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Effect of finance on growth through more efficient utilization of technological innovations

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Pasi Ikonen

**Effect of finance on growth
through more efficient utilization
of technological innovations**



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Effect of finance on growth through more efficient utilization of technological innovations

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Abstract

This paper models the effects of financial development on economic growth through better or more efficient utilization of technological innovations. The model is based on the endogenous growth theory of Aghion and Howitt and its derivatives, especially the growth model of Aghion, Howitt and Mayer-Foulkes, which covers the effect of financial development on convergence. The main contribution of this paper is to model the innovation channel of finance explicitly. The paper focuses particularly on the interaction term between the measure of own innovation and financial development. As countries approach the technological frontier, own innovation becomes more important to sustain a high growth rate. An adequate level of financial development is needed to realize the full potential of own innovation for economic growth. The data covers the period 1960–2007 for advanced economies, emerging markets and some other countries for which data are available. In estimation of the model, different regression specifications for the data panel are applied. The robustness of the results is also tested in several ways. The results show a significant and positive sign for the interaction term between the measure of own innovation and financial development in the most important configurations. This suggests that the innovation channel of finance is likely to have a positive role to play in economic growth.

Keywords: endogenous growth, innovation, financial development, growth empirics

JEL classification numbers: O31, O33, O47

Rahoitusmarkkinoiden kehittyneisyyden vaikutus talouskasvuun teknologisten innovaatioiden tehokkaamman hyödyntämisen kautta

Suomen Pankin keskustelualoitteita 21/2010

Pasi Ikonen

Rahapolitiikka- ja tutkimusosasto

Tiivistelmä

Tässä tutkimuksessa mallinnetaan rahoitusmarkkinoiden kehittyneisyyden vaikutusta talouskasvuun teknisten innovaatioiden paremman tai tehokkaamman hyödyntämisen välityksellä. Malli perustuu Aghionin ja Howittin endogeeniseen kasvuteoriaan ja siitä johdettuihin malleihin, erityisesti Aghionin, Howittin ja Mayer-Foulkesin kasvumalliin, jossa tarkastellaan rahoitusmarkkinoiden kehittyneisyyden vaikutusta asukasta kohden lasketun BKT:n kasvuvauhdin konvergenssiin. Tutkimuksen pääanti on siinä, että työssä mallinnetaan rahoituksen innovaatiokanava eksplisiittisesti. Erityisesti keskitytään maan omien innovaatioiden ja rahoitusmarkkinoiden kehittyneisyyden väliseen yhteisvaikutukseen. Kun maat lähestyvät teknisen kehityksen eturintamaa, omista innovaatioista tulee yhä tärkeämpi tekijä nopean kasvuvauhdin ylläpitämisessä. Rahoitusmarkkinoiden on oltava riittävän kehittyneitä, jotta omien innovaatioiden täysi talouskasvupotentiaali saadaan hyödynnettyä. Aineisto on vuosilta 1960–2007 ja käsittää teollisuusmaat, kehittyvät markkinat ja eräitä muita maita, joiden tiedot ovat saatavilla. Estimoinnissa sovelletaan paneeliaineistoon erilaisia regressiomalleja. Tulosten robustisuutta testataan usealla tavalla. Omien innovaatioiden ja rahoitusmarkkinoiden kehittyneisyyden välinen ristitermi on etumerkiltään positiivinen ja tilastollisesti merkitsevä tärkeimmissä estimointituloksissa. Tämä viittaa siihen, että rahoituksen innovaatiokanavalla on todennäköisesti myötävaikuttava rooli taloudellisessa kasvussa.

Avainsanat: endogeeninen kasvuteoria, innovaatiot, rahoitusmarkkinoiden kehittyneisyys, kasvuteorian empiirinen tutkimus

JEL-luokittelu: O31, O33, O47

Contents

Abstract.....	3
Tiivistelmä (abstract in Finnish).....	4
1 Introduction.....	7
2 Estimation and results	9
2.1 Specification and data.....	9
2.2 Methodology.....	16
2.3 Replicating the AHM results	18
2.4 The basic results	20
2.5 Robustness checks	29
2.6 Own innovation vs fixed effects	34
3 Conclusions	36
References.....	38

1 Introduction

Levine (1997) has summarized transmission mechanisms from finance to growth. Financial markets and institutions are born to provide solutions to the problems that are created by information and transactions frictions. Specific financial contracts, markets, and institutions arise because of specific types and combinations of information and transaction costs. According to Merton and Bodie (1995), the primary function of financial systems is to facilitate the allocation of resources, across space and time, in an uncertain environment. In the same spirit, Mckinnon (1991) argues that capital markets should gather savings and allocate capital to the most efficient private sector projects. Levine (1997) decomposes the primary function of financial systems into facilitating the trading, hedging, diversifying, and pooling of risk, allocating resources, monitoring managers and exerting corporate control, mobilizing savings and facilitating the exchange of goods and services. This kind of basic financial functions are already mentioned in Schumpeter (1911).

There are two possible channels from finance to growth. The first of the two channels through which each financial function may affect economic growth is capital accumulation. This is the case in growth models that use capital externalities or capital goods produced using constant returns to scale but without the use of non-reproducible factors to generate steady-state per capita growth (Paul Romer, 1986; Robert Lucas, 1988; Sergio Rebelo, 1991). Aghion and Howitt (2005) call this set of endogenous growth models the AK paradigm. In this paradigm, the functions performed by the financial system affect steady-state growth by influencing the rate of capital formation. Impact on capital accumulation takes place either by altering the savings rate or by reallocating savings among different capital producing technologies. The second of the two channels through which each financial function may affect economic growth is technological innovation. This is the case in growth models that focus on the invention of new production processes and goods (Paul Romer, 1990; Philippe Aghion and Peter Howitt, 1992). According to Aghion and Howitt (2005), this set of endogenous growth models forms the two other paradigms of endogenous growth theories: the product-variety paradigm of Romer (1990) and the Schumpeterian paradigm of Aghion and Howitt (1992). In these paradigms, the functions performed by the financial system affect steady-state growth by altering the rate of technological innovation. Aghion and Howitt (1992) has been followed by many derivatives, like Aghion and Howitt (1998) which is a hybrid of neoclassical and Schumpeterian growth models. In principle, one could make the exogenous rate of technological progress in neoclassical growth models (Ramsey, 1928; Solow, 1956; Swan, 1956; Cass, 1965; Koopmans, 1965; Mankiw, Romer and Weil, 1992) dependent on financial development so that even these models

could be used in examining of effect of finance on growth. However, the model would not be called neoclassical anymore since the long-term growth rate has become endogenous!

The effect of finance on growth has extensively been addressed empirically. Partly based on these results, the finance-growth nexus seems to have become accepted as part of mainstream economics. In an influential paper, King and Levine (1993a) have extended the cross-country framework introduced in Barro (1991) by adding financial variables and found a robust, positive, and statistically significant relationship between initial financial conditions and subsequent growth in real per capita incomes. King and Levine (1993b) construct an endogenous growth model in which better financial systems would improve the probability of successful innovation and thereby accelerate economic growth. According to cross-country evidence of Levine and Zervos (1998), stock market and banking development liquidity both would contribute a significant positive influence on GDP growth. However, Andong Ash and Pollin 2004 show that when controls for outliers are introduced to Levine and Zervos (1998), stock market liquidity no longer exerts any statistically observable influence on GDP growth. Rousseau and Wachtel (2000) estimate vector autoregressions, which indicate leading roles for stock market liquidity and the intensity of activity in traditional financial intermediaries on per capita output. Demirgüç-Kunt and Maksimovic (1998) show that in countries whose legal systems score high on an efficiency index, a greater proportion of firms use long-term external financing and that an active stock market and a large banking sector are also associated with externally financed firm growth. According to La Porta et al (1998), English common-law countries generally have the strongest, and French-civil-law countries the weakest, legal protections of investors. German- and Scandinavian-civil-law countries are located in the middle. Levine, Loayza and Beck (2000) find that the exogenous component of financial intermediary development is positively associated with economic growth by using both cross-sectional procedures with instrumental variables and dynamic panel techniques and that cross-country differences in legal and accounting systems help account for differences in financial development. Beck, Levine and Loayza (2000) find that financial intermediaries exert a large, positive impact on total factor productivity growth. Rajan and Zingales (1998) ask whether industrial sectors that are relatively more in need of external finance develop disproportionately faster in countries with more developed financial markets and find this to be true. The Schumpeterian growth model of Aghion, Howitt and Mayer-Foulkes (2005) predicts that any country with more than some critical level of financial development will converge to the growth rate of the world technology frontier. They present evidence by using a cross-country growth regression and find a significant and sizable negative coefficient on initial per-capita GDP relative to the technological frontier (assumed to be the United States) interacted with financial intermediation. In Howitt (2000) convergence clubs arise

eg because of differences in productivity of R&D. Rousseau and Wachtel (2005) find that the finance-growth relationship is positive among poorer countries, absent among very rich countries and in general not as strong with more recent data as with the original studies for 1960–1989. They find that including fixed or random effects for countries results in disappearance of the usual evidence, suggesting that the measures of financial depth in the standard growth equation may be standing in for other unobserved country-specific factors. Same kind of result was obtained with a different panel specification by Benhabib and Spiegel (2000) who show that adding fixed effects to growth regressions leads to coefficient instability and a loss of significance for financial development variables. Other studies that either question the positive empirical results for financial depth in promoting economic growth or reduce their generality include Demetriades and Hussein (1996), Arestis and Demetriades (1997), Rousseau and Wachtel (1998), Arestis, Demetriades, and Luintel (2001), Wachtel (2003) and Rioja and Valev (2004).

The objective of this paper is to examine, whether financial development affects economic growth through more efficient utilization of technological innovations. The theoretical and empirical model is based on an extension of Aghion, Howitt and Mayer-Foulkes (2005). The main contribution of this paper is to model the innovation channel of finance explicitly. The better functioning are the financial markets, the higher is the probability that a high-quality technological innovation finds the necessary finance to realize its potential for growth. In particular, the interaction term between the measure of innovation and financial development is focused on.

