FINANCE-LED GROWTH IN THE OECD SINCE THE 19TH CENTURY: HOW DOES FINANCIAL DEVELOPMENT TRANSMIT TO GROWTH?

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Abstract: It is well established in the literature that financial development (FD) is conducive to growth, and yet the channels through which FD affects growth are not well understood. Using a unique new panel data set for 21 OECD countries over the past 140 years, this paper examines the extent to which FD transmits to growth through ideas production, savings, fixed investment, and schooling. Unionization and agricultural share are used as instruments for FD. The empirical results show that FD influences growth through all four channels. In particular, ideas production is found to be the most important channel through which FD impacts on growth.

Keywords: ideas production; savings; investment; schooling; growth; financial development.

JEL classification: O16; O30; O40; O53

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1. Introduction

Following the seminal contributions of King and Levine (1993a, b) and Levine (1997), a number of studies have investigated the role of financial development (henceforth FD) in enhancing economic growth (see, e.g., Arestis and Demetriades, 1996; Demetriades and Hussein, 1996; Rajan and Zingales, 1998; Levine *et al.*, 2000; Claessens and Laeven, 2003; Beck and Levine, 2004; Guiso *et al.*, 2004; Aghion *et al.*, 2005; Arcand *et al.*, 2012; Henderson *et al.*, 2012). Common to almost all cross-sectional or panel studies that examine the effects of FD on growth is that growth is regressed directly on indicators of FD without paying attention to the channels through which FD influences growth, as stressed by Levine (2005). Very few studies such as King and Levine (1993a), Beck *et al.* (2000) and Benhabib and Spiegel (2000), have examined capital accumulation, savings and total factor productivity as potential channels through which FD influences growth.

This paper constructs a unique macroeconomic dataset for 21 OECD countries over the period 1870-2009 and tests ideas production, savings, investment, and secondary and tertiary education as channels through which FD transmits to growth. Considering the transmission channels beyond the investment and saving ones may shed some light on two paradoxes in the FD literature. First, the nexus between FD or financial liberalization and investment/saving has been disputed both theoretically and empirically (see, e.g., Bayoumi, 1993; Jappelli and Pagano, 1994; Bandiera *et al.*, 2000; Beck *et al.*, 2000). Second, FD must influence growth through channels other than just the traditional savings-investment ones since investment does not have permanent growth effects unless there are constant or increasing returns to fixed capital stock and several studies have found that the FD has permanent productivity growth effects (see, e.g., Ang, 2011; Ang and Madsen, 2012). Since constant returns to capital stock are highly unlikely, there must be constant returns to knowledge in the ideas production function for FD to have permanent productivity growth effects. Thus, an essential channel of transmission of FD to economic growth must be through ideas production, as echoed in the theoretical literature on FD and growth, which increasingly focuses on innovations as a crucial channel of transmission of FD to growth (see, e.g., Morales, 2003; Aghion *et al.*, 2005; Buera *et al.*, 2011).

This study extends previous research in a number of ways. First, it examines whether FD influences growth through ideas production, savings, investment, and secondary and tertiary education and gives special attention to the role of increasing returns as the precondition for FD to have permanent growth effects. While the channels through which finance is linked to growth have been examined in the literature, previous studies (e.g., King and Levine, 1993a, Beck *et al.*, 2000 and Benhabib and Spiegel, 2000) have only examined the impact of FD on capital accumulation and productivity without paying attention to channels that can create a permanent growth effect such as ideas production.

Second, data on Tobin's *q*, bank assets, private credit, monetary stock, stock market capitalization, stock market volatility, R&D expenditure, innovations, hours worked, age dependency rates, capital stock, and gross enrollment rates, among other variables, are constructed over the period from 1870 to 2009. This unique dataset enables us to undertake a detailed macroeconomic analysis of the transmission of FD to growth. Collecting data on FD prior to 1950 is a challenging task because these data were not routinely reported by statistical agencies, and credit, deposits and bank assets are often disaggregated into credit provision of numerous types of credit institutions. Moreover, the deflators implicit in credit, money, and bank asset aggregates are often inconsistent with the GDP deflator during periods of high inflation, thus creating a structural break in the indicator of FD, unless such inconsistency is corrected.

This study is one of the very few that uses long historical data for multiple countries to investigate the economic implications of FD. Most multi-country studies typically cover a short time span of 30 to 40 years.[1] The use of long data enables us to exploit the large historical variations in the data for countries that have transformed from being financially underdeveloped in the 19th century into being quite developed at the beginning of the 20th century, and for financial systems that experienced increasing repression from the start of WWI to the end of WWII but enjoyed more liberalized and open regimes in the post WWII period. In his seminal analysis, Gerschenkron (1962) argues that a key condition for industrialization is the presence of a sufficiently developed financial system and that countries that were the first to industrialize relied on banking capital. Furthermore, in the absence of private capital, successful growth spurts could only occur if the government became the principal source of finance (Sandberg, 1982). Our data include the years 1870-1913, which is the crucial period of industrialization in the Western world (Gerschenkron, 1962).

Third, external instruments are used for FD to overcome the possibility that growth and FD are both driven by other variables and guard against the possibility that, "where enterprise leads, finance follows" (Robinson, 1952). Following the influential papers of La Porta *et al.* (1997, 1998) and Beck *et al.* (2003), legal origin has predominantly been used as the instrument for FD; however, the time-invariance of this instrument renders it unsuitable for panel regressions and limits the cross-country variations in the instrumented estimates. Furthermore, Rajan and Zingales (2003) find that countries with English common law systems were not financially more developed than others in 1913. They argue that a theory with a more variable factor is needed to explain both the time-series variations as well as the cross-sectional differences in FD. Against this backdrop, we use unionization and the share of agriculture in economy-wide GDP as instruments for FD. These

[1] An exception is Rousseau and Sylla (2003) who examine the nexus between growth in per capita income and financial development employing data for 17 countries on a decadal basis over the period from 1850 to 1997 using the ratio of broad money stock to GDP as a measure of FD. They find a robust correlation between FD and economic growth.

variables meet the criteria for being good instruments by satisfying the exclusion restrictions and being significant determinants of FD, as elaborated in Section 4.

The rest of the paper is organized as follows. The macroeconomic framework is established in the next section. The four channels of transmission and model specifications are presented in Section 3. Section 4 discusses data, identification and estimation method. The estimation results are presented in Section 5 and some robustness checks are undertaken in Section 6. Section 7 examines the relative importance of these channels by providing a simulation exercise. The last section concludes the paper.

2. Transmission Channels

This section briefly shows how FD influences innovations, savings, investment, and schooling and under which conditions FD has temporary or permanent productivity growth effects.

Consider the following homogenous Cobb-Douglas production function:

$$Y = AK^{\alpha}H^{1-\alpha} = AK^{\alpha}(hL)^{1-\alpha}, \quad (1)$$

where Y is output, A is total factor productivity (TFP), K is capital stock, H is the total quantity of human capital used to produce output, L is employment, h is human capital per worker, and α is capital's share of income.

Human capital is computed following the Mincerian approach:

$$h = \exp(\theta \cdot sc) \quad (2)$$

where θ is the returns to education and sc is years of schooling (educational attainment).

The production function can be written as:

$$\frac{Y}{L} = A^{1/(1-\alpha)} \left(\frac{K}{Y}\right)^{\alpha/(1-\alpha)} h. \quad (3)$$

Taking logs and differentiating Eq. (3) and using Eq. (2) yield the following income per worker growth rate, $g_{Y/L}$:

$$g_{Y/L} = \frac{1}{1-\alpha} g_A + \frac{\alpha}{1-\alpha} g_{K/Y} + \Delta(\theta \cdot sc), \quad (4)$$

where g_A is the technology growth rate and $g_{K/Y}$ is the growth rate in the capital-output ratio.

Since the *K*-*Y* ratio is constant along the balanced growth path and educational attainment cannot grow to infinity, Eq. (4) confirms the standard result in economic growth models that labor productivity is driven entirely by technological progress in the steady state. From this it follows that FD can only have potential permanent growth effects if it influences the rate of technological progress. If FD is assumed to influence the savings-investment decision, as often stressed in the literature, FD can only have temporary growth effects under the assumption of diminishing returns to fixed capital.

Growth in technology is determined by the following ideas production function (Peretto, 1998; Dinopoulos and Thompson, 1998; Peretto and Smulders, 2002; Dinopoulos and Waldo, 2005; Ha and Howitt, 2007; Ang and Madsen, 2011, Venturini, 2012a, b):

$$g_A = \left(\frac{\dot{A}}{A}\right) = \lambda \left(\frac{X}{Q}\right)^{\sigma} A^{\phi-1}, \qquad 0 < \sigma \leq 1,\ \phi \leq 1 \tag{5}$$

$Q \propto L^{\beta}$ in steady state,

where X is R&D researchers, Q is product variety, L is employment or population, λ is a research productivity parameter, σ is a duplication parameter (0 if all innovations are duplications and 1 if there are no duplicating innovations), ϕ is returns to scale of knowledge, and β is the coefficient of product proliferation. The ratio X/Q is referred to as research intensity.

This ideas production function extends the first-generation models of knowledge production function to allow for product proliferation and decreasing returns to knowledge stock, as highlighted in the second-generation models of economic growth (see Aghion and Howitt, 1998, 2006; Peretto, 1998; Peretto and Smulders, 2002; Ha and Howitt, 2007). R&D expenditure is divided by product variety following the Schumpeterian paradigm in which R&D spreads more thinly across the variety of products as the economy grows. Since, in steady state, product variety is growing at the same rate as population or the labor force, it follows that the growth rate, g_A, cannot increase in response to an increase in the number of researchers that keeps the number of researchers in fixed proportion to the population.

Extending the knowledge production function to allow for the influence of FD yields:

$$g_A = \lambda \left(\frac{X}{Q}\right)^{\sigma} FD^{\pi} A^{\phi-1}, \tag{6}$$

where FD is financial development and π is a positive constant. From Eq. (6) it follows that research intensity and FD have only permanent growth effects if there are scale effects in ideas production, i.e., $\phi = 1$.

The simple framework presented here shows that FD can influence productivity growth through the four principal channels considered in this paper. Temporary growth effects can be expected from the investment and schooling channels, given that they transmit to output through the production function under the assumption of diminishing returns to physical and human capital. FD will have permanent growth effects, provided that it feeds through ideas production with scale effects.

3. Model specifications

This section develops the empirical framework that is used to test for the influence of FD on ideas production, savings, investment, and schooling, and the theories underlying each specific transmission channel are discussed.

3.1 Knowledge production function

FD affects knowledge production due to the presence of asymmetric information in financial markets, which hinders efficient allocation of financial resources and effective monitoring of investment projects. Morales (2003) argues that FD increases research productivity by mitigating the problems of moral hazard and demonstrates that FD improves the monitoring technology of financial intermediaries and, thereby, forces researchers to exert a higher level of effort. Furthermore, Gorodnichenko and Schnitzer (2013) argue that a firm's decision to invest in R&D is sensitive to financial frictions that can prevent the firm from adopting better technologies. They show that the larger the cost of external finance, the more sensitive are innovations to negative liquidity shocks.

Aghion *et al.* (2005) demonstrate that a developed financial system facilitates the adoption of new products or processes, leading to improvements in productive efficiency and increasing the speed at which laggards catch up to the frontier. In their model, an innovator can avoid repaying his/her creditors by hiding the outcomes of successful innovations. Assuming that the hiding costs are positively related to the level of FD, innovative activity will be constrained for a financially underdeveloped country. In a similar vein, Buera *et al.* (2011) show that financial underdevelopment distorts the allocation of capital among incumbents and potential innovative entrants by delaying the entry of productive but financially poor individuals, whereas incompetent, but rich, entrepreneurs remain in business. As a result, talented but poor individuals are prevented from doing business until they can self-finance the capital needed for a profitable operation.

Taking logs of Eq. (6) and extending it to allow for international knowledge spillover effects yields the following stochastic specification of knowledge production:

$$ln\dot{A}_{it}^{D} = \alpha_0 + \alpha_1 ln(R/Y)_{it}^{D} + \alpha_2 lnDTF_{it} + \alpha_3 (R/Y)_{it}^{D} \cdot \ln DTF_{it} + \alpha_4 lnA_{it}^{D}$$
$$+\alpha_5[(M/Y^n)_{it} \cdot ln(Pat/L)_{it}^{F}] + \alpha_6 lnFD_{it} + CD + TD + e_{1,it}, \quad (7)$$

where the superscripts D and F refer to domestic and foreign, respectively; $\dot{A}^D$ is measured by the number of patents filed by domestic residents; $(R/Y)^D$ is domestic research intensity, measured as the ratio of nominal R&D expenditure to nominal GDP; DTF is distance to the frontier, measured as the ratio of TFP in the US to country *i*; *M* is nominal imports of goods; Y^n is nominal income; $(Pat/L)^F$ is research intensity spillovers through imports; *FD* is an indicator of financial development; *CD* is country dummies; *TD* is time dummies; and *e* is a stochastic error term. The model, as well as all the other empirical specifications presented below, is estimated in five-year differences to filter cyclical influences out.

International knowledge spillovers influence knowledge production through the channel of imports following Coe and Helpman (1995) and through the interaction between distance to the frontier and research intensity. According to them, productivity is an increasing function of the knowledge embodied in imported products. This line of reasoning suggests that the productivity of domestic innovators is a positive function of R&D intensity in the countries from which they import. The interaction between distance to the frontier and research intensity is included in the model to allow for the possibility that researchers can tap into the world stock of knowledge, following the model of Howitt (2000). Accordingly, the higher is the research intensity, the more capable is a country of adapting and improving on the technology that is developed at the frontier.

3.2 Savings

As has been stressed for a long time in the literature on FD, savings may be curbed by financial underdevelopment, in that poor enforcement of financial contracts increases the spread between borrowing and lending rates and, consequently, depresses the domestic rate of return to savers. In the classical contributions of McKinnon (1973) and Shaw (1973), it is argued that FD is associated with greater mobilization of savings and more efficient allocation of resources. As elaborated in the literature survey of Levine (1997) and Ang (2008), savings from households may be insufficient to fully fund potential borrowers. Financial systems perform a key task of mobilizing savings by pooling the savings of diverse households and making this aggregate fund available for lending. Hence, as financial systems expand, more deposits will be attracted from savers, and more funds will be available for investment.

