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Financial architecture and the source of growth

International evidence on technological change

L. Giordano, C. Guagliano

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luglio 2014

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Stampa e allestimento
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www.tiburtini.it

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ISSN 2281-1915 (online)
ISSN 1121-3795 (stampa)

Architettura finanziaria e progresso tecnico

Un'analisi empirica dei paesi OCSE

L. Giordano, C. Guagliano***

Sintesi del lavoro

Il legame tra sviluppo finanziario e crescita economica é stato storicamente al centro dell'analisi economica che ha cercato di indagare in che misura l'ampiezza e la profondità del sistema finanziario (la sua "dimensione") abbiano favorito e tuttora favoriscano la crescita economica. Più recentemente l'indagine empirica ha adottato un approccio più ampio di quello meramente "dimensionale", investigando la superiorità del sistema finanziario orientato al mercato (*market-oriented*) in alternativa a quello tradizionalmente orientato agli intermediari (*bank-oriented*) nel promuovere la crescita economica.

Questo lavoro – superando la tradizionale dicotomia tra sistema finanziario *market-oriented vs bank-oriented* – indaga il legame tra le più ampie caratteristiche morfologiche del sistema finanziario ("*financial architecture*") di un campione di Paesi OCSE e uno dei principali *driver* della crescita economica, ovvero il progresso tecnico ("*technological change*").

I risultati mostrano che sistemi finanziari (i) più orientati al mercato, (ii) con una maggior presenza di banche straniere, (iii) più concorrenziali, ovvero meno concentrati e con *spread* bancari più contenuti, (iv) con una maggior propensione delle imprese a quotarsi e (v) con mercati azionari meno volatili, sono caratterizzati da tassi di progresso tecnico superiore a quello sperimentato da Paesi con sistema finanziari ugualmente sviluppati ma privi di queste caratteristiche.

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Si ringraziano Adriano Giannola, Alberto Pozzolo e Domenico Sarno per gli utili commenti. Errori e imprecisioni sono imputabili esclusivamente agli autori. Le opinioni espresse nel lavoro sono attribuibili esclusivamente agli autori e non impegnano in alcun modo la responsabilità dell'Istituto. Nel citare il presente lavoro, non è, pertanto, corretto attribuire le argomentazioni ivi espresse alla Consob o ai suoi Vertici.

Financial architecture and the source of growth

International evidence on technological change

Luca Giordano, Claudia Guagliano***

Abstract

While a large body of literature argues that financial intermediaries exert a causal impact on long-run growth, it doesn't investigate the links between financial architecture and technological change (as primary source of growth). We seek to shed light on these links by exploring the relationship between financial architecture (thus not only financial development) and what is assumed to be one of the main drivers of economic growth: the technological change (TC). We apply the stochastic frontier approach (SFA) in order to estimate and decompose total factor productivity growth (TFP) into its main components: efficiency change and technological change (TC). As a second step we regress the technological change (TC) on a set of variables capturing the financial characteristics ("*financial architecture*") of a sample of OECD countries in order to identify which features of the financial system affect the country's rate of technological change.

Our results confirm that better functioning financial systems – i.e. more market oriented, open and competitive – improve resource allocation and accelerate the country's rate of technological change with positive impact on long-run economic growth.

JEL Classifications: F3, F43, G1, G15.

Keywords: financial structure, economic growth, technological change, stochastic frontier analysis (SFA), total factor productivity (TFP).

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We wish to thank Adriano Giannola, Alberto Pozzolo and Domenico Sarno for very helpful comments on a previous draft, though the responsibility for any mistakes and for the opinions expressed remains our own. The ideas and positions in the paper are personal views of the authors and cannot be attributable to Consob.

Contents

1 Introduction

Joseph Schumpeter argued in 1911 that financial intermediaries play a pivotal role in economic development because they choose which firms get to use society's savings (see Schumpeter, 1934). According to this view, the financial intermediary sector alters the path of economic progress by affecting the allocation of savings and not necessarily by altering the rate of savings. Thus, the Schumpeterian view of finance and development highlights the impact of financial intermediaries on productivity growth and technological change (TC). Alternatively, a vast development economics literature argues that capital accumulation is the key factor underlying economic growth[1]. According to this view, better financial intermediaries influence growth primarily by raising domestic savings rates and attracting foreign capital. Thus, while many theories note that financial intermediaries arise to ameliorate particular market frictions, the resulting models present competing views about the fundamental channels which connect financial intermediaries to growth (*capital accumulation* vs. *technological change*).