2 Estimation and results

2.1 Specification and data

Aghion, Howitt and Mayer-Foulkes (2005) (hence AHM) introduce imperfect creditor protection in a multicountry Schumpeterian growth model. This theory predicts that any country with more than some critical level of financial development will converge to the growth rate of the world technology frontier, and that all other countries will have a strictly lower long-run growth rate. AHM approximate their theoretical model by the following growth regression

$$g_i - g_1 = \beta_0 + \beta_1 F_i + \beta_2 (y_i - y_1) + \beta_3 F_i (y_i - y_1) + \beta_4 X_i + \varepsilon_i \quad (2.1)$$

where $g_{it} - g_{1t}$ is the average growth rate of per-capita real GDP relative to the United States in country i , F_i the average level of financial development, $y_i - y_1$

log of per-capita real GDP in 1960 relative to the United States, X_i a set of other independent variables and ε_i a disturbance term with mean zero. Country 1 is the technology leader, which AHM take to be the United States. The authors emphasize this (2.2) is a standard growth regression except for the interaction term $F_i(y_i - y_1)$. The main implication of the AHM theoretical model is that the likelihood that a country will converge to the frontier growth rate increases with its level of financial development. Thus, their main hypothesis is that $\beta_3 < 0$. The second essential theoretical implication is that in a country that converges to the frontier growth rate, financial development has a positive but eventually vanishing effect, *ceteris paribus*, on the steady-state level of per-capita GDP relative to the frontier. This produces their additional hypothesis, $\beta_1 = 0$.

According to AHM a country's technological gap in existence of credit constraints evolves according to

$$a_{t+1} = \tilde{\mu}(\omega a_t) + \frac{1 - \tilde{\mu}(\omega a_t)}{1 + g} a_t \quad (2.2)$$

where a_t is country's normalized productivity with respect to technological frontier at time t , g denotes growth of technological frontier and $\tilde{\mu}(\omega a_t)$ is innovation probability where ω accounts for financial development. It is worth noting that innovation probability $\tilde{\mu}(\omega a_t)$ refers to innovation that actually is realized in production activities of a company and produces a monopoly in a sector by creative destruction. Thus, it is different from the concept of own innovation which refers to 'underlying' own innovation that doesn't necessarily lead to any production decisions but can be realized eg by providing it with adequate finance. This distinction is also made in King and Levine (1993b). In the model of AHM, $\tilde{\mu}(\omega a_t)$ depends only on financial development and country's normalized productivity with respect to technological frontier. This fact is reflected in their growth regression (2.1), though they have included a varying set of conditioning variables.

Using (2.1) and (2.2) as a starting point, the model can be extended to take into account other factors that affect realized innovation $\tilde{\mu}(\omega a_t)$ to make it more complete. The above mentioned own innovation is one of the most important of them since it allows for explicit modeling of the innovation channel of finance on growth. In particular, the interaction term between the measure of innovation and financial development is focused on. The interaction term captures the effect of the fact that an adequate level of financial development is needed to realize the full potential of own innovation. It is an important feature of frontier growth models that own innovation becomes more important as countries approach the technological frontier. In the model the growth rate of the world technology frontier is determined by the pace of innovations in the leading countries.

Technology is diffused to other countries from the frontier as they make use of ideas developed elsewhere in the world. This effect is captured by the explicit measure of imitation in the extended model. Even interaction term between the measure of imitation and financial development is included in the extended model to capture the effect of the fact that an adequate level of financial development is also needed to realize the full potential of imitation for economic growth. It is important to note that these two terms are not supposed to affect realized innovation $\tilde{\mu}(\omega a_t)$ as other added variables in the extended model. Imitation is closely related to convergence dynamics, so there is likely to be redundancy between these variables. As countries approach the frontier, own innovation becomes more important to sustain a high growth rate since there are fewer innovations left to be imitated. Near the frontier, a great proportion of growth has to be originated from own innovation as a greater number of intermediate sectors are already at the technological frontier. In the extreme, if the technological frontier consists of only one leading country, each of its intermediate sectors has to innovate to preserve growth. Moreover, successful own innovations can give domestic companies competitive edge or even monopoly power in some sectors in other countries. Since growth of domestic companies with extensive foreign operations is likely to have a disproportionately positive effect on domestic growth compared to growth effects in foreign countries, own innovation can be growth enhancing even for this reason.

The main implication of the AHM theoretical model – ie likelihood that a country will converge to the frontier growth rate increases with its level of financial development – is preserved in this extended model. The implication of their model – that in a country that converges to the frontier growth rate, financial development has a positive but eventually vanishing effect on the steady-state level of per-capita GDP relative to the frontier – could also hold in the extended model. However, it is useful to consider a minor modification in this respect. As a great proportion of growth has to be originated from realized innovation near the technological frontier, this could pose new challenges for financial markets. Many new innovations are created in small or start-up companies. This might require more sophisticated financial intermediation – like more efficient banks, venture capital or markets for IPOs – than at locations further from the frontier. Thus, to realize the necessary innovation near the frontier to attain and sustain a higher steady-state level of per-capita GDP relative to the frontier, more financial development would be needed. In this scenario, growth would be above the frontier growth rate until the steady-state level of per-capita GDP relative to the frontier is attained and be preserved at the frontier growth rate thereafter. Actually, AHM give this kind of modification a thought. They argue that differences in financial development or credit constraints ω in high financially developed countries do not affect the long-run technological gap because the

incentive constraint underlying ω in their model only places an upper bound on the amount borrowed by the entrepreneur. When this constraint no longer binds, ω loses its role in determining the dynamics of productivity. However, AHM note that a different model of credit constraints, like one that would rely on ex ante moral-hazard considerations and a continuous effort choice, could induce a model where differences in financial development always affect long-run productivity. This is exactly what is assumed here.

Additionally, growth of physical capital per capita, its interaction term with financial development, human capital and size of government are added to the model and the regression equation. Physical capital per capita and human capital have been incorporated in Schumpeterian growth theory by Aghion and Howitt (1998). Interaction term between growth of physical capital per capita and financial development is there to capture the effect of financial development on efficiency of capital investments. The bigger the size of government consumption, the bigger is the tax burden. This implies less after-tax monopoly profits for successful innovators, which reduces incentive for innovation. This is a typical feature of Aghion Howitt (1992) and its derivatives. The extended model can even be considered as a universal growth model as it incorporates eg typical variables in neoclassical growth models. In this case, log of per-capita real GDP in 1960 relative to the United States could also be interpreted as capturing the tendency for growth rates to converge across countries and over time.

The constant coefficient term β_0 is omitted in the extended model. There are several reasons of which the first is the most important. First, it is not included in the approximation of the original theoretical model that otherwise generates the estimated equation with the exception of dismissal the quadratic terms. The approximation is presented in Aghion, Howitt and Mayer-Foulkes (2004). Nor is a constant term necessary in growth equations induced by neoclassical growth theory. Second, the better the coverage for variables affecting economic growth, the lesser is the need for a constant term in the regression equation. Third, the PCT (Patent Cooperation Treaty) applications per capita based measures for own innovation and imitation are in fact constants for each country since they are constructed by extending the most recent observation in each country for the whole time period. This is done because the PCT data covers only a relatively short period of time and different countries have entered the PCT at different points of time. Thus, only the most recent observations describe differences in own innovation across countries accurately enough. As changes in own innovation in a country are not likely to occur over short period of time, extending the most recent observation to the whole time period should not radically affect the results. Besides, using yearly observations for PCT applications per capita for only those years they are available would leave the time dimension very short and thus, the overall number of observations in the panel small. In general, the same arguments that apply for PCT applications per capita based measures above, also

apply for the aggregate patent originality per capita based measures for own innovation and imitation but to a lesser extent. That's why for this measure, both constant country averages for the whole period as well as yearly observations for those years they are available are used in separate regressions. However, the literature on technological diffusion has suggested that technological diffusion can be driven by trade or foreign direct investments (see eg Keller, 2004). Since the measure of patent originality is calculated on patents granted in the United States, especially later yearly observations are likely to reflect the positive trends in these factors as a result of globalization.

Finally, the extended model uses an average growth rate of per-capita real GDP instead of that relative to the United States. This approach is also followed in Aghion, Howitt and Mayer-Foulkes (2004). Additionally, variation in growth rate of the United States in panel data is relatively minor with respect to variation in GDPs of other countries. Besides, if average growth rate of per-capita real GDP relative to the United States were used, it would be natural to make even other variables relative to the United States.

The regression equation based on the extended model takes the following form

$$\begin{aligned} \Delta y_{it} = & \beta_1 F_{it} + \beta_2 (y_{i(t-1)} - y_{1(t-1)}) + \beta_3 F_{it} (y_{i(t-1)} - y_{1(t-1)}) + \beta_4 N_{it} + \beta_5 F_{it} N_{it} \\ & + \beta_6 M_{it} + \beta_7 F_{it} M_{it} + \beta_8 \Delta k_{it} + \beta_9 F_{it} \Delta k_{it} + \beta_{10} h_{it} + \beta_{11} G_{it} + \varepsilon_{it} \end{aligned} \quad (2.3)$$

where Δy_{it} is growth of per capita real GDP at time t in country i (long series for growth of per capita real GDP in constant dollars available from World Bank's *World Development Indicators* for a large cross section of countries). $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7, \beta_8, \beta_9, \beta_{10}$ and β_{11} are constant coefficients. F_{it} is an indicator of financial development at time t in country i (long series available for domestic credit to private sector from World Bank's *World Development Indicators* for a large cross section of countries, short series available for domestic credit to private non-financial corporations of financial accounts statistics from OECD. Stat for a set of countries close to OECD, dummy variables for British, French, German and Scandinavian legal origin from Reynolds and Flores (1996) for a large cross section of countries are used as alternative instruments for financial development). AHM prefer domestic credit to the private sector as preferred measure of financial development. $(y_{i(t-1)} - y_{1(t-1)})$ is the technology gap at time $t-1$ in country i , ie log of per capita real GDP – log of per capita in the United States (technology frontier) (long series for real GDP per capita in constant dollars available from World Bank's *World Development Indicators* for a large cross section of countries). N_{it} is log of own innovation (PCT applications filed by domestic residents per capita in a year) at time t in country i (short PCT applications series available from OECD. Stat for a large cross section of