Additionally, savers in economies that have underdeveloped financial markets do not have access to good investment opportunities, such as pension schemes and investment in domestic and foreign stocks, but rather they have to rely on bank deposits with ordinary banks or small-holding money lenders in which interest, often per government regulation, is low or even zero. Finally, complicated, time consuming and expensive legal procedures are required for lenders to recoup their investment in financially backward markets when debtors default, thus dampening savings (Valderrama, 2008). A sophisticated financial system can also potentially enhance savings because it provides opportunities for investing in assets with the highest returns and, more importantly, it provides a safeguard against the confiscation of assets, noting that underdeveloped financial markets often operate under legal systems in which financial contracts are poorly enforced (Valderrama, 2008).

Another way that FD enhances savings and innovations simultaneously is by boosting collaboration between domestic and foreign entrepreneurs. In the growth model developed by Aghion *et al.* (2009), catching up to the technology frontier by the laggards depends on the technical collaboration between foreign investors, who are familiar with frontier technology, and domestic entrepreneurs, who are familiar with the local conditions to which the technology must be adapted. Domestic saving is influential for the adoption of frontier technology because it allows the domestic entrepreneur to take a stake in the joint project and, therefore, mitigates the agency problems that would otherwise discourage the foreign investor. Thus, FD also has the potential to stimulate innovative production or knowledge creation through domestic savings, as the provision of domestic funds encourages this cooperative joint venture through reduced agency problems.

The relationship between savings and FD, however, is not unambiguously positive. If financial liberalization is assumed to enhance savings through increasing the rate of interest on them, the long-term effects of FD depend on the interest rate elasticity of savings – a channel that has received only limited empirical support (for discussion, see Bandiera *et al.*, 2000). Furthermore, if FD is associated with the emergence of speculative bubbles in asset markets it may have some adverse effects on savings (Bandiera *et al.*, 2000). The reduced private savings in the decade leading up to the Global Financial Crisis and the associated increase in credit provision is certainly a reminder of the potential negative saving effects of FD, although it is difficult to disentangle these effects from the influence of the housing price run-up on savings and the provision of credit.

Finally, savings should *not* be considered as a channel that is separate from the other three channels of transmission, but rather as one that promotes investment in fixed capital stock, schooling and R&D. An increasing savings rate simultaneously lowers the required returns, which, in turn, increases the discounted returns to investment in fixed capital and R&D. Furthermore, savings may also positively influence the decision to attend school since they enable parents to finance their children's education.

The following standard savings function augmented with FD is estimated (e.g., Liu and Woo, 1994):

$$s_{it} = \gamma_0 + \gamma_1 Age_{it} + \gamma_2 r_{it} + \gamma_3 \Delta \ln y_{it} + \gamma_4 lnFD_{it} + CD + TD + e_{2,it}, \tag{8}$$

$$\gamma_1 < 0, \gamma_2 \lesseqqgtr 0, \gamma_3 \lesseqqgtr 0, \gamma_4 > 0,$$

where Δ is the five-year first-difference operator, s is the savings rate (private savings to income ratio), r is the real interest rate, y is real per capita income, and Age is the age dependency ratio computed as the fraction of the population outside working age (the working age population at time t is the population in the age cohort $j + 15$ to 64, where j is number of years the average person at time t is in the educational system beyond the age of 15). The savings rate is not in logs because it is occasionally negative. Details on the computation of age dependency rates are given in the Data Appendix.

Savings may either be a positive or a negative function of productivity growth. The permanent income hypothesis assumes a negative effect of growth on savings, given that higher expected growth enhances permanent income and, therefore, leads to increases in the propensity to consume out of current income. However, the model of Carroll *et al.* (2000) predicts that the propensity to consume is a declining function of income growth due to habit persistence in consumption. The age dependency rate is expected to impact negatively on consumption, following the life-cycle hypothesis. Finally, the coefficient of the real interest rate can be positive or negative, depending on the trade-off between intertemporal substitution and wealth effects in consumption.

3.3 Investment

One of the key functions of a financial system, as identified in the survey article of Levine (1997), is its role in enabling resource allocation efficiency. With the ability to evaluate investment projects, financial intermediaries allow entrepreneurs to expand their businesses by borrowing at lower rates and on easier terms. Financial intermediaries evaluate different investment opportunities by assessing the associated risks so that funds are channeled to the most promising projects. This leads to an improved quality of investments, which can have positive productivity effects.

Investment may also be positively related to FD when a large fraction of the fixed investment of existing firms is financed externally and when the entrance of new and innovative firms depends on external finance. There is a substantial theoretical literature proposing that market imperfections, such as moral hazard and asymmetric information, lower investment because investors are constrained by the availability of credit (e.g., Stiglitz and Weiss, 1981). Consequently, FD will reduce the extent of credit rationing because it mitigates moral hazard and asymmetric information problems, as shown in the model of Aghion *et al.* (2005). Asymmetric information may, to some extent, explain why new and innovative firms with a small capital base find it particularly difficult, if not impossible, to obtain loans in underdeveloped financial markets (Lingelbach *et al.*, 2005). Conversely, FD may harm investment if it renders it easier to obtain consumer loans leading to a disproportionately high fraction of the credit flow being allocated to this area (Jappelli and Pagano, 1994). Since our credit data do not distinguish between different types of credit we cannot test this hypothesis.

To test for the influence of FD on non-residential investment the following Tobin's *q* model, in which the firm optimizes the discounted profit under credit constraints, is estimated (see Madsen and Carrington, 2012):

$$\left(\frac{I}{K}\right) = (C'')^{-1}(q - 1 - \lambda), \tag{9}$$

where λ is the shadow value of loosening up the credit constraint by one unit under a credit constrained regime, *C* is convex and symmetric adjustment costs ($C'(0) = 0, C'' > 0$), q is the shadow price of fixed capital stock, *I* is gross investment and *K* is capital stock.

From this model it is clear that loosening up the credit constraint lowers the benchmark level of q at which investment is undertaken. Another channel through which FD influences fixed investment is the ability of firms to raise capital in the stock market. Thus, investment at the macroeconomic level may not be closely related to q in a standard Tobin's q model because most firms are not able to raise capital in the stock market, which is either reserved for large and established corporations or does not exist at all in an underdeveloped financial market. Furthermore, banks may not be able to provide lending for fixed investment because they are constrained by their liabilities. As liabilities in an underdeveloped banking system are dominated by deposits, banks cannot easily expand their lending base without experiencing an increase in deposits, which is often dependent on the types of monetary policy implemented.

Log-linearizing Eq. (9) and allowing for the possibility that firms are demand constrained due to nominal rigidities yield the following stochastic investment function:

$$ln(I/K)_{it} = \beta_0 + \beta_1 lnq_{it} + \beta_2 \Delta lny_{it} + \beta_3 lnFD_{it} + CD + TD + e_{3,it}, \tag{10}$$

where *y* is labor productivity (Y/L) growth. It is allowed for in the equation following Chirinko 's (1993) conclusion, in his survey of the literature, that income growth is a very robust determinant of investment.

3.4 Schooling

It is widely accepted in the literature that borrowing constraints lead to underinvestment in human capital (Becker, 1960; Schultz, 1961; Keane and Wolpin, 2001). Financially constrained students are deterred from investing in education because they lack sufficient financial resources to pay for their living and school fees (Cartiglia, 1997; Lochner and Monge-Naranjo, 2012). Furthermore, De Gregorio (1996) shows that the incentive to work when one is young is an increasing function of the extent of credit constraints.

The following schooling model is estimated:

$$ln\ GER_{it}^{x} = \lambda_0 + \lambda_1 Life_{it} + \lambda_2 r_{it} + \lambda_3 \Delta lny_{it} + \lambda_4 lnFD_{it} + CD + TD + e_{4,it}, \quad (11)$$

$x = S, T,$

where GER is the gross enrollment rate and $Life$ is the life expectancy at age 10. Specifically, GER^S is the fraction of the population in the 13-17 year age cohort enrolled in secondary education, GER^T is the fraction of the population in the 18-22 year age cohort enrolled in tertiary education. Primary education is not considered here because it has been compulsory and its provision is almost free for most of the period and for most of the countries considered in this study.

This specification follows the model of Bils and Klenow (2000) in which the optimal level of schooling depends positively on the present value of the skill wage premium, which in turn depends positively on expected productivity growth and life expectancy, but negatively on the real interest rate. Importantly, schooling depends on life expectancy at the age at which the student enters secondary and tertiary education and not life expectancy at birth because the discounted returns from schooling are positively related to life expectancy at the age at which the decision for secondary schooling is made.

Importantly, the dependent variable is *not* measured as educational attainment, which is commonly used as a proxy for human capital in conventional growth regressions. Educational attainment is constructed from gross enrollment rates at the time at which the working population did their education and, as such, is determined at the time when the students enrolled in schools and universities. Gross enrollment rates are used here instead of educational attainment since they reflect schooling at the time when the schooling decision is made.

4. Estimation Method, Data and Identification Strategy

4.1 Estimation method

As noted above, the models are all estimated in five-year non-overlapping intervals and the level data are annual averages within the five-year intervals. The data are pooled across countries to gain efficiency and to allow for fixed time-effects. Fixed time and country effects are included in all regressions including the first-stage regressions. Fixed country effect dummies are included in the regressions to cater for time-invariant unobserved heterogeneity, implying that the parameter estimates are driven entirely by the within country variation of the data.

We estimate a panel generalized instrumental variables specification that accounts for the contemporaneous patterns of correlation between the residuals (see Wooldridge, 2002 for an exposition). That is, the covariance structure allows for conditional correlation between the contemporaneous residuals for cross-section *i* and *j*, but restricts residuals in different periods to be uncorrelated. Specifically, we assume that:

$$E\left(\varepsilon_{it}\varepsilon_{jt}|X_i^*\right) = \sigma_{ij}$$
$$E\left(\varepsilon_{is}\varepsilon_{jt}|X_i^*\right) = 0$$

where $s \neq t$, σ_{ij} is the covariance of the disturbance terms across countries *i* and *j*, and ε is the disturbance term. The White's procedure is also employed to obtain standard errors which are robust to cross-equation (contemporaneous) correlation and heteroskedasticity.

4.2 Data sources and construction of variables

The data span the period 1870-2009 for the following 21 OECD countries: Canada, the US, Japan, Australia, New Zealand, Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the UK (the sources are detailed in the Data Appendix).

Domestic stock of knowledge (A^D) is computed using the perpetual inventory method for patent applications with a depreciation rate of 15%. The economy-wide TFP data, which are used to compute distance to the frontier, are based on the two-factor homogenous Cobb-Douglas production technology with labor augmenting technological progress, $Y = K^{\alpha}(AL)^{1-\alpha}$, where A is TFP. Thus, TFP is computed as $A = (Y/L)(Y/K)^{\alpha/(1-\alpha)}$, where $(1-\alpha)$ is estimated as the unweighted average of labor's income share in country *i* and the US. Labor's income share for each country is in turn estimated as an average during the period for which data are available.

International knowledge spillovers through the channel of imports (*IKS*) are measured following the formula suggested by Lichtenberg and van Pottelsberghe de la Potterie (1998) as follows:

$$A_i^F = \sum_{j=1}^{21}\left[\frac{m_{ij}}{y_j^n} PI_j^d\right], \qquad i = 1, 2, \ldots, 21; \;\; t = 1870, 1871, \ldots 2009 \tag{12}$$

where m_{ij} is country i's nominal imports from the exporting country j; y_j^n is exporter j's nominal GDP; PI_{jt}^d is exporter j's patent intensity (number of patent applications divided by employment), that is, it is the patent intensity of the 21 OECD countries considered in this study.

The log of Tobin's q is measured as the deviation of the log of real share prices from a linear time trend, where stock prices are deflated by the GDP deflator. The trend is removed from stock prices to filter out the influence on them of accumulated retained earnings per share. It can be shown that real stock prices increase over time only because of retained earnings that are reinvested in the company. If companies do not retain earnings, real stock prices would collapse to Tobin's q (see, for exposition, Madsen and Davis, 2006). Under the assumption that the retention ratio and the stock returns are both relatively constant, the log of real stock prices will fluctuate around a linear trend and the deviation of the log of stock prices around this trend will reflect the log of Tobin's q. Empirically, Barro (1990) finds that the deviation of real stock prices from their trend is a good approximation of Tobin's q.

Following the literature, FD is measured as the ratios of credit to GDP, bank assets to GDP, and monetary stock to GDP (see, e.g., Levine, 1997; Ang and McKibbin, 2007). The collection of the data has been complicated by the fact that there have been a myriad of different types of financial institutions in existence since 1870 and the credit, assets and deposits of these institutions have to be added together. Therefore, total assets and credit data have to be put together carefully, keeping in mind that the financial structure is often very different across countries and has been constantly changing over time. Particular knowledge of the financial structure for each individual country is often required. Only rarely are aggregated figures for bank assets and credit available. Furthermore, even though data on private credit are available from the IMF's *International Financial Statistics*, from around 1950, the data are often *not* compatible with national sources and often show very implausible time profiles. Thus, national sources have been used for data updating whenever possible, to get consistent series.

The credit-GDP ratio is used in the benchmark estimates because it ultimately measures the most important function of the financial system, namely lending. Credit is measured as outstanding domestic bank loans to households and the non-financial corporate sector at the end of the year. Bank loans encompass lending by commercial banks, savings banks, postal banks, credit unions, mortgage banks, insurance companies and building societies. The shortcoming of this measure is that it is constructed as the sum of various categories of lending of a myriad of financial institutions that have existed over the course of the past 140 years and is, therefore, prone to aggregation errors.

Bank assets are defined as the ultimo-year sum of assets of the domestic banking sector. The ratio of bank assets to GDP has the virtue of representing large fractions of banks' lending activities, thus reflecting the depth and sophistication of a financial system. The downside of this measure is that the interrelation with foreign banks has become an increasing fraction of banks' assets, particularly after 1995 and, as such, renders it a less useful proxy for banks' lending to the domestic private sector. Furthermore, since banks are often forced to invest in government assets under financial repression, increasing government financing needs will, automatically, lead to an expansion of bank assets and, at the same time, potentially curb private lending.

Monetary stock is measured as broad money whenever possible to ensure that deposits, which are assumed to be lent out eventually, are a significant fraction of broad money. The benefits of using the monetary stock as a measure of FD is that great effort has been expended by central banks, macro economists and economic historians to measure it and, as such, it is probably measured with a higher degree of precision than the other measures of FD. One shortcoming of this measure is that it captures only the liability side of the banks' balance sheets, and, therefore overestimates their willingness to lend in periods in which they hoard cash reserves. During the Great Depression, for example, banks increased their cash holdings in response to increased uncertainty to such an extent that the wedge between lending and money supply increased, as shown in the figure below. Another shortcoming associated with the money-GDP ratio is that it is influenced by the opportunity cost of holding cash or having money in low yielding term deposits. A final limitation of money as a proxy for FD is that definitions change over time and across countries, often reflecting financial innovations and data availability issues. These shortcomings and the heavy influence of uncertainty and the opportunity costs of holding money on the growth path of the M2-GDP ratio in the period 1929-1980, as shown below, suggest that the M2-GDP ratio is probably the least preferred measure of FD among all measures considered here.