There are two general ambiguities between economic growth and the emergence of financial arrangements that are expected to increase the national savings rate (by improving resource allocation and reducing risk). Specifically, higher returns ambiguously affect saving rates due to well-known income and substitutions effects. Similarly, lower risk also ambiguously affects savings rates (Levhari and Srinivasan, 1969). Thus, financial arrangements that improve resource allocation and lower risk may lower saving rates. In a growth model with physical capital externalities therefore, financial development could retard economic growth and lower welfare if the drop in savings and the externality combine to produce a sufficiently large effect. Thus, if finance is to explain economic growth, we need theories that describe how financial development influences resource allocation decisions in ways that foster productivity growth and not aim the analytically spotlight too narrowly on aggregate savings.

Moreover, different measures of financial intermediary structure yield different conclusions regarding the link between financial intermediary development and private savings, thus there is not a robust relation between financial intermediary development and either physical capital accumulation or private savings rates. In sum, our question is consistent with the Schumpeterian view of finance and development: do financial intermediaries affect economic development primarily by influencing total factor productivity growth (via *technological change*)?

One way financial intermediaries promote the identification of the best production technologies is by reducing the costs of acquiring and processing information on entrepreneurial projects. Financial intermediaries may also boost the rate of technological change by identifying those entrepreneurs with the best chances of suc-

1 Traditional finance theory focuses on cross-sectional diversification of risk. Financial systems may mitigate the risks associated with individual projects, firms, industries, regions, countries, etc. Banks, mutual funds, and securities markets all provide vehicles for trading, pooling, and diversifying risk. The financial system's ability to provide risk diversification services can affect long-run economic growth by altering resource allocation and savings rates.

cessfully initiating new goods and production processes (Galetovic, 1996; Blackburn and Hung, 1998; Morales, 2003; Acemoglu et al 2006). This lies at the core of Joseph Schumpeter's view of finance in the process of economic development.

The next important step in the research agenda involves delving deeper into the micro details governing the actual functioning of the finance-growth nexus. Beyond a black-box characterization of the financial sector, implicit in focusing on its relative size only, there is a much more complex web of banks and other institutions interacting in the credit markets. The various attributes of such a system are likely to have a qualifying impact on the finance-growth relationship. The "architecture" of financial industry, reflecting mainly its ability of processing information, is, in our opinion, one such attribute[2].

In our research we try to get new empirical evidence on the relationship between the features of a country's financial system – what we called *financial architecture* (FA) – and the rate of *technological change* (TC)[3]. Technological change is a primary source of growth as it refers to the innovation capability of an economic system and therefore it implies a long-run growth rate more connected to the country's structural characteristics.

Our approach, instead of the classical one focused on the relationship between financial development and growth, is better suited to overcome the unavoidable problem of endogeneity, i.e. the degree to which the financial development consequences of growth have feedback impacts on growth[4]. To tackle these crucial issues we follow an innovative approach and go beyond the historically debated relation between finance and growth, focusing on the impact of *financial architecture* (FA) on the most important determinant of growth, i.e. *technological change* (TC). Doing this, we address the key determinant of growth: technological progress crucially determines the success of an economy. There is a lot of empirical evidence showing clearly that economies characterized by higher level of technological progress have generally more competitive and globalized companies and, as a result, higher GDP growth rates and lower unemployment levels[5]. This is particularly important for mature economies of advanced countries challenged by the competition from emerging markets.

2 A large theoretical literature shows that financial intermediaries can reduce the costs of acquiring information about firms and managers and lower the costs of conducting transactions. By providing more accurate information about production technologies and by exerting corporate control, better financial intermediaries can enhance resource allocation and accelerate growth (Boyd and Prescott 1986; Greenwood and Jovanovic 1990; King and Levine 1993). Similarly, by facilitating risk management, improving the liquidity of assets available to savers, and reducing trading costs, financial intermediaries can encourage investment in higher-return activities (Obstfeld 1994; Bencivenga and Smith 1991; Greenwood and Smith 1997).