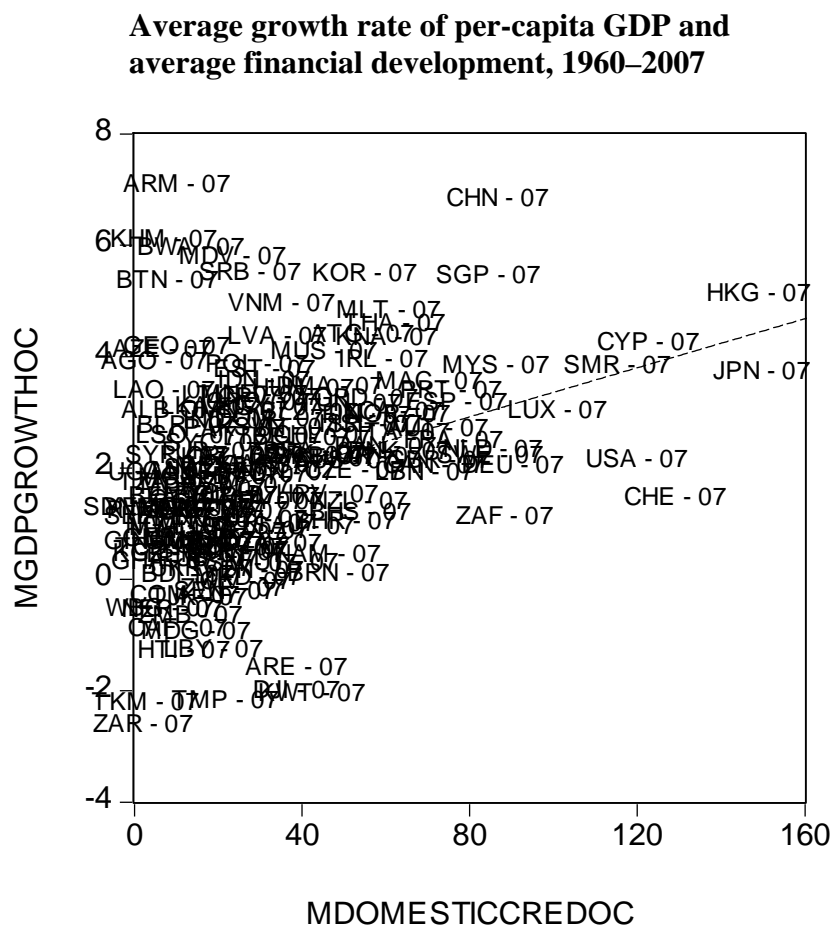
countries (PCT contracting states), long series for population available from World Bank's *World Development Indicators* for a large cross section of countries). M_{it} is log of scope of imitation (national patent applications filed by domestic residents in a year divided by PCT applications filed by domestic residents in a year) at time t in country i (long national patent applications series available from WIPO (World Intellectual Property Organization) for a large cross section of countries). Alternatively, N_{it} and M_{it} are based on patent originality measure first suggested by Trajtenberg, Jaffe and Henderson (1997) and calculated by Hall, Jaffe and Trajtenberg (2001) from NBER patent citations data file on patents granted 1975–1999 in the United States to applicants from different countries. In the alternative measures, PCT applications is replaced by originality aggregated over all patents granted to applicants from a country of first inventor in a year. Δk_{it} is growth of physical capital per capita at time t in country i (physical capital stock available for a large cross-section of countries 1960–1990 in Nehru and Dhareshwar (1993), period of coverage is extended by adding gross fixed capital formation from World Bank's *World Development Indicators* and subtracting depreciation which assumed to amount 4% of the physical capital stock). h_{it} is log of human capital at time t in country i (tertiary education attainment ratio available from Barro and Lee (2000) for a large cross section of countries 1960–1999, period of coverage is extended by linear interpolation and to small extent linear extrapolation). G_{it} is indicator for size of government as percentage of GDP at time t in country i (long series for general government final consumption expenditure available from World Bank's *World Development Indicators* for a large cross section of countries). ε_{it} is disturbance term at time t in country i .¹

The main hypothesis is that the interaction of financial development and own innovation has a positive effect on economic growth, ie: $H_1: \beta_5 > 0$, which implies

¹ Altogether, data have been gathered for 209 countries over the period from 1960 to 2007. However, since all variables are not available for the whole time period and most countries, the panel regressions include significantly less time periods and countries in practice. The number varies according to different specifications. In baseline regressions with PCT applications per capita describing technological innovations the panel includes 60 countries: Algeria, Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, China, Colombia, Costa Rica, Cyprus, Denmark, Ecuador, Egypt, Finland, France, Germany, Greece, Guatemala, Iceland, India, Indonesia, Iran, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kenya, Korea, Kuwait, Malaysia, Malta, Mexico, Netherlands, New Zealand, Norway, Pakistan, Panama, Peru, Philippines, Portugal, El Salvador, Singapore, South Africa, Spain, Sri Lanka, Sweden, Switzerland, Thailand, Trinidad and Tobago, Tunisia, Turkey, United Kingdom, United States, Uruguay, Venezuela and Zimbabwe. Further, in baseline regressions with aggregate patent originality per capita describing technological innovations the panel includes 65 countries; the country set is the same as above except that it excludes Algeria, Jordan and Kuwait but instead includes Bolivia, Dominican Republic, Honduras, Haiti, Mauritius, Malawi, Nicaragua and Paraguay. Finally, in baseline regressions with loans to non-financial corporations describing financial development the panel includes 15 countries: Australia, Austria, Belgium, Germany, Denmark, Spain, Finland, France, Greece, Italy, Mexico, Netherlands, Norway, Portugal and Sweden. This is a subset of both the 60- and 65-country set.

that $H_0: \beta_5 \leq 0$, where H_0 denotes the zero hypothesis and H_1 its counterhypothesis. If H_0 can be rejected, H_1 will be accepted and thus, the main hypothesis is proven. Figure 1 plots the average growth rate of per-capita GDP over 1960–2007 against the average level of financial development over the same period. The scatter plot shows that the data are roughly consistent with the AHM theoretical implication that the likelihood that a country will converge to the frontier growth rate increases with its level of financial development. Figure 2 plots the average growth rate of per-capita GDP over 1960–2007 against a measure of own innovation, PCT applications per capita. This figure provides modest support to the notion that own innovation is beneficial for growth.

Figure 1.



averages. For each of these three setups, separate regressions are run for the whole data set, industrialized countries and emerging markets together and industrialized countries only. In addition to GDP per-capita growth, total factor productivity could also be regressed on financial depth, technological innovations and other affecting variables. AHM and many other studies have found that this doesn't affect the results. That's why this alternative is not considered here. Instead two different financial development variables, three different own innovation variables and three different imitation variables are used.

In each of the setups, least squares estimation, GMM with initial values as instrumental variables (in this case equals two-stage least squares) and least squares with initial values as explanatory variables is carried out. The last two are introduced to reduce any simultaneity or endogeneity bias that would result from the influence of economic growth on the development of the financial sector. In practice, this would take the form of correlation between the financial development variable and the error term. With instrumental variables estimation, lagged value of financial development, initial value in the 5-year average or in the 1960–2007 average is used along with other explanatory variables as columns in the instrument matrix for each regression. With pure cross-sectional analysis, legal origins are used as alternate instruments. One problem with use of instrumental variables is that it reduces efficiency, especially if the chosen instrument is not well correlated with the concerned explanatory variable. This might influence the variance of the estimator and thus even significance levels. Therefore it is useful to run standard least squares regressions, too. An alternative approach to avoiding simultaneity bias is to use lagged values of the explanatory variables in yearly panel, initial values for each 5-year period in 5-year-panel or initial values for 1960–2007 in pure cross-sectional analysis instead of contemporary explanatory variables as regressors in standard least squares specification. With Arellano-Bond (1991) even more efficient GMM would be available. Here the standard Arellano-Bond estimator is not applicable in most setups since it assumes differencing which would eliminate own innovation and imitation variables in most setups. The validity of instruments is controlled with Sargan tests (p-value of J-statistic). A related Hausman-Wu test is used to check, whether regressions could have been run with least squares in the first place. The consequent additional risk of estimator bias can also be assessed by comparing the coefficients between the three setups including least squares with initial values as explanatory variables.

Since lagged GDP per capita is included in explanatory variable distance to frontier and it is also included in GDP growth per capita, it is possible although not very likely that this state of affairs combined with autocorrelation in disturbances could render the OLS estimator biased. It is worth noting though that the presence of a lagged dependent variable as an explanatory variable renders OLS estimator automatically biased when error term is autocorrelated. In

regression equations where there is an explicit country specific variable (like own innovation), autocorrelation is less likely since in general omitting a country-specific dummy and assuming it absorbed in the error term creates autocorrelation in the error term. The number of explanatory variables also reduces the risk of autocorrelation. In the 5-year -average setup, the fact that the dependent variable is a 5-year average also reduces probability of autocorrelation as it has less in common with initial GDP per capita. Further, in pure cross-sectional setups autocorrelation becomes irrelevant. Autocorrelation is measured by reported Durbin-Watson statistic and because of its possible shortcomings, also by Box-Pierce Q-statistic. Since the Q-statistic is calculated for several lags, these results are not reported in tables.

Finally, for each yearly-panel or 5-year-panel setup, OLS, OLS with White diagonal standard errors and GLS with cross-sectional heteroskedasticity and White period standard errors are estimated. For each cross-sectional setup, OLS, OLS with White cross-sectional standard errors and GLS with cross-sectional heteroskedasticity and White cross-sectional standard errors are estimated. This is done because regular standard errors are inconsistent in the presence of heteroskedasticity and or (auto)correlation. Non-normality is not considered a problem as disturbances are asymptotically normal anyway with very general conditions and there is a large number of observations. White diagonal standard errors are consistent in the presence of observation specific heteroskedasticity in the disturbances, White period standard errors are robust to arbitrary serial correlation and time-varying variances and White cross-sectional standard errors are consistent in the presence of contemporaneous correlation as well as different error variances in each cross-section. GLS with cross-sectional heteroskedasticity uses estimates of cross-section-specific variances as weights in a weighted least squares procedure to form the feasible GLS estimates. Heteroskedasticity is usually cross-sectional and correlation periodical.

2.3 Replicating the AHM results

AHM estimate (2.1) by using cross-sectional data averaged over 1960–1995 for the 71 countries also present in the data of Levine Loayza and Beck (2000) (hence LLB). They find that the coefficient of the interaction term $F_i(y_i - y_1)$ is significantly negative ($\beta_3 < 0$) and that the coefficient of F_i is insignificantly negative ($\beta_1 = 0$). These results imply that their hypotheses are supported. Additionally, they find that the coefficient of initial value for relative per-capita real GDP is significantly positive ($\beta_2 > 0$). These results are robust to inclusion of sets of conditioning variables, for which the coefficients and their interactions with $y_i - y_1$ are insignificant. As instruments AHM use legal origins by LLB.

However, they find the same results by using as instruments the initial value of financial development (F_0) and the corresponding interaction term $F_0(y_i - y_1)$. Even rejecting instruments and using OLS yields the same results. Their findings are also robust to removal of outliers.