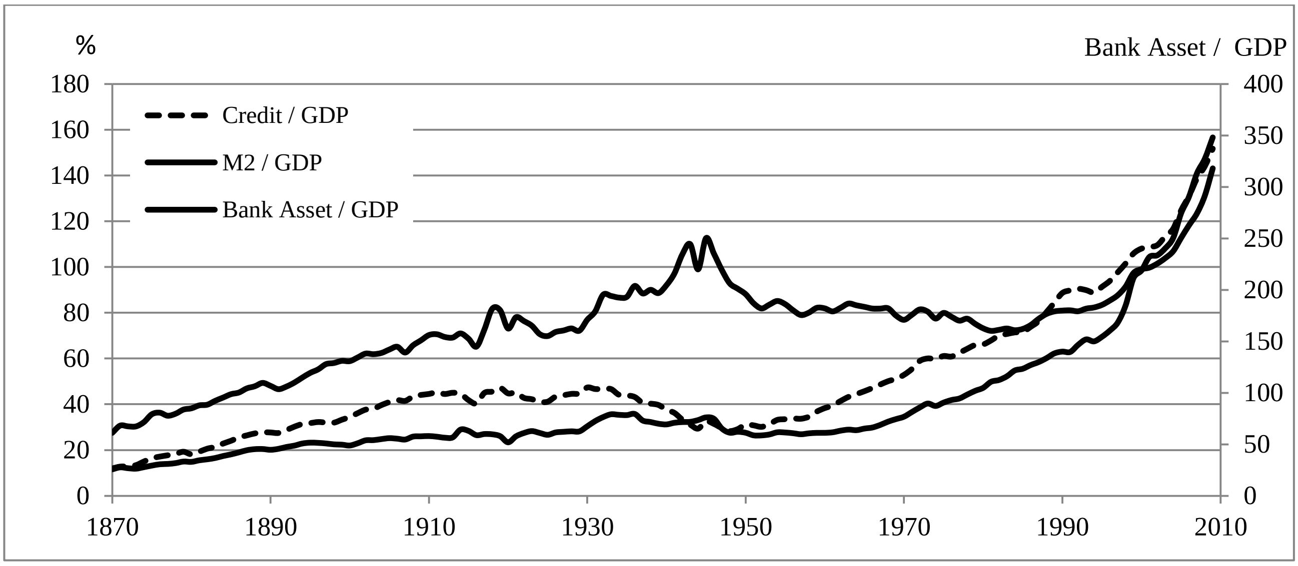
Finally, the largest challenge in constructing the FD indicators has been to adjust for implausible and sudden jumps in the data, caused by inconsistencies in the implicit price index for a financial aggregate (credit, money and bank assets) and the implicit GDP deflator. This inconsistency is widespread across many nominal variables during and immediately after high inflation periods such as those during and immediately following the world wars in the periods 1914-1921 and 1943-1947 and the hyperinflation in Austria in 1922, in Germany in 1922 and 1923 and in Greece over the period from 1941-1944. Discretionary adjustments are made when these implausible jumps occur, as detailed in the Data Appendix.

4.3 Financial development in historical perspective

The time-profiles of the FD indicators are displayed in Figure 1. Although starting from a very low base, financial deepening was already well underway at the turn of the 20^{th} century. Rousseau and Sylla (2003) provide a fascinating account of the evolution of FD. It started in the Netherlands in the early 17^{th} century and gradually spread to the UK in the late 17^{th} and early 18^{th}

centuries and then to the US a century later, and was an important contributor to productivity growth and the industrial revolutions in these countries. Furthermore, Rousseau and Sylla (2003) also attribute the post-Meiji Japanese modernization to the financial revolution that followed the Meiji restoration. Although Japan was geographically and culturally isolated from the Western World, it went through a phase of financial modernization that coincided with the Second Industrial Revolution during the second half of the 19th century.

Figure 1: Indicators of Financial Development



Notes: the series are unweighted averages for all 21 OECD countries. The left-hand-side scale pertains to Credit / GDP and M2 / GDP while the right-hand-side scale pertains to Bank Assets / GDP.

The credit-GDP ratio has increased approximately 14-fold over the period 1870-2010, indicating a significant financial deepening during this period. The periods 1870-1930 and 1960-2010 represent two long waves of financial modernization that are, to a large degree, driven by financial liberalization (Wray, 2009). However, financial liberalization could not have been the whole story since the growth in the credit-GDP ratio gained strong momentum during the 1960s and 1970s, despite the fact that the financial markets were quite heavily regulated and not loosened up during that period. The post-WWII financial liberalization, which started in the early 1980s and gained momentum in the 1990s, did not increase the growth rates in the credit-GDP ratio up to 2004. The marked increase in the credit-GDP ratio since 2004 has partly been fuelled by the asset market run-up that started in the mid-1990s and lasted until 2007, or later, depending on the country in question.

The period 1930-1960 represents a period of increasing regulation of the financial sector, following the stock market crash in October 1929. However, increasing regulation was not the only factor keeping the credit-ratio from increasing during that period (Wray, 2009). Relatively flat real asset prices during that period kept the collateral values from increasing and the deterioration of the banks' asset side during the Great Depression rendered banks cautious in their lending policies.

Although the long-term trend is clearly upwards for all three FD indicators there are discrepancies between them at the medium-term frequencies. The most important discrepancy is between the credit-based and the money-based measures of FD in roughly the period 1929-1980. The discrepancy is particularly pronounced during the period 1930-48 in which the M2-GDP and the credit-GDP ratios moved in opposite directions, probably reflecting banks', firms' and consumers' increased hoarding of cash balances associated with increasing uncertainty during the Great Depression and WWII. Furthermore, banks were increasingly forced to hold government bonds during WWII, which meant that broad money could increase while credit to the private sector was curbed because the government sector was claiming an increasing share of deposits.

The decline in the M2-GDP ratio during the period 1948-1982 is associated with the inflation-induced increasing opportunity costs of holding money and reduced cash holdings of banks as the uncertainty about the macroeconomic environment was normalized after the Great Depression. Furthermore, the more frequent use of non-monetary bank instruments in the post-WWII period also contributed to the emerging wedge between the M2-GDP ratio and the other FD indicators (Schularick and Taylor, 2012). In other words, banks have increasingly relied upon non-deposit funding of lending in the post-WWII period.

4.4 Instruments

Although indicators of FD are often not instrumented in growth regressions there are reasons to believe that demand factors may also be influential for FD and, therefore, that FD is an endogenous variable. As an example of how demand can drive FD, Rajan and Zingales (2003) illustrate how the massive financing requirements of railroads in the US in the second half of the 19th century resulted in significant improvements in the financial infrastructure in the US. This highlights the importance of instrumenting FD to ensure that their coefficients are unbiased.

Accordingly, the share of agriculture in total income ($Agr.Share$) and unionization ($Un.Mem$) are used as instruments to cater for potential endogeneity and the possibility that some unobserved omitted factors influence growth and FD simultaneously. These variables satisfy the criteria for being good instruments since they are sufficiently independent of demand shocks and, as shown in the regression results below, are robust determinants of FD. It is important to note that the choice of instruments was constrained by the difficulties associated with finding instruments that vary over time and are available from 1870 for all the 21 countries considered in this study.

$Agr.Share$, which is measured as the ratio of agricultural output to economy-wide GDP, proxies the strength of the landed class relative to the urban merchant class. The agricultural share is hypothesized to deter FD because the landed class, or land owners in general, has an interest in maintaining the status quo, whereas the merchant class has an interest in promoting FD in order to lower the entry costs of firms. This hypothesis is consistent with the political economy model of Rajan and Zingales (2003) in which agriculturalists have a large amount of collateral (land) and, therefore are in less need of an efficient financial system. The merchants and venture capitalists, by contrast, are heavily dependent on external sources of funding for new projects. Furthermore, as urban sectors grow, the migration of workers from rural to urban areas will put upward pressure on the wages of agricultural workers and, consequently, lower land rent and land prices. This follows that land owners suffer as a result of FD and hence have a great interest in opposing FD.

More importantly, the landed class has a strong incentive to resist economic development because it undermines its power. Using a political economy model, Robinson and Acemoglu (2000) show that the effects of economic change on political power is a key factor in determining whether economic progress will be blocked. Since the landed aristocracy and large landholders before WWII in the countries considered in this study were often influential in politics they had strong incentives to block economic advances that would undermine their power. This argument is consistent with a proposition of David Ricardo, who argues that "the interest of the landlord is always opposed to the interest of every other class in the community" (Ricardo, 1951, p. 21). Finally, the more important is the agricultural sector in total economic activity the larger is the incentive to invest in land as opposed to money and stocks that necessitate financial intermediation.

In summary, we would expect the agricultural share to be influential for FD because of the changing power relationship between the landed class and capitalists. To check the exclusion restriction, that it is actually reduced agricultural share that drives FD and not the other way around, we carry out a Granger causality test between FD (measured as credit/GDP) and $Agr.Share$ on a time series panel with two lags for all countries considered in this study over the period 1870-2009 (both variables are measured in five-year intervals). The null hypothesis that $Agr.Share$ does not Granger cause FD is rejected at the 1% level of significance ($p = 0.003$). On the other hand, the null hypothesis that FD does not Granger cause $Agr.Share$ cannot be rejected at any conventional levels of significance ($p = 0.628$). This provides strong evidence in favor of the hypothesis that FD is an outcome of changes in agricultural share and not *vice versa* and, therefore, gives credence to the use of the agricultural share as an instrument for FD.

$Un.Mem$, which is measured as the ratio of union membership to economy-wide employment, is hypothesized to be positively associated with FD since unions are allowed in freer societies with little government interference. Although high union membership rates are often associated with union militancy and anti-capitalist undercurrents in popular writings, the relationship is often in reverse. France, which is well-known for its militant unions, has had union membership rates well below 10% for most of the period considered here, while the Nordic countries, which are not at all renowned for having militant unions, have had membership rates around 60% in the post-WWII period. Furthermore, union membership rates were increasing under the autocratic regimes of Hitler, Franco and Mussolini, reflecting pro-business attitudes.

Following from the political economy model of Rajan and Zingales (2003), unions have an economic interest in FD because it lowers the rents of incumbent firms and, therefore, increases labor's share. This result can also be generated from the general equilibrium model of Blanchard and Giavazzi (2003). They consider an economy with both product and labor market regulations and demonstrate that product market deregulation that lowers entry costs leads to higher real wages and lower unemployment in the long run. Consequently, in the interest of workers, unions will support policies that lower entry costs of firms, such as lowering the cost of funding and easing access to credit, which improve financial efficiency. Overall, union membership rates are inversely related to the degree to which governments interfere with the private sector and, therefore, are positively associated with the pace of FD. Performing Granger causality tests using the same data sample we find that unionization Granger causes FD but not the other way around.[2]

Figure 2. FD and Agricultural Output Share

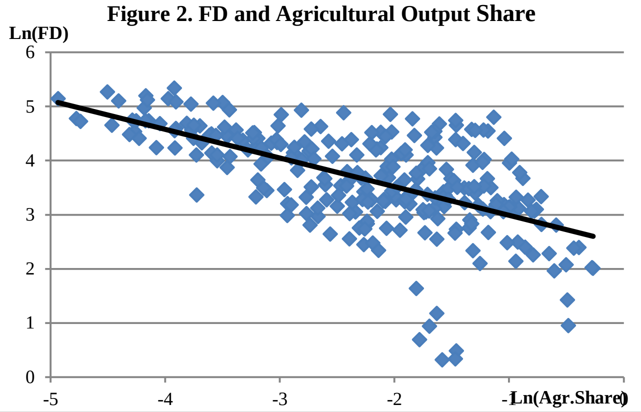
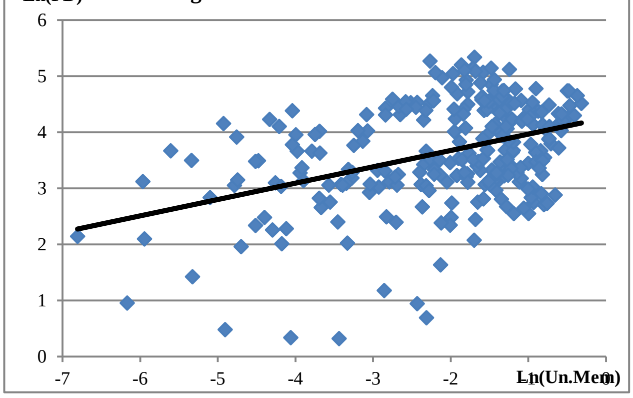


Figure 3. FD and Unionization



Notes: FD = Credit-GDP ratio; $Agr.Share$ = agricultural share of GDP; $Un.Mem$ = unionization ratio. Each observation is a 10-year average. All 21 OECD countries are included in the sample over the period 1870-2009.

The relationships between our instruments and FD are displayed in Figures 2 and 3. The variables are measured in natural logs, following the regression models. Figure 2 shows a significant negative relationship between FD and $Agr.Share$, with a correlation coefficient of 0.6. We maintain the log-log plot for consistency reasons, despite the fact that the association is stronger if the variables are not expressed in logs. Several outliers in the diagram suggest that the impact of $Agr.Share$ on FD becomes muted for very small values of agricultural output shares. Figure 3 shows a close positive relationship between $Un.Mem$ and FD, with a correlation coefficient of

[2] The null hypothesis that $Un.Mem$ does not Granger cause FD is rejected at the 2% level of significance ($p = 0.013$). The null hypothesis that FD does not Granger cause $Un.Mem$ cannot be rejected at any conventional levels of significance ($p = 0.419$). An optimal lag length of six is chosen for the estimations.

0.40. The evidence presented above suggests not only that the relationships between the instruments and FD are consistent with our hypothesis but also that they are sufficiently correlated with FD to potentially serve as good instruments for identification.

4.5 Summary statistics

Summary statistics of the log of the variables measured in five-year intervals are provided in Table 1. The savings rate is not logged because it contains negative values and some of the variables in Table 1 are first introduced in the robustness section. Note that the number of observations is below the full sample for GER^S and GER^T due to a few zero entries because secondary schooling in the UK was not widespread before the early 20th century and the first established university in New Zealand, the University of Otago, was founded in 1869 and initially only had very few students.