3 *Technological change* (TC) is also referred to as "technical change" or "technological innovation".

4 A tool we used to alleviate the classical endogenous problem in estimating the causal link between finance and growth is that we decompose the TFP into its main components (efficiency and technical change) and then use as a dependent variable of our second step regression the technical change which is less affected by feedback impact stemming from growth (as on the contrary is more plausible for the efficiency residual).

5 While separating and accounting for the different factors behind economic growth is complex, Jorgenson et al. (1987) claim that between 1948 and 1979, capital formation accounted for 46% of the economic growth in the United States. Labour growth accounted for 31% and technical change accounted for 24%.

Research that clarifies our understanding of the role of finance in economic growth has strong policy implications. Information about the impact of finance on economic growth will influence the priority that policy makers and advisors attach to reforming financial sector policies. Furthermore, convincing evidence that the financial system influences long-run economic growth will advertise the urgent need for research on the political, legal, regulatory, and policy determinants of financial development.

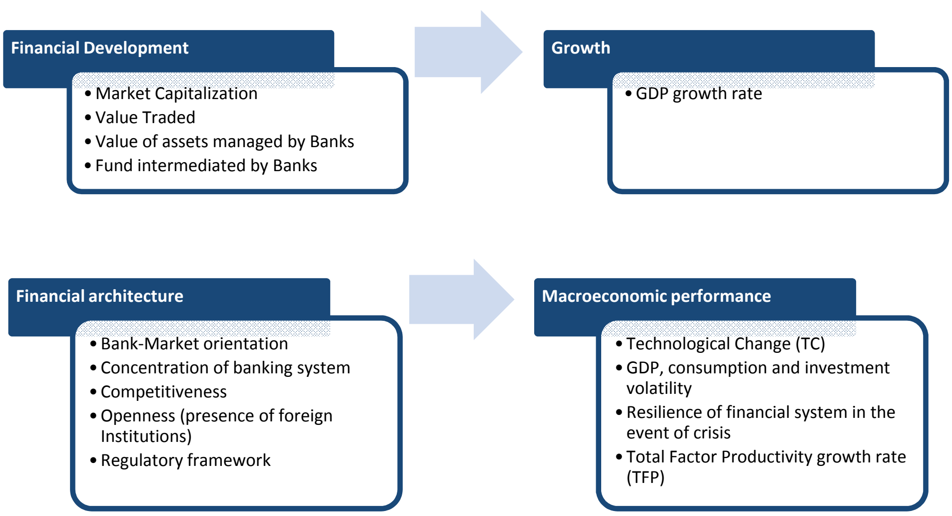
Our results show that more competitive, inclusive and open financial markets promote innovation and technological change.

The paper is organized as follows. Section 2 describes the related literature and develops our hypotheses. In Section 3 we explain the methodology while in Section 4 we show our dataset. The empirical results are described in Section 5 and Section 6 concludes.

2 Literature review

In the next two subsections we review the main contributions on the link between finance and growth taking into account that there are two main paradigms used by theoretical literature. The first one focuses on the causal link between *financial development* (proxied by the size of financial system, e.g. capitalization, volume traded, assets managed by banks, fund intermediated, etc.) and *growth* (proxied by GDP growth rate or equivalent measures). The second one, which is ours, investigates if different features of financial system (what we called *financial architecture*, i.e. the market-bank orientation and other aspects of financial system) affect the countries' macroeconomic performance (which encompasses not only the GDP growth but also others aspects such as the volatility of growth, the innovation and competitiveness of economic systems, the country's *technological change*, etc.).

Finance-Growth Nexus



2.1 Financial development and growth

Significant empirical researches in finance and growth have established that financial development has a positive impact on economic growth[6]. The consensus on the finance-growth link has ignited a renewed interest in the historic debate of whether a nation's *financial architecture* – i.e., very briefly, the degree to which the financial system is market or bank oriented, – matters to its long-run economic growth, and in particular, in fostering innovation and technology. The theoretical debate on both sides of the issue is strong, and the available evidence is both anecdotal and mixed.

