods for the estimation of dynamics for panels with a small number of time series observations. The coefficient on the human capital variable (SCHL) remains insignificant across all models, and with varying sign, but investment is positive and generally significant, except for the system GMM estimations (1) and (4). Finally, inflation has a robust negative effect on growth, which is significant with the single exception of specification (1).

5. Conclusions

In the light of recent literature that suggests financial innovation may be poorly regulated in countries with high levels of R&D (Michalopoulos et al, 2009; Ductor and Grechyna, 2011), this paper investigates the conditional effects of financial development on economic growth, using R&D as a conditioning variable. More specifically, we study the implications of R&D interacting with conventionally measured financial development in impacting on economic growth. Our aim is to combine financial development, innovation and growth through two testable hypotheses: first, the relationship between financial development and economic growth is conditional upon the level of innovation or R&D; and second, a high level of technological innovation (or R&D) is associated with a weak or negative effect of financial development on economic growth.

We employ two measures of financial sector development: finance size (FS) and finance activity (FA) in conjunction with R&D intensity. Further, we use a multiplicative interaction model to capture the conditional effects of financial development on growth which is estimated by employing three estimation techniques of panel data: two-way fixed effects, difference GMM and system GMM estimators to take account of country specific characteristics, as well as dynamics and (using GMM) endogeneity. We take care of influential outliers by applying the Hampel Identifier to the residuals obtained from each model.

Our regression results show that the marginal effects of financial development and R&D on economic growth are positive and significant. Further, the relationship between financial development and growth is conditional upon the level of R&D; that is, it decreases as the level of R&D increases and even becomes negative at very high levels of R&D. Thus, the negative interaction between financial development and R&D suggests that at a very high level of R&D adding more financial development may not be a growth promoting policy.

We provide two explanations for these findings: first, countries with a very high level of innovation or R&D activities may have highly deregulated financial systems that promote financial innovations to meet the demands of innovators or investors. In this situation adding more financial development is likely to deteriorate credit standards, increase growth of non-performing loans, generate credit booms and increase the probability of bank crises. Consequently, financial crises have an adverse impact on economic growth. In this sense our findings are consistent with the most recent literature (Michalopoulos et al, 2009; Rousseau and Wachtel, 2011). Second, as the sign of our interaction terms is negative it suggests that financial development and innovation are substitutes. Hence growth promoting policies should be directed either to financial sector development or innovation sector. In this sense our results are consistent with the view that any subsidy given to either financial or innovation sector is better than if it is given to both (Morales, 2003). Our study proposes that financial development loses its effectiveness in those countries whose investment in R&D, especially industrial R&D, is rather high. This may be an indication, though not a direct proof, that countries which have high R&D (e.g. Japan, Korea, Turkey, Switzerland, Luxembourg, Finland, etc) may be those where the financial systems are less regulated, specifically in relation to financial innovations, which may cause conventionally measured financial development to lose its effectiveness to promote growth in the economy. This could be an agenda for future research.

Appendix

Table A1: List of countries

Argentina, Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Rep., Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Singapore, Slovak Republic, Slovenia, South Africa, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States.

Table A2: Definitions and Sources of Variables used in the Analysis

Variable	Definition and Construction	Source
Real per capita GDP growth (**GROWTH**)	Difference of log real per capita GDP, multiplied by 100	Constructed using data from World Development Indicators (WDI), World Bank
Initial real per capita GDP (**Y0**)	Log of Initial value of real per capita GDP	WDI, World Bank
Average years of schooling (**SCHL**)	Educational Attainment of the Total Population Aged 25 and Over. Calculated as log of (1+average years of schooling)	Constructed using data from Barro and Lee (2010)
Finance Activity (**FA**)	Constructed as the log of the product of Private Credit (value of private credit by deposit money banks as percentage of GDP) and Trading Value (value of the total shares traded at stock exchanges as percentage of GDP ratio)	Constructed using data from “A New Database on Financial Development and Structure (updated Nov. 2008), World Bank”.
Finance Size (**FS**)	Constructed as the log of the sum of Private Credit and Market Capitalization (value of listed shares as percentage of GDP ratio)	Constructed using data from “A New Database on Financial Development and Structure (updated Nov. 2008), World Bank”
R&D expenditure (**R&D**)	Log of business enterprise expenditures on R&D financed by industry as percentage of GDP	Constructed using data from OECD-Main Science and Technology Indicators (MSTI), 2008
Investment (**INV**)	Log of gross fixed capital formation as percentage of GDP	WDI, World Bank
Openness (**OPEN**)	Log of exports plus imports as percentage of GDP	WDI, World Bank
Government Size (**GOV**)	Log of general government final consumption expenditures as percentage of GDP	WDI, World Bank
Inflation (**INFL**)	Percentage change in consumer price index	WDI, World Bank

Estimations employ panel data for $T = 5$ periods, using data averaged over the following sub-periods: 1981-1985, 1986-1990, 1991-1995, 1996-2000, 2001-2006.