Table 1: Summary statistics of key variables (1870-2009)

Variable	Obs	Mean	Min	Max	Std. Dev. (Overall)	Std. Dev. (Between)	Std. Dev. (Within)
Private credit / GDP ($lnFD_{it}$)	588	-1.062	-5.667	0.778	1.009	0.590	0.828
Bank assets / GDP ($lnFD_{it}$)	588	-0.573	-7.006	2.318	1.191	0.803	0.897
Monetary aggregate / GDP ($lnFD_{it}$)	588	-0.548	-3.898	1.530	0.774	0.538	0.568
Stock market capitalization/ GDP ($lnSMC_{it}$)	588	3.090	0.075	5.474	1.073	0.785	0.751
Financial volatility ($lnFV_{it}$)	588	-1.580	-6.186	2.850	2.091	0.866	1.913
Number of patents filed by domestic residents ($ln\dot{A}_{it}^{D}$)	588	7.237	-2.635	12.817	2.464	1.997	1.506
Private savings / GDP (s_{it})	588	0.115	-0.077	0.363	0.100	0.086	0.055
Gross investment / capital stock ($\ln(I/K)_{it}$)	588	-2.249	-3.157	-1.677	0.220	0.056	0.214
Secondary education gross enrollment rate ($lnGER_{it}^{S}$)	582	2.858	-2.257	5.091	1.357	0.434	1.290
Tertiary education gross enrollment rate ($lnGER_{it}^{T}$)	587	1.331	-1.776	4.482	1.475	0.408	1.420
Agricultural output / GDP ($lnAgr.Share_{it}$)	588	-2.173	-5.044	-0.161	1.052	0.471	0.947
Union membership ($lnUn.Mem_{it}$)	588	-2.368	-8.167	-0.295	1.571	0.627	1.446

Notes: Data are in five-year averages. Financial volatility, FV, is measured as the standard deviation of the log of monthly stock prices within the year.

In our study, the use of country fixed effects requires sufficient variability of within-country information. Therefore, it is necessary to examine the degree of between-country and within-country variation in the data. Our main variables of interest do indeed demonstrate a high level of within-country variation. In particular, the ratio of private credit to GDP (logs) shows a between-country standard deviation of 0.590 and a much larger within-country standard deviation of 0.828. The overall standard deviation is 1.009. The within-country standard deviations of the two instruments are also substantially higher than their between-country counterparts, thus providing further support for the use of the fixed-effects (within) estimator.

What's more, by having standard deviations around one, most of the variables have a sufficient degree of identifying variations to yield efficient parameter estimates. The exceptions are relatively low variations in the investment and the savings rates and comparatively high variations in financial volatility and patent counts. It should also be noted that the instruments exhibit large secular changes. For example, unionization in the UK dropped from around 45% in 1977 to 22% in 2009, while it increased by 258%, 68% and 47% in Finland, Denmark and Sweden, respectively, over the period 1960-1993. [3]

Although the agricultural share has been trending downwards for all countries over the period 1870-2009, the decline was arrested in many countries in the interwar period and the share was relatively stable up to 1970, before it started to shrink. Furthermore, the decline in the period 1870-2009 has been marked for Portugal (85%) and Spain (70%), but moderate for Belgium (13%), Italy (l5%) and the Netherlands (15%).

5. Estimation results

5.1 Knowledge production function

The results of estimating the knowledge production function are presented in Table 2. Consider the first-stage regression in Panel B in which the share of agriculture in total income ($Agr.Share$) and the union membership rate ($Un.Mem$) are used as instruments. As noted above, country and time fixed effects dummies are included in all regressions, including the first-stage regressions, throughout the paper. The instruments are all consistently highly significant and carry the expected signs, suggesting that these instruments are sufficiently correlated with FD to act as potentially good instruments. Furthermore, the null hypothesis of the over-identification tests reported in Panel D cannot be rejected, even at the 10% level, indicating that the exclusion restrictions assumption is satisfied. The F-test statistics for excluded instruments and the R-squared values in the first-stage regressions provide evidence to suggest that the instruments have strong explanatory power.

[3] However, increasing unionization does not always go hand in hand with financial development. As an example, the post-1977 decline in unionization in the UK, particularly during the years 1977-1995, was associated with increasing financial development during the same period. Although in principle unions have a vested interest in financial development because it lowers rents of incumbent firms and reduces entry costs that would lead to an increase in labor's share, the UK's experience under Thatcher (1979-1990) was influenced by an ideological desire of her government to deregulate the financial sector and, at the same time, reduce the power of the unions. Therefore, the negative relationship between financial development and the extent of unionization observed in the UK during this period has to be seen in the light of the strong union militancy in Britain during the 1970s and Thatcher's commitment to reduce the power of trade unions (Thatcher, 1993).

The structural regressions are presented in Panel A of Table 2. In the restricted regression in the first column in which patents are regressed on *FD* only, the coefficient of *FD* is highly significant and has the sign consistent with our prior, implying that *FD* promotes ideas production. The coefficient of *FD* remains significant and positive when the unrestricted model is estimated, regardless of whether the numerator of FD is credit to the private sector (column 2), bank assets (column 3), or money stock (column 4). The coefficient of *FD* is, on average, 0.06, implying that a 20% increase in FD is associated with a 1.2% increase in innovative activity. Thus, the approximately 14-fold increase in the ratio of credit to GDP over the period 1870-2009 has resulted in an 84% increase in innovative activity. The average partial *R*-squared value for columns (2) to (4) in the structural model is 0.28 (not reported), suggesting that the variation in ideas production can be significantly explained by the variation in FD.[4]

The coefficients of the non-FD regressors in the ideas production function are statistically significant and have the expected sign in almost all cases. The coefficients of research intensity are positive and significant in two of the three cases, suggesting that R&D increases the number of product lines and only enhances growth to the extent that it increases the fraction of GDP that is allocated to R&D, as predicted by Schumpeterian growth theory. The coefficients of knowledge stock are highly significant and are very close to one, indicating the presence of scale effects in ideas production.

This significance of research intensity and knowledge stock in ideas production has two important implications. First, it implies that R&D intensity has permanent, or at least highly persistent, growth effects. Thus, productivity is growing at a constant rate in steady state due to R&D as long as R&D is kept to a constant fraction of GDP. Second, FD has either permanent or close to permanent productivity growth effects – a result that is crucial because it shows that the findings of permanent growth effects of FD in the literature are initiated from ideas production. That is, FD has permanent growth effects because it influences ideas production directly and because of the presence of scale effects in ideas production. This result is important as it solves the paradox that FD is often assumed to transmit to growth through the savings-investment channel in the literature despite investment being highly unlikely to have permanent growth effects due to diminishing returns to capital.

[4] The partial *R*-squared in the structural model measures the correlation between financial development and the outcome variable after partialling out the effects of all control variables.

Table 2: Financial development and the knowledge production function (Eq. (7))

Dep. Var. = $ln\dot{A}_{it}^{D}$	(1) Restricted model	(2) Add control variables [Benchmark]	(3) FD = bank assets / GDP	(4) FD = money supply / GDP
	A. 2nd-stage regressions			
Intercept	9.849*** (1.558)	-1.686*** (0.179)	-1.168*** (0.122)	-2.795*** (0.215)
lnA_{it}		0.981*** (0.008)	0.973*** (0.004)	0.996*** (0.006)
$ln(R/Y)_{it}^{D}$		0.013* (0.008)	0.060*** (0.009)	-0.013 (0.009)
$lnDTF_{it}$		0.057** (0.027)	0.056** (0.022)	0.198*** (0.035)
$(R/Y)_{it}^{D} \cdot \ln DTF_{it}$		2.457*** (0.878)	0.883 (0.869)	0.497 (1.150)
$(M/Y^{n})_{it} \cdot ln(R/Y)_{it}^{F}$		0.102*** (0.011)	0.040*** (0.010)	0.232*** (0.020)
$lnFD_{it}$	0.177*** (0.010)	0.071*** (0.020)	0.041*** (0.013)	0.063** (0.026)
	B. 1st-stage regressions			
$lnAgr.Share_{it}$	-0.167*** (0.013)	-0.240*** (0.012)	-0.319*** (0.013)	-0.260*** (0.011)
$lnUn.Mem_{it}$	0.147*** (0.004)	0.064*** (0.007)	0.068*** (0.008)	0.029*** (0.006)
	C. 2SLS treating $lnAgr.Share_{it}$ as exogenous			
$lnAgr.Share_{it}$	0.077 (0.152)	-0.017 (0.030)	0.001 (0.012)	-0.034 (0.043)
$lnFD_{it}$	0.936*** (0.000)	0.192*** (0.047)	0.055*** (0.018)	0.130** (0.062)
	D. Diagnostic statistics			
1st-stage F-test for excluded IVs	812.79	240.16	329.45	521.88
1st-stage R-squared	0.661	0.757	0.774	0.661
1st-stage partial R-squared	-	0.536	0.337	0.209
Over-identification test statistic [p-value]	4.560 [p=0.102]	3.582 [p=0.167]	1.970 [p=0.373]	4.324 [p=0.115]
No. of observations	588	588	588	588

Notes: the dependent variable is the log of the number of domestic patents applications ($ln\dot{A}_{it}^{D}$). Financial development (FD) is measured as the ratio of private credit to GDP in columns (1) and (2). The instruments for FD are the share of agricultural output in GDP ($Agr.Share$) and the rate of union membership ($Un.Mem$). The estimates are derived from a panel two-stage least squares estimator with cross-sectional SUR weights that account for both cross-section heteroskedasticity and contemporaneous correlation. The panel is estimated in five-year intervals over the period 1870-2009, covering 21 countries with a total of 588 observations. All regressions include time dummies and country fixed effects. Panel (A): structural estimates; Panel (B): first-stage regressions for structural estimations in Panel (A), Panel (C): structural estimates of regressions in which $lnAgr.Share_{it}$ is treated as an exogenous variable whereas unionization is used as the instrument (the constant term and other control variables included in the first-stage regressions and the 2SLS estimates are not reported); Panel (D): Over-identification tests corresponding to the first and second stage regressions in Panels (A) and (B). The test statistic is distributed as $\chi^2(2)$ under the null hypothesis that the over-identification restrictions are satisfied. The partial R-squared in the first-stage regressions measures the correlation between financial development and the instruments ($Agr.Share$ and $Un.Mem$) after partialling out the effects of all control variables. Figures in parentheses are robust standard errors. *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

Turning to the spillover variables, R&D-intensity spillover through imports is significant in all cases. Thus, the higher is the research intensity among country i's trading partners, the higher is country i's ideas production, highlighting the importance of importing from countries with high research intensity. The coefficients of distance to the frontier are also positive and significant determinants of innovative output in all cases. Thus, the further away that a country is from the frontier the more advantage it can take in absorbing and developing the ideas created at the frontier. The coefficients of the interaction between research intensity and DTF are significant at the 1% level in one out of the three cases, giving some credence to Howitt 's (2000) model that suggests that highly research active countries are more capable of exploiting and developing frontier technology to their own advantage.

As an alternative test of the exclusion restriction, panel C in Table 2 reports the regression results where agricultural share is treated as an exogenous variable instead of as an instrument (note that we cannot treat unionization as an exogenous variable in the structural regressions at the same time because it is used as an instrument). The underlying principle of this test is simple. If $Agr.Share$ has a direct effect on ideas production and, therefore, violates exclusion restrictions, we would expect its coefficient to be significant. On the other hand, if it is found to be statistically insignificant, then it is established that it affects ideas production via FD, thus giving credence to our approach that $Agr.Share$ is a valid instrument for FD. Only the coefficients of $Agr.Share$ and FD are reported in Panel C to conserve space.

The coefficients of FD are all significant and the coefficients of $Agr.Share$ are all insignificant. We repeated this exercise by treating unionization as an exogenous variable in the structural regressions (the results are not shown). The coefficients of unionization were all insignificant at any conventional levels and the coefficients of FD were all significant at the 1% level in the structural regressions. These results indicate that all our instruments influence ideas production through FD and, therefore, that the exclusion restrictions are satisfied.

5.2 Savings function

The results of estimating the savings function are presented in Table 3. The coefficients of the share of agriculture in total income ($Agr.Share$) and the union membership rate ($Un.Mem$) in the first-stage regressions are all highly significant and have signs consistent with our predictions. The over-identification tests reported in Panel D suggest that the over-identifying restriction assumption is satisfied. Regarding the structural estimates, savings are significantly positive functions of the growth in per capita income and, therefore, consistent with the predictions of the model of Carroll *et al.* (2000) that high growth rates are associated with high savings because of habit persistence. The coefficients of the age dependency rate are negative and significant in all cases, which is consistent with the predictions of the life-cycle hypothesis that individuals save during their working age and dis-save beyond their working age. The coefficients of the real interest rate are all positive and significant, suggesting that the substitution effect dominates the income effect.

Table 3: Financial development and savings (Eq. (8))

Dep. Var. = *savings rate*	(1) Restricted model	(2) Benchmark model	(3) *FD* = bank assets / GDP	(4) *FD* = money supply / GDP
	A. 2nd-stage regressions			
Intercept	0.129*** (0.004)	-0.109*** (0.006)	-0.053*** (0.006)	-0.548*** (0.064)
Δlny_{it}		0.268*** (0.016)	0.233*** (0.014)	0.307*** (0.095)
$ln\ Age\ dep_{it}$		-0.249*** (0.013)	-0.248*** (0.015)	-0.746*** (0.051)
$Int\ rate_{it}$		0.024*** (0.001)	0.018*** (0.001)	0.057*** (0.007)
$lnFD_{it}$	0.036*** (0.001)	0.020*** (0.002)	0.027*** (0.003)	0.032*** (0.010)
	B. 1st-stage regressions			
$lnAgr.Share_{it}$	-0.181*** (0.013)	-0.225*** (0.012)	-0.249*** (0.010)	-0.138*** (0.008)
$lnUn.Mem_{it}$	0.167*** (0.006)	0.186*** (0.008)	0.133*** (0.007)	0.104*** (0.006)
	C. 2SLS treating $lnAgr.Share_{it}$ as exogenous			
$lnAgr.Share_{it}$	-0.001 (0.001)	-0.012 (0.014)	-0.003 (0.011)	-0.023 (0.022)
$lnFD_{it}$	0.056*** (0.001)	0.023*** (0.004)	0.100*** (0.005)	0.059*** (0.000)
	D. Diagnostic statistics			
1st-stage F-test for excluded IVs	591.33	668.35	408.56	4457.38
1st-stage R-squared	0.717	0.731	0.752	0.668
1st-stage partial R-squared	-	0.579	0.348	0.198
Over-identification test statistic	1.166 [p=0.558]	0.050 [p=0.975]	0.236 [p=0.889]	2.288 [p=0.319]
No. of observations	588	588	588	588

Notes: see notes to Table 2. The dependent variable is the ratio of private savings to GDP. Figures in parentheses are robust standard errors. *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

Turning to FD, the coefficients of *FD* are consistently highly significant, regardless of whether control variables are excluded from the regressions (first column) or whether FD is measured by credit, money or bank assets relative to nominal GDP (columns (2) to (4)). The quantitative effects of FD on savings are substantial. Dividing the coefficient of *FD* of 0.02 (base-line regression) by the mean savings rate of 0.115, yields the elasticity value of 0.17. Thus a 10% increase in FD would increase savings by 1.7%. Since FD quadrupled over the period 1870-1913, for example, this development has resulted in a 68% or an eight percentage point increase in the savings rate and, therefore, can account for a large fraction of the increase in savings during the same period. FD also explains a high fraction of the variation in savings. The average partial R-squared value for FD in the regressions in columns (2) to (4) in the structural model is 0.63 (not reported), suggesting that 60% of the variation in savings can be explained by the variation in FD.