The major strand of empirical papers has historically contributed to the line of research on financial intermediation and growth. Following the original contributions by Gurley and Shaw (1967), Goldsmith (1969), McKinnon (1973) and Shaw (1973), economists in recent years have returned to this problem.

King and Levine (1993) show that cross-sectional risk diversification – induced by financial development – can stimulate innovative activity. Agents are continuously trying to make technological advances to gain a profitable market niche. Engaging in innovation is risky, however. The ability to hold a diversified portfolio of innovative projects reduces risk and promotes investment in growth-enhancing innovative activities (with sufficiently risk averse agents). Thus, financial systems that ease risk diversification can accelerate technological change and economic growth.

Also using cross-country regression analysis, Levine and Zervos (1998) make an important refinement by showing the joint, independent relevance for growth of both banks and capital markets. Demirguc-Kunt and Maksimovic (1998) use instead firm-level data and show, in a cross-country study, that, where the legal system is more developed, firms have greater access to external funds, which in turn allows them to grow faster.

Meanwhile, Rajan and Zingales (1998) represent an innovative contribution to the field by focusing on a cross-industry, cross-country analysis. First, they construct a measure of the dependence on external finance of a wide range of industrial sectors, in which differences among sectors depend mainly on technology-specific factors. Second, they test whether industries that are more dependent on external finance grow faster in countries that are more financially developed. They find that this is indeed the case, thus providing evidence confirming the overall importance of financial development on growth.

In terms of the links between legal origin and financial intermediary development, a growing body of evidence suggests that legal origin affects the shaping of financial development. La Porta et al. (1998) show that the legal origin of a country materially influences its legal treatment of shareholders, the laws governing creditor rights, the efficiency of contract enforcement, and accounting standards. Shareholders and creditors enjoy greater protection in common law countries than in civil law

6 Financial development indicators are measures of how well financial intermediaries select firms, monitor managers, mobilize savings, pool risk, and ease transactions.

countries. French Civil Law countries are comparatively weak both in terms of shareholder and creditor rights. In terms of accounting standards, countries with French legal origin tend to have company financial statements that are comparatively less comprehensive than the company financial statements in countries with other legal origins. Statistically, these legal, regulatory and informational characteristics affect the operation of financial intermediaries, as shown in La Porta et al. (1997), Levine (1998, 1999), and Levine et al. (2000).

2.2 Financial structure and macroeconomic performance

In considering the importance of financial structure for economic growth economists have tended to focus on whether bank-based or market-based financial systems are more conducive to growth with inconclusive results. Beck et al (2000) test four theoretical alternative views on financial structure: 1) the bank-based view highlights the positive role of banks in mobilizing resources, identifying good projects, monitoring managers and managing risks and highlights the comparative shortcomings of market-based systems; 2) the market-based view highlights the positive role of markets in promoting economic success, facilitating diversification and the customization of risk management devices; 3) the law and finance view argues that the legal system is the primary determinant of the effectiveness of the financial system in facilitating innovation and growth and rejects the entire bank-based versus market-based debate; 4) finally, the financial services view stresses that financial systems provide key financial services that are crucial for firm creation, industrial expansion and economic growth, while the division between banks and markets in providing these services is of secondary importance. Using three different methodologies (cross-country, industry and firm-level approach), they find that financial structure does not help in understanding economic growth, industrial performance or firm expansion. Therefore, their results are inconsistent with both the market-based and bank-based views, while they are consistent with both the financial services and the law and finance views. We find the same results in Levine (2002): after controlling for the overall level of financial development, information on financial structure (always limited to whether the system is bank-based or market-based) does not help in explaining cross-country differences in financial development.

Tadesse (2007), however, using a cross-country approach, argues that while market-based systems outperform bank-based systems among countries with developed financial sectors, bank-based systems are far better among countries with underdeveloped financial sectors.

Another strand of literature, following the influential paper of Rajan and Zingales (1998), employs industry-level data to test the hypotheses that financial market development should be more beneficial to the growth of industries that are more dependent on external finance. They find that measures of financial development do indeed affect economic growth disproportionately in externally dependent industries. Beck and Levine (2002) confirm that greater financial development accelerates the growth of financially dependent industries; financial structure *per se*, however, does not help to explain the different growth rates of financially-dependent industries across countries. Carlin and Mayer (2003) examine the relation between the institutional structures of advanced OECD countries and the comparative growth and investment of 27 industries in those countries over the period 1970-1995. They find a strong relation between the structure of countries' financial systems, the characteristics of industries, and the growth and investment of industries in different countries.