In order to set the starting point, AHM estimations are replicated as far as the data of this study allow. Specifically, (2.1) is estimated by OLS, using the initial value of financial development (F_0) and the corresponding interaction term $F_0(y_i - y_1)$ as instruments, using legal origins by LLB and the corresponding interaction term with frontier gap as instruments and also OLS with initial values. No other regressors are included. According to results the coefficient of the interaction term $F_i(y_i - y_1)$ is still significantly negative ($\beta_3 < 0$) but the coefficient of F_i , β_1 , is positive sometimes even significantly but mostly insignificantly. Additionally, the coefficient of initial value for relative per-capita real GDP is still significantly positive ($\beta_2 > 0$). These results don't change much if the time period is 1960–2007 or 1960–1995 and if all countries or only AHM countries (of which Taiwan is missing) are included. Thus, switching from AHM data to data of this study doesn't seem to affect the essential results. Only negative but insignificant coefficient of financial intermediation becomes positive but mostly insignificant.

By applying data from Penn World Tables (PWT) for the initial value for relative per-capita real GDP used by AHM and LLB, the signs of financial intermediation turn negative in estimation configurations without initial values of financial intermediation. PWT consist of figures that are supposed to be based on purchasing power parity methodology (PPP). They became widely known by Summers and Heston (1991) but there are more recent versions, too. However, Subramanian et al (2009) argue that the PWT methodology leads to GDP estimates that are not valued at purchasing power parity prices. Anyway, in general these figures make differences in per-capita real GDP smaller between nations in comparison with traditional constant dollar figures used in this study. Further, if financial intermediation measure used in this study is replaced by financial intermediation measure used by AHM and LLB, the signs of financial intermediation become negative even in regression configurations with initial values for financial intermediation. Probable reason for this effect is the fact that the financial intermediation measure used by AHM and LLB is calculated as average of 1960 and 1995 while in this study the average is calculated as a simple average of financial intermediation over all the years in the time period. There also some other minor differences in the calculation of the measure. Additionally, AHM's and LLB's data for financial intermediation is obtained from IFS while data of this study is from World Bank's *World Development Indicators*. Finally, using average growth rate of per-capita real GDP instead of that relative to the United States as in Aghion, Howitt and Mayer-Foulkes (2004) doesn't change the results. It's worth of noting that regressions including AHM's and LLB's financial mediation variable or initial value for relative per-capita real GDP or both produce

a (highly) significant negative sign for direct effect of financial intermediation in GLS configuration. This is consistent with the fact that GLS is more efficient than OLS.

To control effect of a panel-data approach on results, AHM estimations are implemented by using panel data instead of cross sectional averages according to (2.4)

$$g_{it} - g_{1t} = \beta_0 + \beta_1 F_{it} + \beta_2 (y_{i(t-1)} - y_{1(t-1)}) + \beta_3 F_{it} (y_{i(t-1)} - y_{1(t-1)}) + \beta_4 X_{it} + \varepsilon_{it} \quad (2.4)$$

The results are similar to those of cross-sectional approach except that now the coefficient of financial intermediation β_1 becomes negative and in many cases significant. In regressions using all countries for 1960–2007 the sign is insignificant in all configurations. Thus, the data of this study in panel format gives exactly the same results qualitatively as AHM data in a corresponding cross-sectional specification. Switching to AHM countries for 1960–1995 makes the sign of β_1 significant in GLS specifications. Finally, using average growth rate of per-capita real GDP instead of that relative to the United States as in Aghion, Howitt and Mayer-Foulkes (2004) makes the sign highly significant in all specifications. Anyway, the AHM main result that the coefficient of the interaction term $F_i(y_i - y_1)$ is significantly negative ($\beta_3 < 0$) still holds.

2.4 The basic results

Tables 1–4 present basic results for the full set of countries with yearly observations. Tables of results for panels of 5-year-averages, pure cross-sectional analysis and other country sets are available from the author at request. In general, R^2 seems relatively high across different specifications. It increases significantly as time period is made less frequent. As a rule, Sargan tests accept use of initial values for financial intermediation and its interaction terms with other variables as instruments. The only exceptions are specifications with loans to non-financial enterprises as financial intermediation variable. Related Hausman-Wu test doesn't reject use of OLS, except for pure cross-sectional regressions for OECD subset. For some reason, Sargan tests seem to reject use of legal origins and their interaction terms with other variables as instruments. This is only problem for pure cross-sectional regressions since legal origins are used as instruments only in them. Durbin-Watson statistic indicates that first-order autocorrelation is present. The same indication is also given by Box-Pierce Q-statistic that at the same time usually rejects any higher-order autocorrelation. This kind of autocorrelation is not necessarily an indication of omitted variables but may reflect eg business cycles.

Dependent Variable: Annual Growth Rate of Per-Capita Real GDP, 1960-2007	IV using Lagged Financial Intermediation									
	Contemporary Values		Lagged Values		White		GMM		OLS	
	OLS	GLS	OLS	GLS	diag.s.e.	White	GMM	OLS	diag.s.e.	per.s.e.
Domestic Credit to Private Sector / GDP	-0.041549*** (0.012412)	-0.041549*** (0.014989)	-0.047189*** (0.014234)	-0.040099*** (0.012606)	-0.040099*** (0.014069)	-0.049277*** (0.014444)	-0.05454*** (0.013456)	-0.05454*** (0.013456)	-0.05454*** (0.016149)	-0.05930*** (0.017509)
Frontier Gap	-0.544317*** (0.117085)	-0.544317*** (0.135602)	-0.351511*** (0.144475)	-0.525855*** (0.118056)	-0.525855*** (0.135542)	-0.333790** (0.146070)	-0.520425*** (0.126234)	-0.520425*** (0.126234)	-0.520425*** (0.144375)	-0.438781*** (0.165284)
(Frontier Gap)*(Domestic Credit to Private Sector / GDP)	-0.007138*** (0.002685)	-0.007138*** (0.002946)	-0.008683*** (0.002689)	-0.007529*** (0.002725)	-0.007529*** (0.002740)	-0.009346*** (0.002713)	-0.012338*** (0.002907)	-0.012338*** (0.002907)	-0.012338*** (0.003176)	-0.011604*** (0.003434)
PCT Applications Per Capita	0.277814*** (0.047601)	0.277814*** (0.05476)	0.197031*** (0.053452)	0.279622*** (0.048146)	0.279622*** (0.056718)	0.198707*** (0.054391)	0.474701*** (0.051240)	0.474701*** (0.051240)	0.474701*** (0.060363)	0.415471*** (0.057375)
(PCT Applications Per Capita)*(Domestic Credit to Private Sector / GDP)	0.002991** (0.001252)	0.002991** (0.001533)	0.003613*** (0.001399)	0.002896** (0.001274)	0.002896** (0.001430)	0.003753*** (0.001423)	0.004103** (0.001355)	0.004103** (0.001355)	0.004103** (0.001700)	0.003929** (0.001705)
National Patent Applications / PCT Applications	-0.188245** (0.086356)	-0.188245** (0.105423)	-0.110791 (0.107908)	-0.172623** (0.087168)	-0.172623** (0.106007)	-0.100204 (0.109339)	-0.037120 (0.093105)	-0.037120 (0.093105)	-0.037120 (0.117377)	-0.021348 (0.124191)
(National Patent Applications / PCT Applications)*(Domestic Credit to Private Sector / GDP)	0.000972 (0.001428)	0.000972 (0.001294)	0.000854 (0.001299)	0.000730 (0.001447)	0.000730 (0.001356)	0.000897 (0.001324)	0.001501 (0.001540)	0.001501 (0.001540)	0.001501 (0.001435)	0.002239 (0.001612)
Per-Capita Physical Capital Growth	0.450089*** (0.036344)	0.450089*** (0.047237)	0.483916*** (0.044239)	0.436575*** (0.037083)	0.436575*** (0.049430)	0.475663*** (0.044997)	0.191085*** (0.039006)	0.191085*** (0.039006)	0.191085*** (0.057561)	0.198834*** (0.047512)
(Per-Capita Physical Capital Growth)*(Domestic Credit to Private Sector / GDP)	0.001037* (0.000613)	0.001037* (0.000615)	0.000911 (0.000620)	0.001234* (0.000631)	0.001234* (0.000658)	0.000978 (0.000642)	0.000262 (0.000656)	0.000262 (0.000656)	0.000262 (0.000845)	0.000312 (0.000722)
Human Capital	0.128037 (0.084325)	0.128037 (0.097727)	0.168938* (0.093762)	0.099225 (0.085246)	0.099225 (0.097541)	0.157230* (0.094968)	-0.181454** (0.091607)	-0.181454** (0.091607)	-0.181454** (0.105230)	-0.205474* (0.106866)
Government Consumption / GDP	-0.064798*** (0.015606)	-0.064798*** (0.019573)	-0.045027** (0.017967)	-0.064074*** (0.015684)	-0.064074*** (0.019854)	-0.043923** (0.018118)	-0.087620*** (0.016861)	-0.087620*** (0.016861)	-0.087620*** (0.019985)	-0.059956*** (0.019973)
R-squared	0.271996	0.271996	0.333722	0.270338	0.270338	0.331204	0.146127	0.146127	0.146127	0.167076
Periods	47	47	47	47	47	47	46	46	46	46
Cross-sections	60	60	60	60	60	60	60	60	60	60
Observations	2446	2446	2446	2427	2427	2427	2423	2423	2423	2423
J-statistic				0.236858	0.236858	1.907152				
P-value				0.626485	0.626485	0.167280				
Hausman-Wu				1.583113						
P-value				0.161404						
Durbin-Watson statistic	1.354614	1.354614	1.406751	1.346307	1.346307	1.403295	1.365567	1.365567	1.365567	1.402321

Notes: *** significant at 1% level, ** significant at 5% level, * significant at 10% level, (standard errors in parentheses)