How do our results compare with the findings in the literature? For a cross-country sample of 29 countries Levine and Zervos (1998) find that a one percentage point increase in the initial credit-GDP ratio is associated with a 3.8 percentage point increase in savings, which is a stronger economic effect than what has been found here. Beck *et al.* (2000) estimate a coefficient of the credit-GDP ratio of 0.21 in their savings function, which is quite close to our estimates. It should be noted, however, that while Beck *et al.* (2000) document a positive correlation between savings rates and financial development, their estimates are sensitive to the measurement of financial development and the estimators used.

Finally, the coefficients of FD remain highly significant when the agricultural share is treated as exogenous and the coefficient of agricultural share is insignificant in the structural regressions, indicating that the exclusion restriction is satisfied (Panel C in Table 3). Repeating this exercise by treating unionization as an exogenous variable in the structural regressions yields the same results (the results are not reported). This again suggests that our instruments impact on saving through FD; thus fulfilling the exclusion restrictions.

5.3 Investment function

The estimated results for the Tobin's q model of investment are presented in Table 4. The coefficients of $Agr.Share$ and $Un.Mem$ in the first-stage regressions are all highly significant and of the expected sign and the over-identification tests in Panel D are all insignificant, indicating that the exclusion restrictions are satisfied. Turning to the structural regressions in Panel B, the coefficients of Tobin's q are significant in only one case, while the coefficients of income growth are highly significant – a result that is consistent with the findings in the literature (see Chirinko, 1993; Greasley and Madsen, 2006). The coefficients of *FD* are consistently statistically significant regardless of how FD is measured and whether or not the control variables are included in the regressions. This result is consistent with the finding of Madsen and Carrington (2012) that bank lending is, by far, the most important driver of investment in the US.

The importance of FD as a determinant of investment is signified by the magnitude of the coefficients of *FD*, indicating that a 10% increase in FD results in a 0.2% increase in the investment rate. Therefore, the twenty-fold increase in the credit ratio for the average country in the sample over the period 1870-2009 has resulted in a 40% increase in the *I-K* ratio over the same period. Thus, FD has been a powerful force behind the increase in the *I-K* ratio over the considered period.

This result is also supported by a high partial *R*-squared value of 45%, which indicates that FD contributes significantly to explaining variations in the *I-K* ratio (results are not shown).

Finally, the coefficients of *FD* remain significant when the agricultural share is treated as exogenous and the coefficient of agricultural share is insignificant in the structural regressions, indicating that agricultural share has no direct impact on the *I-K* ratio (Panel C in Table 4). The results are consistent when we treat unionization as an exogenous variable in the structural regressions (the results are not shown).

Table 4: Financial development and investment (Eq. (10))

Dep. Var. = $ln(I/K)_{it}$	(1) Restricted model	(2) Benchmark model	(3) *FD* = bank assets / GDP	(4) *FD* = money supply / GDP
	A. 2nd-stage regressions			
Intercept	-2.081***	-2.322***	-2.267***	-2.239***
	(0.050)	(0.033)	(0.018)	(0.013)
lnq_{it}		0.001*	0.071	0.059
		(0.001)	(0.045)	(0.048)
Δlny_{it}		0.139***	0.144***	0.145***
		(0.019)	(0.020)	(0.020)
$lnFD_{it}$	0.021***	0.018***	0.017***	0.016***
	(0.003)	(0.003)	(0.003)	(0.005)
	B. 1st-stage regressions			
$lnAgr.Share_{it}$	-0.229***	-0.219***	-0.217***	-0.126***
	(0.007)	(0.009)	(0.010)	(0.008)
$lnUn.Mem_{it}$	0.355***	0.354***	0.345***	0.172***
	(0.009)	(0.008)	(0.006)	(0.006)
	C. 2SLS treating $lnAgr.Share_{it}$ as exogenous			
$lnAgr.Share_{it}$	0.001	0.001	-0.006	-0.016
	(0.009)	(0.017)	(0.008)	(0.018)
$lnFD_{it}$	0.072***	0.032**	0.017*	0.085***
	(0.014)	(0.016)	(0.009)	(0.027)
	D. Diagnostic statistics			
1st-stage F-test for excluded IVs	2913.12	2725.64	1772.82	1534.93
1st-stage R-square	0.668	0.669	0.716	0.629
1st-stage partial R-squared	-	0.495	0.236	0.129
Over-identification test statistic	2.039	1.534	3.316	0.307
	[p=0.361]	[p=0.465]	[p=0.191]	[p=0.858]
No. of observations	588	588	588	588

Notes: see notes to Table 2. The dependent variable is the logs of total domestic investment over total domestic capital stock ($ln(I/K)_{it}$). Figures in parentheses are robust standard errors. *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

Our results are comparable with the post-WWII results in the literature. Levine and Zervos (1998) find, for a cross-country sample of 41 countries, that a one percentage point increase in the initial credit-GDP ratio is associated with an increase in the capital stock growth rate of 0.014%. Beck *et al.* (2000) find the coefficient of the credit ratio in their capital growth model to be between 2.8 and 3.4, implying that the approximately 25 percentage point increase in the credit ratio in the period 1870-1913 is associated with capital stock growth of between 70% and 85%. The findings of Beck *et al.* (2000), however, are sensitive to the use of different financial development indicators and econometric techniques. Finally, based on GMM estimates for a panel of countries, Benhabib and Spiegel (2000) estimate the coefficient of the financial sector's liquid liabilities relative to GDP to be approximately 0.1, when fixed effects dummies are excluded from the regressions. This implies that a 10 percentage point increase in the investment-GDP ratio is associated with a one percentage point increase in the investment ratio, suggesting that the approximately 25 percentage point increase in the credit ratio in the period 1870-1913 in our sample has resulted in a 2.5 percentage point increase in the investment ratio over the same period.

5.4 Schooling function

Schooling regressions are presented in Tables 5 and 6. Consider first the regressions for secondary gross enrollment rates in Table 5. The coefficients of all the instruments in the first-stage regressions are, again, highly significant and have signs consistent with our predictions. In the structural regressions the coefficients of per capita income growth are significant in only one of the three cases, indicating that increasing income may have only made a minimal contribution to the increase in secondary education over the past 140 years.

The coefficients of life expectancy at age ten are positive and significant and the coefficients of real interest rates are all statistically significant and have the expected negative sign. Increasing real interest rates lowers schooling because the wage premium associated with secondary schooling is discounted at a higher rate and, consequently, lowers the present value of the excess earnings from schooling. However, it is possible that the negative coefficients of the real interest rate may have been driven by inflation fluctuations and that gross enrollment rates are positive functions of the inflation rate as precautionary savings increase in periods of uncertainty.

The coefficients of FD are highly significant in all cases and the magnitude is 0.3 in the baseline regression, implying that the 24-fold increase in credit-based FD over the period from 1870 to 2009 has resulted in a seven-fold increase in the secondary schooling enrollment rate. While this increase may seem implausibly high, it has to be recognized that secondary gross enrollment rates were 2.4% in 1870 and, therefore, the sevenfold increase is only a fraction of the actual almost 36-fold increase over the period 1870-2009. Quantitatively, life expectancy at the age of ten has been even more influential than FD for secondary schooling. It has increased by 53% on average over the period from 1870 to 2009, implying that increasing life expectancy has been responsible for an approximately 36% increase in secondary gross enrollment rates in the base-line regression. The significance of FD in this model is supported by the partial R-squared, which shows that FD alone accounts for 30% of the variation in the secondary school enrollment rate (results are not shown).

Regressions for tertiary gross enrollment rates are presented in Table 6. The coefficients of $Agr.Share$ and $Un.Mem$ in the first-stage regressions are all highly significant and have the expected signs. The coefficients of FD are, again, highly significant in all cases reinforcing the results in Table 5 that FD is influential for schooling. The coefficient of FD is 1.7 in the baseline regression, implying that the 24-fold increase in credit-based FD over the period from 1870 to 2009 has resulted in a 41-fold increase in the tertiary schooling enrollment rate. This impact, again, has to be seen in the light of the minuscule GER^T back in 1870, typically close to 0.5. Thus, the 41-fold increase would mean that GER^T would increase from, say, 0.5 to 20.5.

Table 5: Financial development and secondary gross enrollment rates (Eq. (11))

Dep. Var. = $ln\ GER_{it}^S$	(1) Restricted model	(2) Benchmark model	(3) *FD* = bank assets / GDP	(4) *FD* = money supply / GDP
	A. 2nd-stage regressions			
$Intercept$	1.752***	-1.155***	-8.371***	1.040
	(0.061)	(0.408)	(0.349)	(0.913)
Δlny_{it}		0.054***	0.008	-0.004
		(0.017)	(0.019)	(0.023)
$lnLife_{it}$		0.681***	2.343***	0.349*
		(0.103)	(0.088)	(0.210)
$real\ int\ rate_{it}$ /1000		-0.054***	-0.065***	-0.046*
		(0.015)	(0.007)	(0.026)
$lnFD_{it}$	0.364***	0.308***	0.041***	0.616***
	(0.018)	(0.011)	(0.008)	(0.053)
	B. 1st-stage regressions			
$lnAgr.Share_{it}$	-0.120***	-0.064***	-0.159***	-0.087***
	(0.013)	(0.015)	(0.010)	(0.008)
$lnUn.Mem_{it}$	0.449***	0.125***	0.192***	0.097***
	(0.008)	(0.008)	(0.006)	(0.009)
	C. 2SLS treating $lnAgr.Share_{it}$ as exogenous			
$lnAgr.Share_{it}$	0.012	-0.047	-0.090	-0.015
	(0.019)	(0.042)	(0.059)	(0.023)
$lnFD_{it}$	1.149***	0.162*	0.303***	0.121***
	(0.034)	(0.094)	(0.065)	(0.033)
	D. Diagnostic statistics			
1st-stage F-test for excluded IVs	1275.33	130.37	709.74	121.21
1st-stage R-squared	0.585	0.749	0.540	0.613
1st-stage partial R-squared	-	0.561	0.451	0.256
Over-identification test statistic	2.838	3.737	1.529	0.609
	[p=0.242]	[p=0.154]	[p=0.466]	[p=0.767]
No. of observations	582	582	582	582

Notes: see notes to Table 2. The dependent variable is the gross enrollment rate for secondary education. Figures in parentheses are robust standard errors. *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

The control variables are, again, mostly significant. The coefficients of the real interest rate and life expectancy at age 10 are all highly significant and of the expected sign and the coefficients of income growth are significant in two of the three cases. Compared to GER^S, the marginal contribution of FD in explaining the variation in GER^T after taking into account the effects of income growth, life expectancy and interest rates is much higher in this case, at 54% (results are not shown).

Table 6: Financial development and tertiary gross enrollment rates (Eq. (11))

Dep. Var. = $ln\ GER_{it}^T$	(1) Restricted model	(2) Benchmark model	(3) *FD* = bank assets / GDP	(4) *FD* = money supply / GDP
	A. 2nd-stage regressions			
Intercept	4.307*	-4.045***	-26.652***	-8.173***
	(2.436	(0.632)	(0.625)	(1.232)
Δlny_{it}		0.174***	0.355***	0.040
		(0.029)	(0.074)	(0.034)
$lnLife_{it}$		1.448***	7.066***	2.728***
		(0.146)	(0.209)	(0.279)
$real\ int\ rate_{it}$ / 1000		-0.303***	-0.117***	-0.333***
		(0.007)	(0.016)	(0.020)
$lnFD_{it}$	0.729***	1.674***	0.949***	1.709***
	(0.069)	(0.034)	(0.048)	(0.084)
	B. 1st-stage regressions			
$lnAgr.Share_{it}$	-0.151***	-0.063***	-0.293***	-0.394***
	(0.013)	(0.015)	(0.012)	(0.010)
$lnUn.Mem_{it}$	0.181***	0.131***	0.362***	0.061***
	(0.005)	(0.008)	(0.008)	(0.007)
	C. 2SLS treating $lnAgr.Share_{it}$ as exogenous			
$lnAgr.Share_{it}$	0.006	-0.277	0.573	0.038
	(0.014)	(0.229)	(0.455)	(0.030)
$lnFD_{it}$	0.677***	1.195**	0.875***	1.870***
	(0.017)	(0.565)	(0.334)	(0.100)
	D. Diagnostic statistics			
1st-stage F-test for excluded IVs	960.53	145.23	1100.02	867.77
1st-stage R-squared	0.732	0.749	0.561	0.437
1st-stage partial R-squared	-	0.573	0.468	0.308
Over-identification test statistic	2.813 [p=0.245]	0.428 [p=0.808]	1.444 [p=0.486]	0.765 [p=0.682]
No. of observations	587	587	587	587

Notes: see notes to Table 2. The dependent variable is the gross enrollment rate for tertiary education. Figures in parentheses are robust standard errors. *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

The result that FD is influential for schooling is consistent with the finding in the microeconomic literature that credit constraints hamper schooling (see, for survey, Lochner and Monge-Naranjo, 2012). The macroeconomic evidence, however, is sparse and tends to focus on credit constraints, which are to some extent, related to FD. Calibrating the Ben-Porath model of human capital investment, Córdoba and Ripoll (2013) show that introducing credit constraints significantly improves the ability of a Ben-Porath model to explain the cross-country variation in the average years of schooling. Estimating the effects of FD on school enrollment for developing countries, De Gregorio (1996) finds a coefficient of the credit/GDP ratio of 0.18 in the GER^T

regression and a coefficient of 1.19 for the GER^Sregression. Benhabib and Spiegel (2000) find the coefficient of the credit ratio to be an insignificant determinant of the change in educational attainment in their panel estimates. However, since educational attainment is determined by past gross enrolment rates, it is not surprising that they fail to find any significant relationship.