Table A3:

Panel (a) Univariate Summary Statistics

Variable	N	Mean	Median	StdDev	Min	Max
GROWTH	183	2.1608	1.9849	2.3703	-9.5022	10.3767
Y0	181	9.2988	9.6534	0.9762	5.2281	10.7424
SCHL	182	2.2105	2.2695	0.2466	1.3634	2.5839
FA	142	6.6281	6.8509	2.2224	-1.4857	10.4676
FS	143	4.5755	4.6374	0.7811	2.1447	5.9914
R&D	156	4.4228	4.4611	0.1526	3.6771	4.6151
FA*R&D	129	30.1571	30.7492	9.5526	-1.2809	47.3198
FS*R&D	130	20.4033	20.6198	3.4795	8.2162	27.085
INV	185	3.0930	3.0705	0.1965	2.7032	3.8236
OPEN	177	4.1285	4.1325	0.5602	2.7113	6.0202
GOV	182	2.8555	2.9266	0.3079	1.4267	3.6355
INFL	175	1.7366	1.4955	1.3195	-1.1841	7.0830

Panel (b) Correlations

	GROWTH	Y0	SCHL	FA	FS	R&D	FA× R&D	FS× R&D	INV	OPEN	GOV	INFL
GROWTH	1.0000											
Y0	-0.2003	1.0000										
SCHL	-0.1350	0.4846	1.0000									
FA	0.2478	0.5918	0.4302	1.0000								
FS	0.1865	0.7010	0.3372	0.8286	1.0000							
R&D	0.1131	0.3294	-0.1855	0.2269	0.3038	1.0000						
FA×R&D	0.2678	0.6276	0.3440	0.9959	0.8515	0.3021	1.0000					
FS×R&D	0.1887	0.7726	0.2628	0.8317	0.9854	0.4560	0.8467	1.0000				
INV	0.3297	-0.2387	-0.2234	0.0948	0.0807	0.3127	0.0610	0.1285	1.0000			
OPEN	0.1527	0.1530	0.1409	0.0088	0.1501	0.0132	-0.0535	0.0256	-0.0380	1.0000		
GOV	-0.1260	0.3430	0.3120	0.2463	0.2769	-0.0694	0.1551	0.1438	-0.3300	0.2541	1.0000	
INFL	-0.3450	-0.5437	-0.3360	-0.7163	-0.7993	-0.3660	-0.7279	-0.8050	-0.0757	-0.2601	-0.2657	1.0000

Table A4: List of Excluded Outlier Observations

Tables 1 through 4 contain models that exclude outlier observations from their analysis using the Hampel Identifier (see subsection 3.2.5); the list of excluded outlier observations from our analysis are as follows:

Table 1	
Model (2)	Ireland 1996-2000; Korea, Rep. 1991-1995; Norway 1991-1995; Romania 2001-2006; Slovak Republic 1991-1995; South Africa 2001-2006.
Model (4)	Hungary 1991-1995; Ireland 1996-2000; Mexico 1986-1990, 1991-1995; New Zealand 1986-1990; Slovak Republic 1991-1995; South Africa 2001-2006.
Model (6)	Ireland 1996-2000; Norway 1991-1995; Portugal 2001-2006; Romania 2001-2006, Slovak Republic 1991-1995, South Africa 2001-2006.
Table 2	
Model (2)	Czech Republic 1991-1995; Hungary 1991-1995; Ireland 1991-1995,1996-2000; Italy 2001-2006; Korea 1991-1995; Mexico 1986-1990, 1991-1995; Norway 1991-1995; Portugal 2001-2006; Romania 2001-2006; Slovak Republic 1991-1995, 2001-2006; South Africa 2001-2006; Turkey 1996-2000; United Kingdom 2001-2006.
Model (4)	Ireland 1996-2000; Mexico 1986-1990, 1991-1995; Romania 2001-2006; Slovak Republic 1991-1995, 2001-2006.
Model (6)	Ireland 1996-2000; Portugal 2001-2006; Slovak Republic 1991-1995; South Africa 2001-2006.
Table 3	
Model (1)	Romania 1996-2000.
Model (2)	NA
Model (3)	Italy 2001-2006; Norway 1986-1990; Slovak Republic 1991-1995, 2001-2006.
Model (4)	Ireland 1991-1995; Italy 2001-2006; Norway 1986-1990; Slovak Republic 1991-1995, 2001-2006.
Model (5)	Romania 1996-2000, 2001-2006.
Model (6)	NA
Model (7)	Ireland 1991-1995; Italy 2001-2006; Norway 1986-1990; Portugal 1981-1985; Slovak Republic 1991-1995, 2001-2006.
Model (8)	Ireland 1991-1995; Italy 2001-2006; Norway 1986-1990; Slovak Republic 1991-1995, 2001-2006.
Table 4	
Model (1)	Ireland 1996-2000; Norway 1991-1995; Portugal 2001-2006; Romania 2001-2006; Slovak Republic 1991-1995; South Africa 2001-2006.
Model (2)	NA
Model (3)	NA
Model (4)	Ireland 1996-2000; Portugal 2001-2006; Slovak Republic 1991-1995; South Africa 2001-2006.
Model (5)	NA
Model (6)	NA

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