Innovation Variable	Dependent Variable: Annual Growth Rate of Per-Capita Real GDP, 1960-2007									
	Contemporary Values					Lagged Values for Independent Variables				
	OLS	OLS, White	GLS, White	GMM	GMM, White	GMM, GLS w.,	OLS	OLS, White	GLS, White	per.s.e.
Domestic Credit to Private Sector / GDP	-0.042439** (0.017170)	-0.042439** (0.016746)	-0.032121* (0.018308)	-0.047111*** (0.017411)	-0.047111*** (0.017027)	-0.038770** (0.018674)	-0.032123* (0.018892)	-0.032123* (0.017580)	-0.018193 (0.022928)	-0.018193
Frontier Gap	0.186359** (0.094051)	0.186359** (0.107201)	0.157998 (0.121525)	0.242773** (0.095195)	0.242773** (0.106440)	0.190746 (0.122261)	0.351588*** (0.103465)	0.351588*** (0.115247)	0.317808** (0.144891)	0.317808**
(Frontier Gap)*(Domestic Credit to Private Sector / GDP)	-0.014146*** (0.003202)	-0.014146*** (0.002787)	-0.011212*** (0.003270)	-0.016456*** (0.003276)	-0.016456*** (0.002781)	-0.013041*** (0.003331)	-0.016113*** (0.003530)	-0.016113*** (0.002999)	-0.012517*** (0.004112)	-0.012517***
Average Aggregated Originality Per Capita	0.139291*** (0.044533)	0.139291*** (0.049187)	0.081714 (0.050097)	0.130456*** (0.045016)	0.130456*** (0.049443)	0.080827 (0.050701)	0.208184*** (0.048779)	0.208184*** (0.053895)	0.171055*** (0.057780)	0.171055***
(Average Aggregated Originality Per Capita)*(Domestic Credit to Private Sector / GDP)	0.002955** (0.001233)	0.002955** (0.001152)	0.002153* (0.001265)	0.003520*** (0.001254)	0.003520*** (0.001166)	0.002643** (0.001291)	0.002402* (0.001356)	0.002402* (0.001200)	0.001369 (0.001567)	0.001369
Average National Patent Applications / Aggregated Originality	0.095607 (0.071996)	0.095607 (0.085069)	0.091640 (0.091591)	0.130138* (0.072951)	0.130138 (0.085296)	0.108446 (0.092518)	0.300506*** (0.079200)	0.300506*** (0.094845)	0.297717*** (0.108271)	0.297717***
(Average National Patent Applications / Aggregated Originality)*(Domestic Credit to Private Sector / GDP)	-0.001277 (0.001469)	-0.001277 (0.001409)	-0.000850 (0.001508)	-0.001841 (0.001493)	-0.001841 (0.001480)	-0.000946 (0.001528)	-0.001962 (0.001612)	-0.001962 (0.001553)	-0.001664 (0.001831)	-0.001664
Per-Capita Physical Capital Growth	0.501422*** (0.033089)	0.501422*** (0.040124)	0.519808*** (0.041489)	0.487641*** (0.033764)	0.487641*** (0.041539)	0.506194*** (0.042137)	0.218626*** (0.036286)	0.218626*** (0.053562)	0.236025*** (0.046883)	0.236025***
(Per-Capita Physical Capital Growth)*(Domestic Credit to Private Sector / GDP)	0.001037* (0.000597)	0.001037* (0.000601)	0.000783 (0.000626)	0.001217** (0.000615)	0.001217* (0.000644)	0.000973 (0.000645)	0.000983 (0.000655)	0.000983 (0.000853)	0.000467 (0.000735)	0.000467
Human Capital	0.118602 (0.081840)	0.118602 (0.086482)	0.126435 (0.095094)	0.081786 (0.082551)	0.081786 (0.086750)	0.107277 (0.096052)	-0.228410** (0.090274)	-0.228410** (0.095391)	-0.273480** (0.110943)	-0.273480**
Government Consumption / GDP	-0.053830*** (0.015165)	-0.053830*** (0.018723)	-0.030218* (0.017794)	-0.051305*** (0.015232)	-0.051305*** (0.018824)	-0.028704 (0.017846)	-0.060070*** (0.016654)	-0.060070*** (0.020230)	-0.037016* (0.020531)	-0.037016*
R-squared	0.259503	0.259503	0.308589	0.256952	0.256952	0.307820	0.102967	0.102967	0.124783	0.124783
Periods	47	47	47	47	47	47	46	46	46	46
Cross-sections	65	65	65	65	65	65	65	65	65	65
Observations	2658	2658	2658	2639	2639	2639	2630	2630	2630	2630
J-statistic				5.160195	5.160195	1.824901				
P-value				0.023110	0.023110	0.176731				
Hausman-Wu				1.737330	1.737330					
P-value				0.122648	0.122648					
Durbin-Watson statistic	1.378482	1.378482	1.398920	1.370669	1.370669	1.394476	1.354125	1.354125	1.380126	1.380126

Notes: *** significant at 1% level, ** significant at 5% level, * significant at 10% level, (standard errors in parentheses)

Variable	Dependent Variable: Annual Growth Rate of Per-Capita Real GDP, 1960-2007									
	Contemporary Values			IV using Lagged Financial Intermediation			Lagged Values for Independent Variables			
	OLS	OLS, White	GLS, White	GMM	GMM, White	GMM, GLS w.,	OLS	OLS, White	GLS, White	
	diag.s.e.	per.s.e.		diag.s.e.	White per.s.e.		diag.s.e.	per.s.e.	per.s.e.	
Domestic Credit to Private Sector / GDP	-0.076730*** (0.025167)	-0.076730*** (0.027595)	-0.060558** (0.023466)	-0.076761*** (0.025547)	-0.076761*** (0.027631)	-0.062434*** (0.023964)	-0.077238*** (0.028230)	-0.077238*** (0.031289)	-0.077238*** (0.031289)	-0.039225 (0.027232)
Frontier Gap	-0.090654 (0.197180)	-0.090654 (0.205608)	0.034321 (0.162880)	-0.117376 (0.198473)	-0.117376 (0.213159)	0.053551 (0.163844)	0.142920 (0.220237)	0.142920 (0.233515)	0.142920 (0.233515)	0.112265 (0.183720)
(Frontier Gap)*(Domestic Credit to Private Sector / GDP)	-0.012745** (0.005074)	-0.012745** (0.005356)	-0.014205*** (0.004754)	-0.012270** (0.005152)	-0.012270** (0.005407)	-0.015234*** (0.004769)	-0.014950*** (0.005685)	-0.014950*** (0.006173)	-0.014950*** (0.006173)	-0.011014* (0.005673)
Aggregated Originality Per Capita	0.201395** (0.086404)	0.201395** (0.111470)	0.138055* (0.072557)	0.205054** (0.087347)	0.205054** (0.116875)	0.147531** (0.073681)	0.199257** (0.096333)	0.199257** (0.111825)	0.199257** (0.111825)	0.223457*** (0.082432)
(Aggregated Originality Per Capita)*(Domestic Credit to Private Sector / GDP)	0.003450* (0.001823)	0.003450* (0.002032)	0.003212* (0.001662)	0.003273* (0.001874)	0.003273* (0.002101)	0.003263* (0.001693)	0.003957* (0.002044)	0.003957* (0.002498)	0.003957* (0.002498)	0.001655 (0.001897)
National Patent Applications / Aggregated Originality	-0.296907** (0.129845)	-0.296907** (0.158262)	-0.195902* (0.112732)	-0.301179** (0.133254)	-0.301179** (0.171432)	-0.194776* (0.116351)	-0.002641 (0.145377)	-0.002641 (0.179787)	-0.002641 (0.179787)	0.021279 (0.125042)
(National Patent Applications / Aggregated Originality)*(Domestic Credit to Private Sector / GDP)	0.003682 (0.002242)	0.003682 (0.002298)	0.001214 (0.001907)	0.003940* (0.002306)	0.003940 (0.002487)	0.001281 (0.001993)	0.003196 (0.002502)	0.003196 (0.003106)	0.003196 (0.003106)	0.001400 (0.002054)
Per-Capita Physical Capital Growth	0.617104*** (0.071192)	0.617104*** (0.094232)	0.590857*** (0.071599)	0.582346*** (0.072431)	0.582346*** (0.101974)	0.573159*** (0.073146)	0.363659*** (0.079227)	0.363659*** (0.139061)	0.363659*** (0.139061)	0.269083*** (0.093187)
(Per-Capita Physical Capital Growth)*(Domestic Credit to Private Sector / GDP)	0.000256 (0.001017)	0.000256 (0.001199)	0.000657 (0.000975)	0.000720 (0.001063)	0.000720 (0.001397)	0.000834 (0.001016)	-0.000449 (0.001133)	-0.000449 (0.001818)	-0.000449 (0.001818)	0.000127 (0.001276)
Human Capital	0.514728*** (0.168984)	0.514728*** (0.173378)	0.461665*** (0.156698)	0.475533*** (0.168762)	0.475533*** (0.172040)	0.438622*** (0.155756)	0.166389 (0.188045)	0.166389 (0.213834)	0.166389 (0.213834)	0.019623 (0.176587)
Government Consumption / GDP	-0.046550* (0.024500)	-0.046550* (0.031468)	-0.029306 (0.021628)	-0.039390 (0.024608)	-0.039390 (0.031741)	-0.029504 (0.021645)	-0.039413 (0.027264)	-0.039413 (0.033269)	-0.039413 (0.033269)	-0.030999 (0.024449)
R-squared	0.261367	0.261367	0.393494	0.260925	0.260925	0.347905	0.090815	0.090815	0.090815	0.067147
Periods	25	25	25	25	25	25	25	25	25	25
Cross-sections	65	65	65	65	65	65	65	65	65	65
Observations	895	895	895	886	886	886	894	894	894	894
J-statistic				6.533286	6.533286	2.406242				
P-value				0.010587	0.010587	0.120852				
Hausman-Wu				1.117653	1.117653					
P-value				0.349239	0.349239					
Durbin-Watson statistic	1.183256	1.183256	1.349153	1.186599	1.186599	1.346913	1.114255	1.114255	1.114255	1.278859

Notes: *** significant at 1% level, ** significant at 5% level, * significant at 10% level, (standard errors in parentheses)