Common to the secondary and tertiary schooling regressions is that the coefficients of FD remain highly significant when the agricultural share is treated as exogenous and the coefficient of agricultural share is insignificant in the structural regressions, indicating that the assumption of the exclusion restriction is not violated (Panel C in Tables 5 and 6). The results, again, do not vary when we consider unionization as an exogenous variable in the structural regressions.

6. Robustness checks

This section tests the robustness of the baseline results to the use of alternative estimators, the consideration of stock market-based indicators of FD, the allowance of disequilibria in asset markets and the split of estimation periods. FD is measured by credit to the private sector in all regressions in this section to save space. Most importantly, the qualitative aspects of the results are invariant when FD is based on bank assets and broad money.

6.1. Using different estimators

Thus far the results have been based on the 2SLS fixed-effect SUR estimator. The regressions in Table 7 consider several alternative estimators, including OLS, GMM, and 3SLS, to check the sensitivity of the results to the choice of estimator. The baseline regressions in the second columns in Tables 2-6 are repeated in column (1) in Table 7 for comparison. OLS estimates (column (2)) are reported since IV regressions can be severely biased if the instruments are poor and, unlike many system estimators, the OLS estimator is considered to be quite robust to model specification. The system GMM estimator has long been a popular estimator because it automatically creates instruments from the orthogonal conditions in the data; however, it has come under increasing criticism because it tends to create too many instruments relative to the number of observations, over-fitting, and biasing the estimates, yields results that are highly sensitive to the number of lags, and impairs the quality of the over-identification tests (see, for discussion, Roodman, 2009). Note that internal as well as external instruments (unionization rates and agricultural share) are used in system GMM regressions in Table 7. The results do not vary significantly if only internal instruments are considered.

Table 7: Robustness checks using alternative estimators

	(1) Baseline (IV-2SLS)	(2) OLS	(3) System GMM	(4) 3SLS
Dep. Var. = $ln\dot{A}_{it}^{D}$	*Panel I: Knowledge production function (Eq. (7))*			
lnA_{it}	0.981***	0.999***	1.164***	0.996***
	(0.008)	(0.000)	(0.274)	(0.010)
$ln(R/Y)_{it}^{D}$	0.013*	0.013	-0.165	-0.023
	(0.008)	(0.112)	(0.097)	(0.054)
$lnDTF_{it}$	0.057**	0.089***	0.012	0.047***
	(0.027)	(0.000)	(0.179)	(0.092)
$(R/Y)_{it}^{D} \cdot \ln DTF_{it}$	2.457***	2.053**	11.930**	19.995
	(0.878)	(0.018)	(5.494)	(10.821)
$(M/Y^{n})_{it} \cdot ln(R/Y)_{it}^{F}$	0.102***	0.146***	0.275	0.215
	(0.011)	(0.000)	(0.207)	(0.067)
$lnFD_{it}$	0.071***	0.013**	0.201***	0.089**
	(0.020)	(0.010)	(0.060)	(0.034)
No. of observations	588	588	588	588
Dep. Var. = savings rate	*Panel II: Savings function (Eq. (8))*			
Δlny_{it}	0.268***	0.024***	-0.004	0.934*
	(0.016)	(0.000)	(0.086)	(0.537)
$ln\ Age\ dep_{it}$	-0.249***	-0.003**	-0.097*	0.186
	(0.013)	(0.028)	(0.047)	(0.401)
$Int\ rate_{it}$	0.024***	0.001***	-0.001	0.124*
	(0.001)	(0.000)	(0.004)	(0.069)
$lnFD_{it}$	0.020***	0.009***	0.027**	0.118***
	(0.002)	(0.000)	(0.012)	(0.042)
No. of observations	588	588	588	588
Dep. Var. = $ln(I/K)_{it}$	*Panel III: Investment function (Eq. (10))*			
lnq_{it}	0.001*	0.001***	-0.001	0.001
	(0.001)	(0.003)	(0.000)	(0.001)
Δlny_{it}	0.139***	0.133***	0.346*	0.403**
	(0.019)	(0.000)	(0.178)	(0.174)
$lnFD_{it}$	0.018***	0.049***	0.076**	0.020*
	(0.003)	(0.000)	(0.028)	(0.010)
No. of observations	588	588	588	588
Dep. Var. = $ln\ GER_{it}^{secondary}$	*Panel IV: Secondary gross enrollment rates function (Eq. (11))*			
Δlny_{it}	0.054***	0.041***	-0.075	-0.821
	(0.017)	(0.006)	(0.109)	(0.432)
$lnLife_{it}$	0.681***	1.097***	4.223**	9.149***
	(0.103)	(0.000)	(1.610)	(1.407)
$real\ int\ rate_{it}$ /	-0.054***	-0.018*	-0.136**	-1.689
1000	(0.015)	(0.076)	(0.054)	(1.156)
$lnFD_{it}$	0.308***	0.245***	0.309**	0.200***
	(0.011)	(0.000)	(0.138)	(0.055)
No. of observations	582	582	582	582
Dep. Var. = $ln\ GER_{it}^{tertiary}$	*Panel V: Tertiary gross enrollment rates function (Eq. (11))*			
Δlny_{it}	0.175***	0.073***	-0.053	0.346
	(0.029)	(0.003)	(0.084)	(0.441)
$lnLife_{it}$	1.448***	7.083***	9.686***	8.479***
	(0.146)	(0.000)	(1.073)	(1.221)
$real\ int\ rate_{it}$ /	-0.303***	-0.120***	-0.320**	-0.297
1000	(0.007)	(0.000)	(0.152)	(1.314)
$lnFD_{it}$	1.674***	0.191***	0.280**	0.844***
	(0.034)	(0.000)	(0.113)	(0.169)
No. of observations	587	587	587	587

Notes: see notes to Table 2. In the system GMM estimations, the share of agricultural output in GDP ($Agr.Share$) and unionization ($Un.Mem$) are included as external instruments. Figures in parentheses are robust standard errors. *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

The three-stage least square (3SLS) estimator produces consistent estimates through instrumentation and achieving efficiency through accounting for the correlation structure of the residuals across equations. The procedure involves the following steps: (1) generate the predicted values from regressions for each endogenous variable on all exogenous variables, which are taken to be instruments in the system; (2) retrieve the covariance matrix based on the above 2SLS estimation; and (3) perform a type of GLS estimation using the covariance matrix obtained in the previous step. The 3SLS estimator is normally considered to be more asymptotically efficient than the 2SLS estimator in large samples because it exploits the cross-equation co-variation.

Consider first the ideas production function in Panel I in Table 7. The coefficients of FD are all significant at least at the 5% level and the coefficients of knowledge stock are all highly significant and are very close to one except for the system GMM estimates. This gives further support to the hypothesis that FD has permanent growth effects. For the system GMM estimates the coefficient of knowledge stock is 1.16, suggesting increasing returns to knowledge stock. This implies that the production of new knowledge rises more than proportionally with the existing knowledge stock; thus advances in FD create ever-increasing growth rather than converging to a balanced growth path. This result is empirically implausible and points towards the aforementioned problems associated with the system GMM estimator.

The coefficient of FD remains highly significant in the saving function estimates (Panel II) and the coefficients of age dependency and growth remain significant in most cases. The coefficient of FD also remains significant in all the investment regressions (Panel III) and growth also remains significant in all cases, while Tobin's *q* is only significant in two cases. Finally, the coefficient of FD is consistently significant in the schooling regressions regardless of whether secondary or tertiary GER is the dependent variable, and life expectancy at age 10 is also a consistently highly significant determinant of schooling (Panels IV and V). In summary, FD remains a robust and highly significant determinant of the outcome variables when alternative estimators are used.

It should be highlighted that while the qualitative aspects of the estimates provided by these alternative estimators do not differ significantly from the baseline results, some of the coefficients do vary across different estimation techniques. In particular, the magnitudes of the coefficients on FD are generally lower in the OLS estimates. This is consistent with the fact that indicators of FD are often measured with errors, which would create an attenuation bias in the OLS estimates. Sizes of the system GMM and 3SLS estimates on FD do not show any systematic difference from the baseline IV-2SLS estimates. However, in common with the previous case, these estimates are systematically larger than their OLS counterparts, suggesting the presence of attenuated bias in the OLS estimates due to measurement errors of FD.

6.2 Using the Schularick-Taylor credit ratio

The first column in Table 8 reports regression results in which FD is based on the ratio of private credit to GDP compiled by Schularick and Taylor (2012) over the period 1870-2008 for 14 countries (the US, Canada, Australia, Denmark, France, Germany, Italy, Japan, the Netherlands, Norway, Spain, Sweden, Switzerland, and the UK). These data serve as a robustness check on data that are compiled from alternative and overlapping sources to our data. We only report the results based on the credit ratio since we use these data in our baseline regressions and because we arrive at almost similar results when we use the other two series collected by Schularick and Taylor (2012), namely the ratio of broad money to GDP and the ratio of bank assets to GDP.

The coefficients of FD are all highly significant in the regressions for all outcome variables and are close to the coefficients in the baseline regressions. The significance of the other regressors is quite similar to those in the baseline regressions. This finding is not surprising since the Schularick-Taylor measure and our private-credit ratio show a strong correlation of 0.68. The significance of these results is not only that our baseline results are robust to alternative data sources but also to a smaller subset of countries in our sample. Finally, coefficients of the instruments in the first-stage regressions, which are not reported, are all significant and carry the signs in line with our priors. The over-identification test results also do not suggest any evidence that the exclusion restrictions are violated.

6.3 Using stock market-based indicators of FD

The FD indicators used in the previous section have been bank-based and, therefore, relate predominantly to the banking sector as the intermediating sector through its provision of credit, directly or indirectly, through banks' asset or liability positions on their balance sheets. Thus, the FD indicators used thus far exclude intermediation through stock markets and may, therefore, not give a complete picture of the effects of FD on outcome variables. To overcome this omission the ratio of stock market capitalization to GDP and stock market volatility are used as indicators for market-based FD.

Stock market capitalization is probably the most widely used market-based measure of FD (Levine, 1997) while stock price volatility is proposed and used by Levine and Zervos (1998) as a measure of the influence of gyrations in the stock market on growth and, therefore, whether volatility hinders investment and resource allocation. We have also used the ratios of stock market total value traded to both GDP and stock market capitalization. However, to conserve space, the estimates are not reported here since they provide similar findings.

Table 8: Robustness checks using other financial development indicators

	(1) Schularick-Taylor's private credit data	(2) Stock market capitalization	(3) Bank-based vs. market-based system	(4) Stock market volatility
Dep. Var. = $ln\dot{A}_{it}^{D}$	*Panel I: Knowledge production function (Eq. (7))*			
lnA_{it}	0.990***	0.943***	0.985***	0.996***
	(0.008)	(0.016)	(0.040)	(0.006)
$ln(R/Y)_{it}^{D}$	0.018*	-0.013	-0.016	0.020***
	(0.011)	(0.009)	(0.028)	(0.007)
$lnDTF_{it}$	-0.029	0.047*	0.138	0.069***
	(0.049)	(0.029)	(0.153)	(0.019)
$(R/Y)_{it}^{D} \cdot \ln DTF_{it}$	5.211***	8.192***	-1.837	0.802
	(1.392)	(2.297)	(8.343)	(0.825)
$(M/Y^{n})_{it} \cdot ln(R/Y)_{it}^{F}$	0.034	0.224***	0.109***	0.093***
	(0.028)	(0.017)	(0.035)	(0.006)
$lnFD_{it}$	0.207***		0.123***	
	(0.021)		(0.020)	
$lnSMC_{it}$		0.213***	-0.029	
		(0.035)	(0.139)	
$lnFV_{it}$				-0.017**
				(0.007)
No. of observations	342	588	588	588
Dep. Var. = savings rate	*Panel II: Savings function (Eq. (8))*			
Δlny_{it}	0.007	0.050***	0.451***	0.016***
	(0.014)	(0.007)	(0.078)	(0.005)
$ln\ Age\ dep_{it}$	-0.135***	-0.107***	-0.084*	-0.208***
	(0.020)	(0.005)	(0.044)	(0.015)
$Int\ rate_{it}$	0.004***	0.001***	0.035***	0.001**
	(0.001)	(0.000)	(0.005)	(0.000)
$lnFD_{it}$	0.040***		0.045***	
	(0.008)		(0.016)	
$lnSMC_{it}$		0.008***	0.008	
		(0.001)	(0.013)	
$lnFV_{it}$				-0.085***
				(0.012)
No. of observations	342	588	588	588
Dep. Var. = $ln(I/K)_{it}$	*Panel III: Investment function (Eq. (10))*			
lnq_{it}	0.001***	0.001	0.001	0.001***
	(0.000)	(0.001)	(0.001)	(0.001)
Δlny_{it}	0.045	0.150***	0.129***	0.189***
	(0.035)	(0.018)	(0.019)	(0.014)
$lnFD_{it}$	0.124***		0.023**	
	(0.023)		(0.010)	
$lnSMC_{it}$		0.028***	-0.023	
		(0.005)	(0.015)	
$lnFV_{it}$				-0.053***
				(0.007)
No. of observations	342	588	588	588
Dep. Var. = $ln\ GER_{it}^{secondary}$	*Panel IV: Secondary gross enrollment rates function (Eq. (11))*			
Δlny_{it}	0.150***	0.217***	0.070***	0.043**
	(0.045)	(0.011)	(0.017)	(0.019)
$lnLife_{it}$	0.582***	2.119***	0.024	1.808***
	(0.218)	(0.157)	(0.120)	(0.226)
$real\ int\ rate_{it}$ / 1000	-0.114***	-0.029*	-0.065***	-0.158***
	(0.022)	(0.015)	(0.019)	(0.015)
$lnFD_{it}$	0.104***		0.292***	
	(0.023)		(0.013)	
$lnSMC_{it}$		0.966***	0.174***	
		(0.022)	(0.009)	
$lnFV_{it}$				-0.296***
				(0.034)

No. of observations	337	582	582	582
Dep. Var. = ln $GER_{it}^{tertiary}$	*Panel V: Tertiary gross enrollment rates function (Eq. (11))*			
Δlny_{it}	0.683 (0.470)	-0.449 (0.397)	-0.049 (0.038)	3.611* (1.940
$lnLife_{it}$	11.325*** (3.242)	4.654*** (0.733)	6.469*** (0.119)	7.540*** (2.030)
$real\ int\ rate_{it}$ / 1000	-0.290*** (0.050)	-0.351*** (0.010)	-0.093*** (0.012)	-0.617** (0.258)
$lnFD_{it}$	0.568*** (0.125)		0.562*** (0.015)	
$lnSMC_{it}$		1.570*** (0.108)	0.378*** (0.010)	
$lnFV_{it}$				-0.289*** (0.096)
No. of observations	342	587	587	587

Notes: see notes to Table 2. Schularick-Taylor's indicator of FD is measured as credit to the private sector / GDP for 14 OECD countries over the period 1870-2008. *FD* = credit / GDP; *SMC* = stock market capitalization / GDP; *FV* = stock market volatility. Figures in parentheses are robust standard errors. *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

The stock market capitalization to GDP ratio, *SMC*, is included as the sole FD indicator in the regression in column (2) in Table 8. Stock market capitalization is measured as the value of listed companies on domestic stock exchanges and the data are compiled from various national and international sources. The value of non-residential capital stock is, predominantly, used to backdate and interpolate the missing data. The coefficients of *SMC* are all highly significant and the magnitudes of the coefficients are comparable with the results in the baseline regressions. Furthermore, coefficients of the instruments in the first-round regressions were highly significant and the over-identification tests were all insignificant (results not shown); a result that applies to all regressions in Table 8.