Variable	Dependent Variable: Annual Growth Rate of Per-Capita Real GDP, 1960-2007												
	Contemporary Values			IV using Lagged Financial Intermediation			Lagged Values for Independent Variables						
	OLS	OLS, White	GLS, White	GMM	GMM, White	GMM, GLS w.,	OLS	OLS, White	GLS, White	OLS	OLS, White	GLS, White	
	diag.s.e.	per.s.e.		diag.s.e.	White per.s.e.		diag.s.e.	per.s.e.		diag.s.e.	per.s.e.		
Loans to Non-Financial Corporations / GDP	-12.20546*	(6.669618)	-12.20546*	-16.84444**	(6.686183)	-16.84444**	-17.66291*	(9.2053380)	-13.02576*	(6.686368)	-13.02576*	-10.96693	(8.504707)
Frontier Gap	1.617685*	(0.854448)	1.617685*	2.649694**	(0.867048)	2.649694**	2.558879**	(1.062626)	2.557778**	(0.852863)	2.557778**	2.451018**	(1.211432)
(Frontier Gap)*(Loans to Non-Financial Corporations / GDP)	-5.820366**	(2.473855)	-5.820366**	-8.018320***	(3.398967)	-8.018320***	-7.686903**	(2.405926)	-8.483498***	(2.479200)	-8.483498***	-7.419601**	(3.248030)
PCT Applications Per Capita	-0.110887	(0.212145)	-0.110887	-0.365818*	(0.239854)	-0.365818*	-0.435538*	(0.193766)	-0.340733	(0.209084)	-0.340733	-0.408711	(0.250605)
(PCT Applications Per Capita)*(Loans to Non-Financial Corporations / GDP)	1.280413**	(0.589415)	1.280413**	1.815013***	(0.789247)	1.815013***	1.977687**	(0.593820)	1.556448***	(0.591212)	1.556448***	1.460385*	(0.741751)
National Patent Applications / PCT Applications	1.303823***	(0.533646)	1.303823***	1.617459***	(0.425891)	1.617459***	1.494309***	(0.554299)	1.733132***	(0.487825)	1.733132***	1.593066**	(0.663709)
(National Patent Applications / PCT Applications)*(Loans to Non-Financial Corporations / GDP)	-2.557939**	(1.001880)	-2.557939**	-3.015149***	(0.835226)	-3.015149***	-2.619631**	(1.073263)	-3.213401***	(0.995761)	-3.213401***	-2.859853**	(1.248550)
Per-Capita Physical Capital Growth	0.142499	(0.436502)	0.142499	0.341025	(0.408012)	0.341025	0.726320	(0.476251)	0.025923	(0.437860)	0.025923	0.355813	(0.507081)
(Per-Capita Physical Capital Growth)*(Loans to Non-Financial Corporations / GDP)	0.771576	(0.822114)	0.771576	0.663059	(0.695868)	0.663059	0.223768	(0.879848)	-0.033697	(0.826344)	-0.033697	-0.571854	(0.924626)
Human Capital	0.354155	(0.447813)	0.354155	0.862166*	(0.575745)	0.862166*	0.838808	(0.464661)	0.817818*	(0.441000)	0.817818*	0.886257	(0.582800)
Government Consumption / GDP	0.034916	(0.053933)	0.034916	0.035553	(0.047369)	0.035553	0.021994	(0.053633)	0.057965	(0.053520)	0.057965	0.046741	(0.065391)
R-squared	0.150962		0.150962	0.206867		0.206867	0.367105		0.116514		0.116514	0.129449	
Periods	21		21	20		20	20		20		20	20	
Cross-sections	15		15	15		15	15		15		15	15	
Observations	204		204	189		189	189		203		203	203	
J-statistic				21.92363		21.92363	19.37624						
P-value				2.84E-06		2.84E-06	1.07E-05						
Hausman-Wu				0.633280		0.633280							
P-value				0.674568		0.674568							
Durbin-Watson statistic	1.018229		1.018229	1.045808		1.045808	1.049537		1.097690		1.097690	1.11005	

Notes: *** significant at 1% level, ** significant at 5% level, * significant at 10% level, (standard errors in parentheses)

The problem of multicollinearity is likely to be present in regressions since correlation of some variables with each other is very high. Unfortunately, the highest correlations are those between financial intermediation variable and the interaction term between own innovation and financial intermediation variable. They reach as high value as 0.94 when domestic credit to private sector is financial intermediation variable and 0.95 when loans to non-financial corporations is applied. Multicollinearity increases variance of the estimator. According to Greene (2008) symptoms of multicollinearity include the following: small changes in data produce wide swings in parameter estimates, coefficients may have wrong sign or implausible magnitudes and coefficients may have very high standard errors and low significance levels although they are jointly significant and the R^2 for the regression is quite high. Thus, the coefficients of financial intermediation variable and the interaction term between own innovation and financial intermediation variable are likely to become insignificant in specifications where number of observations is low. They may even get the wrong sign if number of observations gets very low. This is exactly the case in the results. The fact is highlighted in regression presented in Table 4 where loans to non-financial corporations stands for financial intermediation. Magnitudes and signs are in many cases different from those in other tables. Further, loans to non-financial corporations is only available for more developed countries and only for a short and recent time period. Thus, variability in loans to non-financial corporations is small, which is likely to make the problems worse.

An interesting observation is that the sign and magnitude of the central coefficient of interest – interaction term between financial intermediation and own innovation – remain roughly the same in different specifications in Tables 1–3. The same applies more or less to the other variables, too, except for the sign of distance to frontier when average aggregate originality per capita serves as financial intermediation variable. This indicates that the eventual estimator bias or the choice of technique to ameliorate potential problems of simultaneity and bias of estimator does not seem to affect conclusions on these variables, even though it must be mentioned that the applied techniques are in most cases very close in practice.

The sign of interaction term between financial intermediation and own innovation is usually found to be positive and in many cases significant. The magnitude is not very large. Consistently very significant are signs for specifications where time frequency is one year, PCT applications or average aggregate originality per capita stands for own innovation and subset is whole sample or OECD countries and emerging markets. These are the most important specifications since they cover the whole period and all or the most important countries. Significance becomes more seldom as time dimension is made less frequent, with smaller country subsets or as number of observations gets down for other reasons. Thus, interaction variable with PCT applications or average

aggregate originality per capita as own innovation is more often significant than interaction variable with aggregate originality per capita. Negative signs are almost exclusively restricted to two small groups. The first group includes cases with aggregate originality as own innovation when using initial values for all variables as regressors and time frequency of five years (or one year in case of OECD subset). The second group includes cases with PCT applications per capita cases as own innovation when using legal origins and their interaction terms with other variables as instruments. This is only problem for pure cross-sectional regressions since legal origins are used as instruments only in them. In the first group the number of observations is low and in the second very low. Thus, multicollinearity is likely to blame. It is encouraging, however, that the other measure for own innovation shows positive sign in both groups.

The sign of financial intermediation variable is found to be negative in most cases and significant in many cases. The magnitude is relatively small. The above applies both for domestic credit to private sector and loans to non-financial corporations. According to AHM the sign should be zero since thus the overall effect of financial development on steady-state relative output will vanish at least for one country (the leader). However, coefficients of AHM also have negative sign; they are just all insignificant. RW report many negative and some significantly negative signs for financial intermediation variables for 1960–2003. King and Levine (1993a) used data for 1960–1989 and they obtained significantly positive signs. RW got similar results when cutting their data for the same period. According to RW possible explanations for significant positive sign for 1960–1989 could be: that financial depth makes countries better to withstand the large nominal shocks – oil shocks and high inflation – characterizing that period, and that perhaps financial liberalization that started in the 80's was carried out without requisite development of lending expertise, mechanisms for monitoring, and supervisory and regulatory skills.

Since financial intermediation variables used are only correlated with financial depth, it could also be argued that perhaps domestic credit to private sector or loans to non-financial enterprises are not optimal indicators for financial depth. Institutions and policies that facilitate greater financial depth should lead to higher debt levels and focus on credit to private sector should ensure that efficiently allocated credit is measured. Thus, financial depth enhancing policies and institutions should be correlated with higher debt levels. However, there might be other reasons for higher debt levels and don't necessarily reflect only sound policies and institutions. There exists theoretical and empirical literature on effect of high levels of external debt on growth. This framework could be used to analyse high levels of debt on growth in general if it were assumed that financial crises are not just external debt crises but more general balance sheet crises. In economic theory a possible negative effect of high debt on growth is a direct crowding out -effect: high levels of debt as such hamper growth simply by

increasing amount of due redemptions and interest payments – which can't be allocated to investment. Another possible negative effect of high debt on growth in economic theory is based on the debt Laffer curve: the debt Laffer curve shows that along the left or 'good' side of the curve, increases in the face value of debt service are associated with increases in debt repayment, while increases in the face value lower expected repayment on the right or 'wrong' side of the curve. Theoretical arguments supporting the existence of a debt Laffer curve fall into two broadly defined categories. First are theories based on multiple equilibria where investment endogenously collapses beyond a certain level of indebtedness, in preparation for default and in order to minimize penalty payments and exogenously assumed to equal a fixed proportion of output. Second are theories where the nature and terms of the optimal debt contract are affected by the level of existing indebtedness. As debt levels rise, it becomes increasingly difficult, and eventually impossible, for a creditor with imperfect monitoring technology to elicit effort on the part of the debtor. The borrowing economy then loses all incentives to implement policies that are painful in the short run but beneficial in the long run. The most well known of theories around the debt Laffer curve is the debt overhang theory. Krugman (1988) defines debt overhang as a situation where the expected present value of future country transfers is less than the current face value of its debt. The higher the amount of debt, the more difficult it is to raise new debt to finance investments because of the reluctance of lenders. Finally, although the debt overhang theory has not explicitly traced the effect to growth, it may be possible to extend these types of models and translate a debt Laffer curve into Laffer curve for the effect of debt on growth. For example, Pattillo, Poirson and Ricci (2002) and Imbs and Ranci re (2005) find clear evidence that debt becomes detrimental for growth in highly indebted economies and quantify the threshold levels in the thus confirmed debt Laffer curve. Based on the recent financial crisis, it is also possible that financial depth in general enhances economic growth but there can be a crash if financial sector balance sheet grows too much as bankers forget lessons of previous depressions and become less risk-averse. This could be modeled with a hazard function. It can also be argued that perhaps high levels of inflation especially during the 70's partly allowed economic agents to escape risen debt levels.

The sign of own innovation variable is usually found to be positive and in many cases significant. Even the magnitude is relatively large. Specifications with loans to non-financial enterprises as financial intermediation variable are exceptions where the sign is negative but almost never significant; in these cases sign for distance to frontier is usually positive. Correlation between these two variables is high which implies that the reverse signs could be a result of multicollinearity as number of observations is low in specifications with loans to non-financial enterprises as financial intermediation variable. PCT applications or average aggregate originality per capita as own innovation variable is more often

significant than aggregate originality per capita. Significance becomes more seldom as time dimension is made less frequent.

The sign of distance to frontier is usually negative and often significant. Negative sign indicates a direct convergence effect. Positive sign indicates a direct non-convergence effect – ie a country starting below its steady-state relative output would fall increasingly behind over time. According to all AHM and replicating specifications the direct effect of initial value for relative per-capita real GDP was significantly positive. It is worth noting that initial value for relative per-capita real GDP is highly correlated with own innovation included in (2.3). The sign of the interaction variable between financial intermediation and distance to frontier is found to be negative in most cases and significant in many cases. Significance becomes more seldom as time dimension is made less frequent and within the subset of OECD countries. According to AHM this coefficient should be negative so that likelihood of convergence will increase with financial development. Even AHM find the sign of this variable significantly negative but the magnitude larger.

The sign for imitation variable is usually negative and insignificant. The sign for the interaction variable between imitation and financial intermediation is in most cases positive but insignificant. It is negative usually when sign for imitation variable is positive. In theory, imitation is closely related to convergence dynamics, so there is likely to be redundancy between it and distance to frontier. The same applies for corresponding interaction variables. The frequent insignificance of imitation and interaction variable between imitation and financial intermediation can probably be traced back to these variables' close relation to convergence dynamics. The sign for physical capital per capita growth is almost always positive and in most cases very significant. The magnitude is large. The interaction variable of physical capital per capita growth and financial intermediation is usually negative and insignificant. Human capital variable is often positive and significant when time frequency is one (or even five) years and domestic credit to private enterprises stands for financial intermediation. This doesn't apply for other country sets than the subset of OECD countries and emerging markets. The sign for government consumption variable is in most cases negative and in many cases significant. This is consistent with the theory that private sector is in many instances more efficient and that higher taxes hamper growth (by reducing incentives).

2.5 Robustness checks

To assess robustness of results, several checks have been implemented. These include recursive least squares, unit root tests, regressions with differenced data, regressions including cross-sectional or period dummies or both, using financial intermediation variables that are expressed in percent of trend GDP and multicollinearity tests. Outliers have already been removed from the data when estimating the basic results. Tables for robustness test results are available from the author at request. Regressions with loans to non-financial corporations divided by GDP as financial development variable are not analysed in this chapter unless stated otherwise because of their inherent multicollinearity problems.

Figures 3–5 present paths for coefficients for financial development, PCT applications per capita and aggregate patent originality per capita from recursive ordinary least squares regressions. Presented coefficient paths for financial development and PCT applications per capita are from the same set of recursive regressions for years 1960–2007. Presented coefficient path for aggregate patent originality per capita is from a separate set of recursive regressions 1975–1999. All the other coefficients (including average aggregate patent originality per capita and interaction terms between financial development and the three own innovation variables not shown here but available from the author at request) seem to converge as number of years is increased, except aggregate patent originality per capita. The shorter time period is clearly a good candidate for explanation. It is worth noting that this coefficient starts to decrease as globalization takes full speed ahead in the nineties. Perhaps globalization has affected this variable in a way that doesn't necessarily reflect only own technological innovations. What is more, the coefficient for financial development is positive in the early years and turns negative as time goes forward. This is consistent with RW.

Figure 3.

**Path of coefficient for financial development
from recursive least squares 1960–2007**

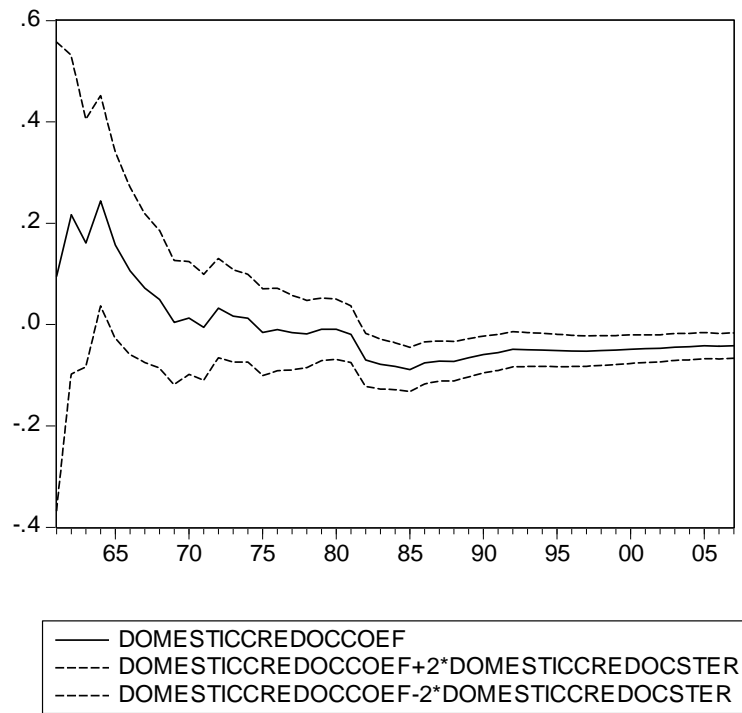
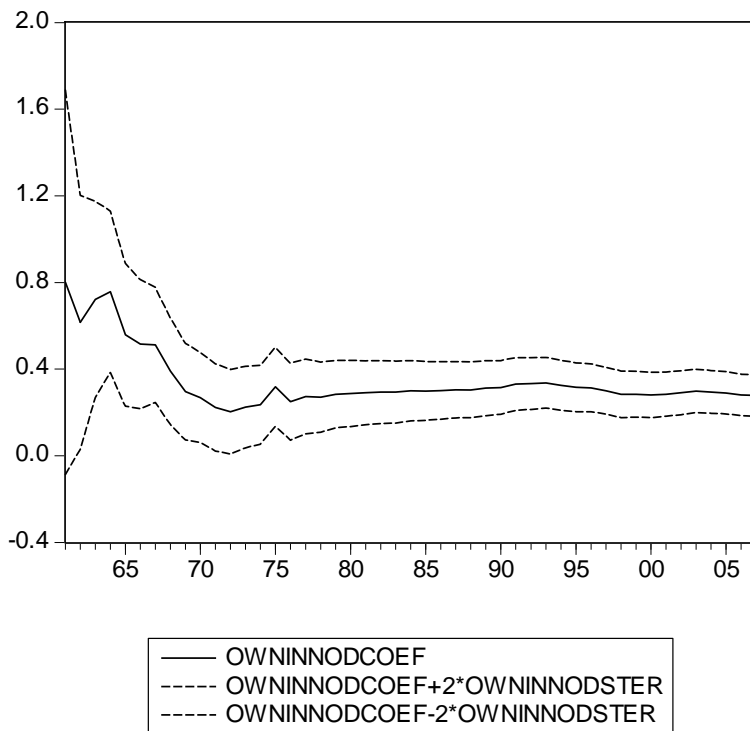


Figure 4.

**Path of coefficient for PCT applications per capita
from recursive least squares 1960–2007**



In general, unit root tests reject the hypothesis of unit root in the series with the exception of financial development variable. Figure 6 presents series for growth rate of per-capita GDP and financial development as medians of countries 1960–2007. As growth rate of per-capita GDP appears stationary, series for financial development seems non-stationary. Since the dependent variable is stationary, non-stationarity of financial development is not that worrying. Anyway, differenced regressions are run also to control whether the relationship is strong enough to stand differencing. Differencing is implemented in regular way and also by differencing only financial development variable. In neither case, differencing doesn't seem to affect qualitative results for the sign of interaction term between own innovation variable and financial development even though significance levels are lower for obvious reasons. Regular differencing can be carried out only in the case of aggregate patent originality per capita as own innovation variable since differencing a country-specific constant, like PCT applications per capita or average aggregate patent originality per capita, would remove it altogether.

Regressions including cross-sectional or period fixed effects or both are run to test robustness baseline results in those specifications where this is technically possible. A cross sectional fixed effect is constant over time but varies over countries. A period fixed effect is constant for each cross section of countries but varies over time. It is usual practice to include such fixed effects in panel growth regressions to take into account unmodeled country- or period -specific factors. They are not included in the baseline regressions here since they are not induced by the theoretical model and it is implicitly assumed that variables PCT applications per capita or (average) aggregate patent originality per capita could replace cross-sectional fixed effects. Besides, $\mathbf{X}'\mathbf{X}$ becomes nearly singular if cross-section dummies are introduced in regressions which include country-specific constants, like PCT applications per capita or average aggregate patent originality per capita that are highly correlated with the fixed effects (see the next chapter). This renders estimation unfeasible. Introducing cross-sectional fixed effects for regressions using aggregate patent originality per capita reduces significance levels to insignificance and makes sign for interaction term between aggregate patent originality per capita and financial development negative in some specifications. If a financial intermediation variable that is expressed in percent of trend GDP is used instead, the sign remains positive in all relevant cases. If both cross-sectional and period fixed effects are used in the same regression, the sign remains positive in all specifications except one if regular financial development variable is applied. The sign becomes positive in all relevant cases if a financial intermediation variable that is expressed in percent of trend GDP is used. Introducing only period fixed effects doesn't change the sign of interaction term between financial development and PCT applications per capita or average aggregate patent originality per capita but reduces significance levels to insignificance. However, period effects in these specifications remain

insignificant as well. If a financial intermediation variable that is expressed in percent of trend GDP is used instead in these regressions, the sign becomes negative in one relevant specification. Again, period effects remain insignificant. If aggregate patent originality per capita is used as own innovation variable, the sign becomes negative in all cases. This is the only setup, where introducing fixed effects would essentially change the sign of interaction term between own innovation variable and financial development. It is also the only setup, where period effects are significant. Signs for PCT applications per capita and (average) aggregate patent originality per capita remain positive and very significant in all fixed effects regressions while sign for financial development is still negative but becomes insignificant.

Using financial intermediation variables that are expressed in percent of trend GDP instead of regular financial intermediation variable doesn't change results much, only reduces significance levels a bit. It is interesting that significance levels of interaction between aggregate patent originality per capita and financial development becomes more significant than with regular financial intermediation variable, though.

The problem of multicollinearity is evident according to all indicators: correlation tables, variance inflation factor (VIF) and condition number of $\mathbf{X}'\mathbf{X}$. All indicators suggest that the problem is lowest when PCT applications per capita or average aggregate patent originality per capita is used as own innovation variable, higher when aggregate patent originality per capita stands for as own innovation and highest when loans to non-financial corporations divided by GDP is financial development variable. Correlation is over 0.90 between financial development and interaction between financial development and own innovation variable always, between frontiergap and own innovation variable when loans to non-financial corporations divided by GDP stands for financial development or aggregate patent originality per capita is used as own innovation variable and between financial development and interaction between financial development and national patent applications divided by aggregate patent originality.

Figure 5.