The significance of *SMC* begs the question whether it is a complement or a substitute to the credit-based measure of FD. To investigate this issue the credit-based measure of FD and SMC are included jointly in the regressions in column (3) in Table 8. The coefficient of the credit-based FD is consistently highly significant and, perhaps surprisingly, it has, on average, not lost its economic significance when *SMC* is included in the regressions. The coefficients of *SMC* are significant in the schooling regressions; however, they are insignificant in the ideas production and the savings and investment models, suggesting that bank credit is a more important source of finance compared to the stock market in these cases.

Finally, stock market volatility (*FV*) is included as the FD variable in the regression in the last column in Table 8, where stock market volatility is measured as the standard deviation of monthly stock prices within the year. The coefficients of *FV* are consistently negative and statistically significant showing potential downsides of FD. In other words, a highly developed financial system may be more prone to financial crises, as signified by high stock market volatility. The question is the extent to which stock market volatility reflects malfunctioning of the stock market. From an option-pricing modeling point of view it follows that stock market volatility is increasing in a declining stock market (Black, 1976). The results suggest that capital markets may impinge negatively on drivers of growth in periods of uncertainty such as during the Great Depression, the oil price shocks in 1974-1975 and 1980-1982 and other downturns that have been associated with a deterioration of banks' balance sheets. Quantitatively, stock market volatility has an especially negative impact on GERs, perhaps suggesting that schooling decisions are sensitive to uncertain prospects or that high volatility is associated with deteriorating bank balance sheets that lower the provision of credit.

6.4 Ten-year interval estimates

The models are also estimated using 10-year non-overlapping observations in the first column of Table 9 to check whether the previous results, based on five-year interval data, have been overly influenced by outliers and movements at business cycle frequencies. Note, however, that the SUR regressions require the number of time periods to exceed the number of cross-section units – a requirement that is satisfied in the 5-year interval but not in the 10-year interval regressions. In the 5-year interval regressions we have used a covariance structure that allows for conditional correlation between the contemporaneous residuals for any two cross-sections, but residuals in different periods are restricted to be uncorrelated. This type of covariance structure is commonly referred to as "clustering by period", given that observations for a given period are correlated to form a cluster. In the ten-year interval regressions we cluster by cross section to satisfy the requirement that the number of cross section units must exceed the number of time periods. Specifically, a covariance structure that allows for heteroskedasticity and serial correlation between the residuals for a given cross section is used; however, the residuals in different cross sections are restricted to be uncorrelated.

Common to the instruments in the first-stage regressions in column (1) of Table 9 is that their coefficients are significant and carry consistent signs and the over-identification tests do not indicate that the over-identification restrictions are violated at conventional significance levels (the results are not shown). The coefficient of FD remains consistently highly significant in all models (knowledge production, savings, investment, and secondary as well as tertiary education). Most of the control variables also remain significant. From this it can be concluded that the baseline regression results have not been significantly influenced by the business cycles or outliers that go beyond five-year intervals and that the results are robust to clustering by cross-section as opposed to clustering by period.

6.5 Allowing for disequilibrium in the housing market

The deviation of house prices from their fundamental value, *HPD*, is included as a control variable in the regressions in column (2) in Table 9. This variable is included essentially to counter the effects of potential disequilibria in financial markets on the outcome variables. The almost uninterrupted economic upturn from 1995 to 2008, for example, is often attributed to the asset market run-up, particularly the house price appreciation (Madsen, 2012; The Economist, 2013). Since housing collateral is increasing in house prices it follows that mortgage lending, which is a large proportion of credit to the private sector, may go hand-in-hand with house prices and, consequently, influences the outcome variables through house prices.

Table 9: Other robustness checks

	(1) 10-year averages	(2) Include Tobin's *q* house price deviation	(3) Period I (1870-1938)	(4) Period II (1947-2009)
	Panel I: Knowledge production function (Eq. (7))			
lnA_{it}	0.965***	0.983***	0.965***	0.989***
	(0.006)	(0.006)	(0.003)	(0.006)
$ln(R/Y)_{it}^D$	0.031**	0.008	-0.015	0.037***
	(0.015)	(0.009)	(0.011)	(0.007)
$lnDTF_{it}$	0.017	0.098***	0.040*	0.147**
	(0.051)	(0.028)	(0.023)	(0.067)
$(R/Y)_{it}^D \cdot \ln DTF_{it}$	2.128*	1.134	2.467	-2.634
	(1.276)	(0.986)	(3.213)	(1.750)
$(M/Y^n)_{it} \cdot ln(R/Y)_{it}^F$	-0.051	0.074***	0.105***	0.291***
	(0.049)	(0.015)	(0.029)	(0.063)
$lnHPD_{it}$		-0.057***		
		(0.019)		
$lnFD_{it}$	0.077***	0.115***	0.045***	0.186***
	(0.019)	(0.021)	(0.012)	(0.013)
No. of observations	294	588	294	273
	Panel II: Savings function (Eq. (8))			
Δlny_{it}	0.017***	-0.003	0.026***	0.030**
	(0.003)	(0.005)	(0.009)	(0.012)
$ln\ Age\ dep_{it}$	-0.089***	-0.196***	0.025	-0.201***
	(0.022)	(0.011)	(0.028)	(0.061)
$Int\ rate_{it}$	0.001	0.002**	0.002***	0.003**
	(0.000)	(0.001)	(0.001)	(0.002)
$lnHPD_{it}$		-0.029***		
		(0.010)		
$lnFD_{it}$	0.013**	0.068***	0.014***	0.210***
	(0.006)	(0.010)	(0.005)	(0.005)
No. of observations	294	588	294	273
	Panel III: Investment function (Eq. (10))			
lnq_{it}	0.001	0.001	0.001*	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Δlny_{it}	0.189***	0.137***	0.197***	0.339**
	(0.023)	(0.021)	(0.035)	(0.160)
$lnHPD_{it}$		-0.025		
		(0.039)		
$lnFD_{it}$	0.079***	0.022**	0.044***	0.073***
	(0.005)	(0.011)	(0.003)	(0.015)
No. of observations	294	588	279	252
	Panel IV: Secondary gross enrollment rates function (Eq. (11))			

Δlny_{it}	0.052*** (0.017)	0.033** (0.015)	0.052 (0.057)	0.164*** (0.043)
$lnLife_{it}$	0.920*** (0.242)	1.065*** (0.131)	1.341*** (0.317)	5.358*** (1.648)
$real\ int\ rate_{it}$ / 1000	-0.126** (0.060)	-0.063*** (0.012)	-0.237*** (0.011)	0.864 (1.482)
$lnHPD_{it}$		-0.252*** (0.015)		
$lnFD_{it}$	0.178*** (0.036)	0.323*** (0.011)	0.442*** (0.016)	0.280*** (0.100)
No. of observations	291	582	288	273
	Panel V: Tertiary gross enrollment rates function (Eq. (11))			
Δlny_{it}	0.199*** (0.043)	-0.029 (0.037)	0.279** (0.115)	0.209*** (0.065)
$lnLife_{it}$	3.104*** (0.572)	2.685*** (0.078)	-1.129 (1.075)	6.814*** (1.212)
$real\ int\ rate_{it}$ / 1000	-0.434*** (0.077)	-0.374*** (0.010)	-0.263*** (0.062)	-0.463** (0.210)
$lnHPD_{it}$		0.291*** (0.037)		
$lnFD_{it}$	1.594*** (0.171)	1.085*** (0.023)	0.306*** (0.088)	0.797*** (0.090)
No. of observations	294	587	293	273

Notes: See notes to Table 2. "Culture" is measured as the marriage rate whereas "Openness" is measured as the ratio of imports to GDP, and *HPD* is the deviation of house prices from their fundamental value. Figures in parentheses are robust standard errors. *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

To cater for that we include the deviation of house prices from their fundamental value in the regressions, noting that the deviations of stock prices from their fundamental value are not considered because they are already included as Tobin's *q* in the investment regressions (see, for discussion of fundamental value of stocks, Madsen and Davis, 2006). The fundamental value of house prices is measured by the building deflator under the hypothesis that the fundamental value of replaceable assets is determined by acquisition costs (see, for exposition, Madsen, 2012).

The coefficients of FD remain statistically highly significant in all the regressions and their magnitude remains close to those in the baseline regressions when the deviation of house prices from their fundamental values, *HPD*, is included as a control variable. *HPD* is significant in the regressions except for the investment function. Ideas production may be negatively related to *HPD* because talents are driven into the financial sector during asset price booms. Savings are probably negatively affected by *HPD* because home owners feel wealthier when house prices exceed their equilibrium and realign their consumption to their permanent income, and because myopic consumers increase their consumption when lending standards are lenient during house price booms. Secondary schooling is negatively related to *HPD*, whereas tertiary education is positively related to *HPD*. A possible explanation for the latter finding is that financially constrained parents of would-be students use home equity collateral to finance their children's tertiary education, and that tertiary education, at least to some extent, is a luxury good. Why the coefficient of *HPD* is negative in the secondary education regression is more difficult to explain and this may reflect some spurious correlations.

6.6 Pre- and post-WWII regressions

Covering a period of 140 years renders it likely that there have been structural changes in the relationship between FD and the outcome variables. Patrick (1966), for example, argues that the supply side is the dominant force behind FD in early stages of industrialization while demand becomes a more important factor as the economy develops. To investigate this issue the baseline models are regressed in the *pre*- and *post*-WWII periods. WWII marks a period in which growth rates start increasing as a consequence of structural changes in OECD economies and a surge in educational attainment and innovative activity. The regression results are reported in the last two columns in Table 9. The coefficients of FD are all highly significant and have the expected signs in both periods; however, the magnitude of the coefficient of FD is higher in the *post*-WWII regressions than in the *pre*-WWII regressions, except for secondary gross enrollment. This difference may partly reflect an attenuation bias in the *pre*-WWII estimates because the data quality deteriorates as we go back in time and partly be a manifestation of stronger economic effects of FD in the *post*-WWII period as credit has become a more vital part of economic development. For example, increasing relative costs of innovation and schooling because of slow productivity advances in these sectors and the fact that innovations have become increasingly complicated have rendered schooling and innovation more dependent on credit.

7. Simulations

Thus far we have been concerned only about the quantitative effects of FD on the outcome variables and have not considered the contribution of FD to productivity growth through different channels to gain insight into their relative importance for growth. This section simulates the productivity growth effects of FD through ideas production, savings, and secondary and tertiary education. For this purpose Eq. (4) is used; however, Eq. (4) cannot be used as it stands because a direct mapping between labor productivity growth ($g_{Y/L}$) and the right-hand-side variables (g_A, $g_{K/Y}$ and *sc*) is lacking. Specifically, 1) patent counts do not directly measure g_A and, therefore, a mapping needs to be estimated; 2) $g_{K/Y}$ can be derived from the Solow model; 3) the social returns to schooling (θ) needs to be estimated; and 4) *sc* needs to be derived from GERs. The growth effects of investment are not considered because they will be accounted for through the saving function and the principal results are insensitive to whether the investment or saving functions are used in the simulations. The output effects through each channel are computed as follows.

Ideas production. The coefficients of FD in the regression output reported in Table 2 are used to simulate the effects of FD on ideas production. The coefficient of patent stock in the productivity regressions of Madsen (2007) is used to find a mapping between ideas production and productivity growth. Based on Madsen's (2007) preferred estimates in columns (1) and (5) of Table 1, the average estimate for patent stock of 0.11 is used. Thus, the growth effect of FD is given by:

$$\left.\frac{dln(Y/L)}{dln\,FD}\right|_{\dot{A}^D} = \frac{dln(Y/L)}{dln\,\dot{A}^D} x \frac{dln\dot{A}^D}{dlnFD} = 0.11\hat{\alpha}_6, \tag{13}$$

where $\hat{\alpha}_6$ is the coefficient of $lnFD$ in the ideas production function (Eq. (7)). Simulations are first carried out for the credit-GDP, bank asset-GDP or money-GDP ratios and their associated estimates of $\hat{\alpha}_6$ (columns (2) to (4) in Table 2) individually and the unweighted average is then estimated.

Savings. The Solow model is used to gauge the saving effects on productivity growth. Based on the Cobb-Douglas production function given by Eq. (1) without educational attainment the Solow model yields the steady-state per capita income of:

$$\frac{Y}{L} = \left(\frac{s}{n+g+\delta}\right)^{\alpha/(1-\alpha)} = \left(\frac{s}{n+g+\delta}\right)^{1/2}, \tag{14}$$

where *n* is the population growth rate; g is the growth in labor augmenting technological progress; and δ is the depreciation rate for fixed capital. Capital's income share, α, is set to 1/3, following the standard practice in the literature. Differentiating the logs of (Y/L) with respect to FD using the chain rule and inserting these numbers yield the effects of FD on labor productivity through savings as follows:

$$\left.\frac{dln(Y/L)}{dln\,FD}\right|_{S} = \frac{dln(Y/L)}{ds}\cdot\frac{ds}{d\ln FD} = \frac{1}{2}\left(\frac{s}{n+g+\delta}\right)^{-1}\left(\frac{1}{n+g+\delta}\right)\frac{ds}{d\ln FD} \cong \frac{1}{2\bar{s}}\frac{ds}{d\ln FD} = \frac{1}{0.23}\hat{\gamma}_4, \tag{15}$$

where $\hat{\gamma}_4$ is the coefficient of $lnFD$ in the estimates of the savings models and $\bar{s}$ is the sample mean and is estimated to be 11.5% in our sample (private saving rate over the period 1870-2009 for the OECD countries). Simulations are first carried out for the credit-GDP, bank asset-GDP or money-GDP ratios and their associated estimates of $\hat{\gamma}_4$ (columns (2) to (4) in Table 3) individually and an unweighted average is then estimated.