Path of coefficient for aggregate patent originality per capita from recursive least squares 1975-1999

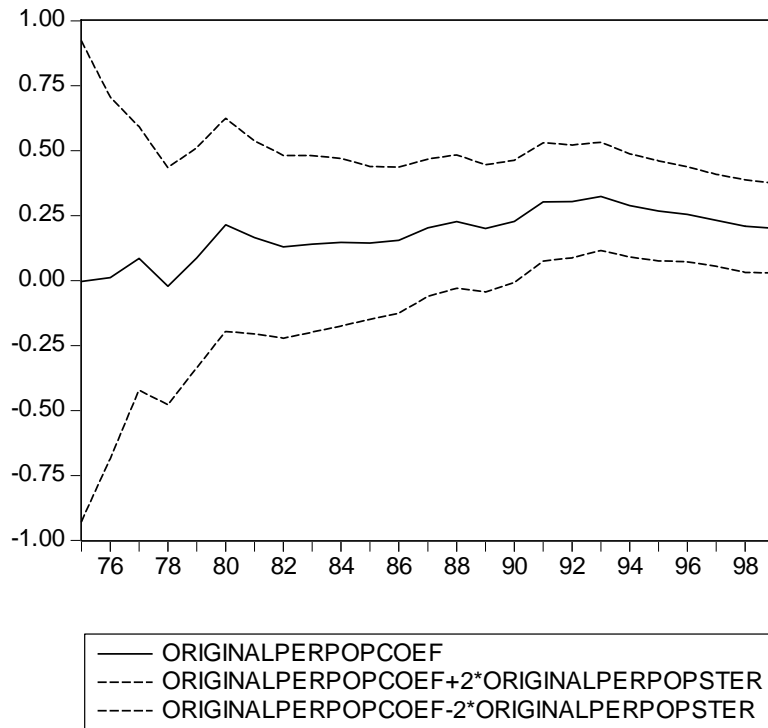
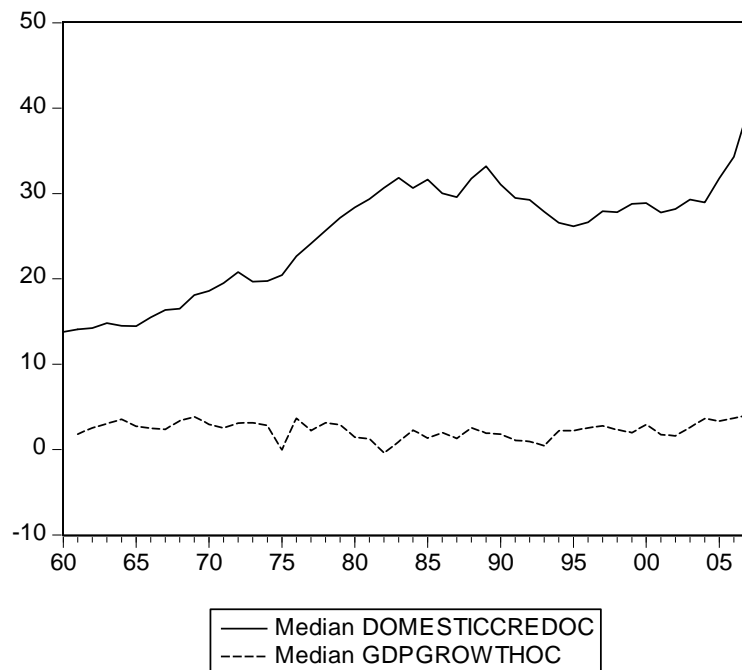


Figure 6.

Growth rate of per-capita GDP and financial development, median of countries 1960–2007



2.6 Own innovation vs fixed effects

Especially constant country-specific own innovation variables could be candidates for omitted unobserved country-specific variables behind significant country-specific fixed effects typically present in panel cross-country studies. The problem is that it is not possible to include both country-specific fixed effects and these variables in the same regression as $\mathbf{X}'\mathbf{X}$ would become nearly singular since PCT applications per capita and average aggregate patent originality per capita are highly correlated with the fixed effects. Thus, it is not possible to verify whether country-specific fixed effects would be significant in the presence of constant country-specific own innovation variables. From the previous chapter is known that period effects are insignificant in this case, though. Additionally, with regressions in previous chapters it has been shown that own technological innovation variables have the right sign and are highly significant in most specifications. This implies that they have a role to play in growth regressions. It is interesting to see what happens when own technological innovation variables are removed and country fixed effects are included instead in regressions. Similarity of coefficients for own technological innovation variables and estimated fixed effects would give support to the hypothesis. Indeed, the high correlations between these fixed effects and PCT applications per capita and average aggregate patent originality per capita illustrated in figures 7–8 suggest that the own innovation variables could be plausible candidates for replacing those abstract fixed effects.

Figure 7.

PCT applications per capita and fixed effects from OLS regression with initial values as explanatory variables excl PCT applications per capita and national patent applications divided by PCT applications, 1960–2007

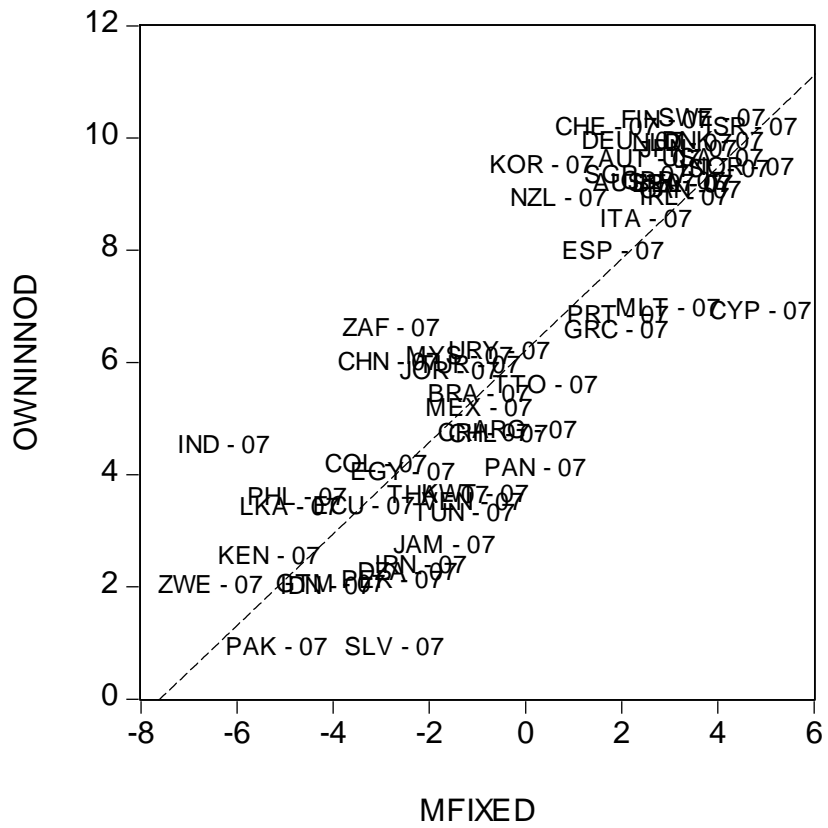
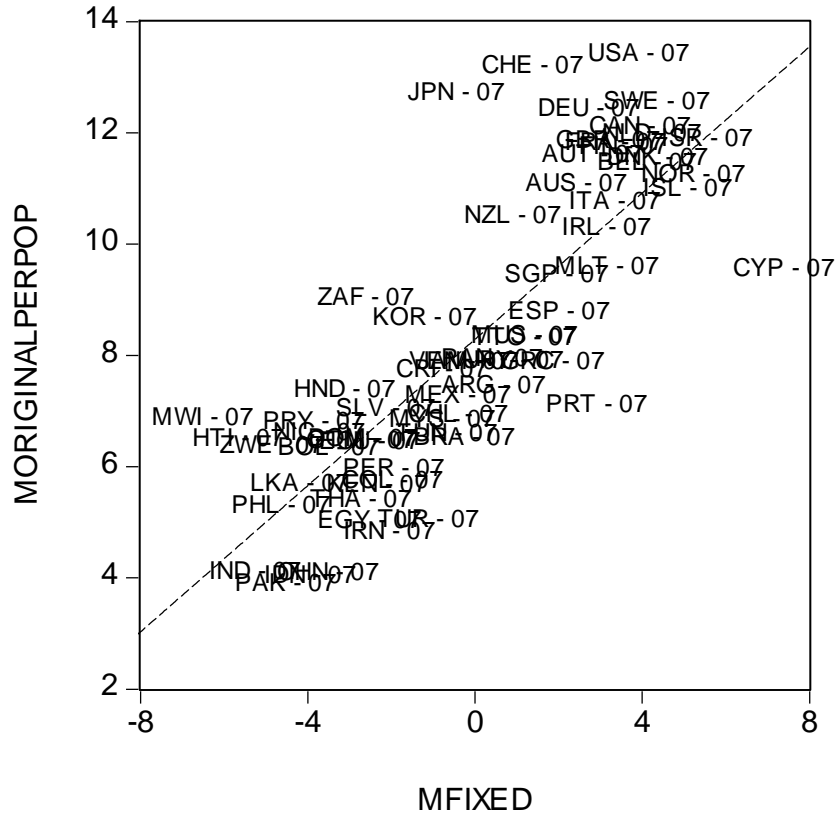


Figure 8.

Average aggregate patent originality per capita and fixed effects from GMM regression with initial values as instruments and with GLS weights excl average aggregate patent originality per capita and average national patent applications divided by aggregate patent originality, 1960–2007



3 Conclusions

The objective of this paper was to extend the research by Aghion, Howitt and Mayer-Foulkes (2005) and examine, whether financial development affects economic growth through more efficient utilization of technological innovations. This hypothesis was based on the notion that the better functioning are the financial markets, the higher is the probability that a high-quality technological innovation finds the necessary finance to realize its potential for growth. In estimation of the model, different regression configurations for the data panel were applied. They varied in estimation method, instrumental variables used, measures used, time frequency and set of countries. The robustness of results was also tested in several ways. The results show a significant and positive sign for the interaction term between the measure of innovation and financial development in

most configurations, although there is serious presence of multicollinearity in the data. Most robustness tests support the result. The evidence suggests that the innovation channel of finance has a positive role to play in economic growth but the magnitude of the coefficient implies that this role is not decisive. The positive role is consistent with Schumpeterian growth model of Aghion and Howitt (1992) and its derivatives. Further, the negative and significant sign of the interaction variable between financial intermediation and distance to frontier found in most cases confirms the earlier result of Aghion, Howitt and Mayer-Foulkes (2005) that the likelihood of convergence to frontier will increase with financial development. What is more, the relatively large magnitude of the significant positive coefficient for own innovation present in most specifications suggests that it is an important component in growth process. Own innovation variables could be plausible candidates for replacing abstract fixed effects present in many previous cross-country growth regressions. This is highlighted by high correlation between own innovation variables and estimated fixed effects in regressions from which own innovation variables are removed.

As a policy implication, adequate finance should be secured for own innovation in all circumstances. In this respect, start-ups could be one target group since they may not always get the necessary finance because of agency problems. Very complicated financial products are probably not essential for own innovation. Moreover, own innovation should be enhanced by other means than finance, too. For future research, better indicators for financial development should be constructed to obtain more precise results. Indicators like domestic credit to private sector divided by GDP used here are not optimal since they are only correlated with financial development and unfortunately, also correlated with overdebtness which hampers economic growth. Additionally, it would be interesting to know which factors affect own innovation. Explanations must be searched beyond traditional education-based measures of human capital since such a measure was included in all the regressions of this study, or perhaps the standard measure of education is too broad to be informative enough since it embraces all tertiary education. It might be more efficient to construct measures of education that clearly can foster own innovation, like natural sciences or technology. Other explanations to check could be own innovation fostering institutional, historical or cultural factors.

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