Schooling. The effect of financial development on productivity growth through the channel of education is given below:

$$\left.\frac{dln(Y/L)}{dln\,FD}\right|_{GER^X} = \frac{dln(Y/L)}{dlnsc}\cdot\frac{dlnsc}{dlnGER^X}\cdot\frac{dlnGER^X}{dlnFD} = 0.308\frac{dlnsc}{dlnGER^X}\hat{\lambda}_4, \tag{16}$$

where *sc*, as defined above, is educational attainment of the working age population. The point estimate of Madsen (2014) is used to find $dln(Y/L)/dlnsc$, where the coefficient of the *level* of educational attainment is estimated to be 0.041. This yields an average elasticity of human capital of $7.51 \cdot 0.041$ = 0.308, where 7.51 is the average educational attainment in the OECD countries considered in this paper over the period 1870-2009. Simulations are first carried out for the credit-GDP, bank asset-GDP or money-GDP ratios and their associated estimates of $\hat{\lambda}_4$ (columns (2) to (4) in Tables 5 and 6) individually, and then the unweighted average is used in the simulations.

The $dlnsc/dlnGER^X$ term can either be computed as the steady-state effect of GERs on education or estimated by allowing for the dynamic adjustment of *sc* to changes in GERs. The steady-state effect can be computed as follows. For the regressions in Tables 5 and 6, for example, the coefficient of $lnFD$ for the regressions in columns (2) to (4) is, on average, 0.321 for secondary schooling and 1.444 for tertiary education. Since the number of years of schooling at the secondary and tertiary levels is five years in most OECD countries it follows that educational attainment increases by $5 \cdot (0.321 + 1.444)$ for each percentage increase in FD in the steady state. While this method is a good approximation over long periods it is not adequate for short time intervals because of the time lag between entering into education and being in the labor market. Furthermore, some of the graduates die before they reach the pension age of 65. Therefore, we use the following method that allows for dynamic adjustment.

The dynamic effect of changes in GERs on educational attainment, which is derived by Madsen (2014), is computed for secondary education as follows:

$$sc_t^{Sec} = \frac{\sum_{i=0}^{49}\left\{Pop_{15+i}\sum_{j=13}^{17} GER_{t-i+j}^{S}\right\}}{\sum_{a=15}^{64} Pop_t^a}, \tag{17}$$

where sc^{Sec} is secondary educational attainment, Pop^a is the size of the population at the age cohort *a*, Pop_{15+i} is the size of the age cohort *i* starting at the age of 15, *j* is the school grade, and 17 is the maximum schooling age for secondary schooling. From this model it follows that the secondary educational attainment for the 64 year age cohort in 1870 is the sum of GERs in secondary school during the period 1818-1822. Eq. (17) can be readily implemented for tertiary educational attainment, sc^{Ter}, with *j* = 18-22.

The simulations of Eq. (16) are carried out as follows. First, the influence of FD on GERs is computed and the effects of the changes in GERs on educational attainment are calibrated using Eq. (17). Data on FD are constructed back to 1818 because it is the year when the oldest working age cohort in 1870 started secondary schooling. Finally, the growth effects are estimated by multiplying the FD-induced increase in educational attainment by 0.308.

Table 10: Simulations of averages of all models

Period	1	2	3	4	5	6	7
	Ideas production	Savings	GER^S	GER^T	Total	Actual $g_{Y/L}$	*Actual* $g_{Y/Pop}$
1870-1914	0.260	0.260	0.008	0.028	0.556	1.442	1.224
1914-1950	0.400	-0.004	0.008	0.041	0.446	1.852	1.279
1950-2009	0.579	0.223	0.002	0.010	0.814	2.617	2.422
1870-2009	0.432	0.176	0.005	0.024	0.638	2.047	1.747

Notes. The numbers are annual geometric growth rates in percentages and unweighted averages for all countries. The first four columns are the productivity growth attributed FD through ideas production, savings, and gross enrollment at secondary (GER^S) and tertiary (GER^T) levels. The sum of the first four columns is reported in column 5 (Total). Actual productivity growth rates are reported in columns (6) and (7), where $g_{Y/L}$ is the growth in labor productivity (GDP divided by hours worked per year and employment) and $g_{Y/Pop}$ is the growth in per capita GDP. The simulations are based on the regressions in the columns (2) to (4) in Tables 2 (ideas production), 4 (investment), 5 (secondary GERs) and 6 (tertiary GERs).

The simulation results are reported in Table 10 for the sub-periods 1870-1914, 1914-1950, and 1950-2009 and the entire period 1870-2009. The figures are average annual growth rates in percentages. The first four columns show the contribution of FD to average productivity growth through ideas production, savings, and secondary and tertiary education. The quantitatively most significant channel through which FD affects growth is ideas production, followed by savings and education. In this connection, our results are consistent with Beck *et al.* (2000), who find a strong link between finance and productivity but a weak correlation between finance and capital accumulation, but less consistent with King and Levine (1993) and Benhabib and Spiegel (2000) who find that financial development is strongly associated with capital accumulation.

The growth effect of FD through ideas production is positive even in the period 1914-1950 during which FD was decreasing because it is the level of FD and not the growth in FD that is relevant for ideas production. Nor is the contribution through the educational channel negative in this period because of the time-lag between GERs and educational attainment. The overall contribution to growth through the educational channel is lower than the steady-state effects because the marked FD-induced increase in GERs since 1950 has not yet been fully borne out.

The overall growth effects of FD, which are presented in column (5), have been significant, particularly in the period 1950-2009 when FD contributed 0.81% to growth whereas the contribution was lower at 0.64% in the overall period 1870-2009. Of the actual growth rates displayed in column (6) (labor productivity) and column (7) (per capita income), FD explains between 31% and 37% of the actual growth rates, respectively, suggesting that FD has been influential for growth over the past 140 years. Even if FD remains at its average 1950-2009 level in the future, it will perpetually contribute 0.58% growth through ideas production in addition to the lagged effects from the increasing FD-induced GERs that will last over the next 51 years.

8. Conclusions

Based on a newly constructed dataset for OECD countries over the past 140 years this paper has tested the channels through which FD influences growth. Data for OECD countries were used because they are available far back in time, thus ensuring that the parameter estimates are not driven by unobserved cross-country heterogeneity – a paramount problem when the African countries are included in cross-section data samples. Ideas production, savings, investment, and schooling were examined as the principal transmission channels, following the predictions of endogenous growth models. Previous research on FD has almost entirely focused on savings and investment and has not paid much attention to human capital and R&D although these are the fundamental drivers of growth in endogenous growth models.

Unionization and agricultural share were used as instruments for FD since they are highly correlated with FD, have the signs in line with our predictions, and satisfy the exclusion restrictions. Credit to the private sector, broad money, bank assets, stock market total value traded, stock market capitalization and stock price volatility were used to construct measures of FD to ensure that the results were not sensitive to the choice of our FD indicator.

The results showed that FD is a highly significant determinant of growth through ideas production, savings, investment, and secondary and tertiary gross enrollment rates. Sensitivity analysis showed that the results were extraordinarily robust to exclusion of any of the two instruments from the first-stage regression, change in estimation period, various alternative estimators (OLS, system GMM, and 3SLS), estimates in 10-year intervals as opposed to regressions in five-year intervals, allowance for the influence of secular deviations in house prices from their long-run equilibrium, and using the data on FD by Schularick and Taylor (2012). From this it can be concluded that FD has been influential for economic development through its different phases in OECD countries since the onset of the Second Industrial Revolution.

One of the most important contributions of the paper is that it shows that FD has been a driving force behind ideas production as well as secondary and tertiary education. The finding of positive effects of FD on gross enrollment rates implies that productivity growth is affected by FD, with a considerable time lag through this channel, since schooling first influences productivity when a student cohort joins the workforce – an effect that is difficult to capture in standard growth regressions. Second, the findings of significant effects of FD on ideas production and constant returns to ideas production reinforce the evidence of permanent growth effects of FD found in almost all of the literature on finance and growth. Furthermore, simulations showed that ideas production has been the most important channel through which FD has been transmitted to growth over the past 140 years and that it has contributed 0.43% to the average annual growth rate in the

OECD countries over the same period; well above the 0.18% contribution from savings. These findings suggest that ideas production should take a central place in the discussion of the nexus between FD and growth, as opposed to investment and savings since neither of these have any permanent growth effects.

Data Appendix (Not for Publication)

R&D. The data do not exist for every year for most countries. The data are interpolated as follows: The ratio of R&D to nominal GDP is interpolated geometrically and R&D is recovered by multiplying by the interpolated ratio of R&D to nominal GDP by nominal GDP. The data are backdated using the ratio of R&D to nominal GDP as follows: The data are spliced with the average R&D/Y-ratio for the countries for which the data are available. All countries 1963-1980: OECD Archive (OECD -DSTI/EAS) Contact: Elena Bernaldo de Quirós- elena.bernaldo@OECD.org. 1981-2009: OECD, Main Science and Technology Indicators, various years. Before 1962 for individual countries. USA. 1921-1952. Terleckyj, Nestor E. 1963 *Research and Development: Its Growth and Composition.* National Industries Conference Board Studies in Business Economics, No. 82. New York: The Board. 1953-2009. National Science Foundation. Japan. Historical Statistics of Japan, Statistics Bureau and Statistical Research and Training, Institute, Ministry of Internal Affairs and Communication (http://www.stat.go.jp/english/data/chouki/index.htm). Australia. 1940-1964. Table ES 249-257. In Vamplew, W. (1987). *Australians, Historical Statistics*. Fairfax, Syme and Weldon Associates: New South Wales; 1921-2007, HMD. Netherlands. 1959-1972: Statistics Netherlands, Contact: Ferry Lapré at infoservice@cbs.nl. Germany. 1870-1970. Frank R Pfetsch, 1985, Datenhandbuch zur Wissenschaftsentwicklung, Köln: Zentrum für historische Socialforschung. Spain. 1870-1970. Aracil, J and J L Peinado, 1976, "Classification funcional de los gastos del estado (1850-1965)," in Valentin Fernandez Acha (ed.) Datos Basicos para la Historia Financiera de Espana (1850-1975). Madrid: Instituto de Estudios Fiscales.

TFP. See Madsen, J. B. (2008), "Semi-endogenous versus Schumpeterian Growth Models: testing the knowledge production function using international data." *Journal of Economic Growth*, 13(1), 1-26.

Imports. See Madsen, J. B. (2009), "Trade Barriers, Openness, and Economic Growth." *Southern Economic Journal*, 76(2), 397-418.

Construction costs. See Madsen, J. B. (2012), "A Behavioral Model of House Prices." *Journal of Economic Behavior and Organization*, 82, 21-38.

House prices. See Madsen, J. B. (2012), "A Behavioral Model of House Prices." *Journal of Economic Behavior and Organization*, 82, 21-38.

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Age dependency rates. Population of ages below 15 or below the age at which they leave the educational system and above the age of 64 divided by population between 15 and 64 years of age as follows:

$$Age_{it} = \frac{1 - Pop_{it}^{15-19}\left(1 - GER_{it}^{S} - 0.5 * GER_{it}^{T}\right) - Pop_{it}^{20-25}\left(1 - 0.5 * GER_{it}^{T}\right) - \sum_{j=25-29}^{60-64} Pop_{it}^{j}}{Pop_{it}^{15-64}},$$

where Pop^j is the proportion of the population that is in the age cohort j, GER^S is gross enrollment rates in secondary schooling, and GER^T is gross enrollment rates in tertiary schooling. For data sources see Madsen,

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Stock prices, stock price volatility and stock market capitalization. **Annual Share Price Indices.** The main source for the share price data is OECD, Main Economic Indicators, Share Prices, Index (2005=100) (online data retrieved on 01 November, 2011) and the MSCI website online data also retrieved on 01 November 2011. The data was updated from 2009-2010 by forward splicing using OECD main Economic Indicator share price data. Backdating was done by splicing with a country that has a closely correlated data trend. Where available, individual country data sources were used as follows: **Australia:** 1870-1874, spliced using the UK. **Austria:** 1870-1921, spliced using Belgium. **Belgium**: 1831-1914 data is from Annaert, Bulens and Ceuster (2012); 1914-18, spliced using France **Canada**: 1870-1914, spliced using USA; 1915-56 from Urquhart and Buckely (1965). 1956-2002 is from the Canadian Economic Observer, http://www5.statcan.gc.ca/bsolc/olc-cel/olc-cel?catno=11-010-X&chropg=1&lang=eng, accessed on 10 October 2012. **Denmark:** 1870-1874 is from Abildgren (2006); 1875-2005, Danmarks Nationalbank. **Finland:** 1870-1921, spliced using Denmark; **Germany:** 1870-1992 is from Gielen (1994), data for December each year. The series is multiplied by 10 before 1948 to take into account the money reform that replaced the old Reismark with a new DEM at 1:10. Data for 1919-1923 was subsequently growth interpolated due to the hyperinflation. **Greece:** 1870-1927, spliced using Italy. **Ireland:** 1870-1913 is from Hickson and Turner (2005); 1914-1933 was backdated by splicing using UK**. Italy**: 1870-1898 spliced using France; 1899-1978 is from Panetta and Violi (1999); 1979-1999 from Global Finance Database; **Japan:** 1870-1912 spliced using UK. **Netherlands:** 1870-1918, spliced using UK. **New Zealand:** 1870-1925, spliced using Australia. **Norway:** 1870-1916, spliced using Sweden. **Portugal:** 1870-1928, spliced using Spain. **Spain:** 1870-1873, spliced using UK. **Sweden:** 1870-1900 spliced using Denmark; 1919-1989 Frennberg and Hansson (1992). **Switzerland:** 1870-1909 spliced using Belgium; 1910-1971 is from Blickenstorfer, (1996). **United Kingdom:** 1870-1913, Grossman (2002); 1914-2000 is from Barclays Capital (2012). The stock price volatility was computed as the 12-monthly standard deviation of the share price index. The Share Prices Index data up to 2012 is sourced from OECD, Main Economic Indicators, online data, http://stats.oecd.org/BrandedView.aspx?oecd_bv_id=mei-data-en&doi=mei-data-en, retrieved on 30 October, 2012. Norway is backdated from 1914:1 to 1917:12 using http://www.norges-bank.no/en/price-stability/historical-monetary-statistics/stock-price-indices/, assessed on 26 November 2013. Ireland is also backdated to 1870 using Grossman, et al (2013). All gaps in the data are growth interpolated.

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