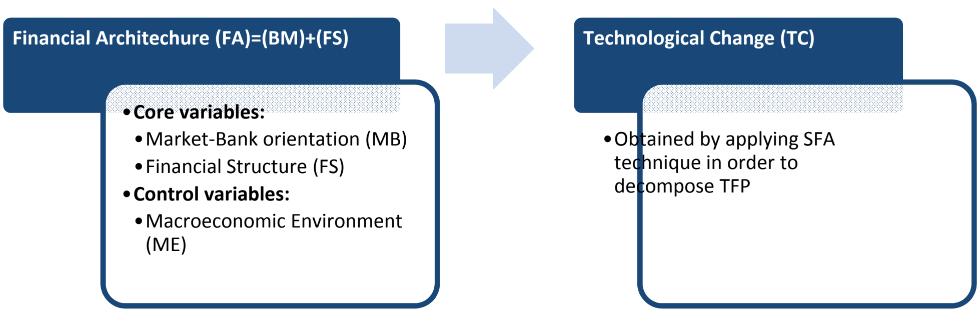
Some recent papers have tried to widen the concept of financial structure, going beyond the traditional division between bank-based and market-based systems. Gole and Sun (2013) enlarge the definition of financial structure using data for four concepts: competition, financial buffers, financial globalization and non-traditional bank intermediation. They use some measurements of financial structure and relate them to four indicators of economic outcomes: the growth of real GDP per capita, the volatility of real growth, financial stability and income inequality. They find that some financial intermediary structures are likely to be more closely related to positive economic outcomes than others. For instance, protective financial buffers within institutions have been associated with better economic performance, and a domestic financial system that is dominated by some types of non-traditional bank intermediation or that has a high proportion of foreign banks has in some cases been associated with adverse economic outcomes, especially during the financial crisis. Their results also suggest that there may be some trade-offs between beneficial effects on growth and stability of some financial structures. For example, the positive association of financial buffers with growth can diminish above a certain, relatively high, threshold, i.e. a too-safe system may limit the available funds for credit and hence growth.

Dabla-Norris and Srivisal (2013) examine the impact of financial depth – measured by the aggregate private credit provided by deposit money banks and other financial institutions as a share of GDP – on macroeconomic volatility using a dynamic panel analysis for 110 advanced and developing countries. They find that financial depth plays a significant role in dampening the volatility of output, consumption, and investment growth, but only up to a certain point. At very high levels, such as those observed in many advanced economies, financial depth amplifies consumption and investment volatility. They also find strong evidence that deeper financial systems serve as shock absorbers, mitigating the negative effects of real external shocks on macroeconomic volatility. This smoothing effect is particularly pronounced for consumption volatility in environments of high exposure – when trade and financial openness are high – suggesting significant gains from further financial deepening in developing countries.

The finding that there may be levels beyond which the beneficial effects of financial depth diminish and even become negative emerge in two other recent papers. Arcand et al (2012) use different empirical approaches to show that there can indeed be "too much" finance. In particular, their results suggest that finance starts having a negative effect on output growth when credit to the private sector reaches 100% of GDP. Moreover, they show that their results are consistent with the "vanishing effect" of financial development and that are not driven by output volatility, banking crises, low institutional quality, or by differences in bank regulation and supervision. Cecchetti and Kharroubli (2012) show that the level of financial development is good only up to a point, after which it becomes a drag on growth. Second, focusing on advanced economies, they show that a fast-growing financial sector is detrimental to aggregate productivity growth. The second result comes from looking at the impact of growth in the financial system – measured as growth in either employment or value added – on real productivity growth. Here, they find evidence that is unambiguous: faster growth in finance is bad for aggregate real growth. One interpretation of this finding is that financial booms are inherently bad for trend growth. Pagano (2013) confirms the hypothesis that initially the expansion of the financial industry contributes to economic growth without endangering the solvency of banks and systemic stability. However, beyond a critical threshold, financial development makes no meaningful contribution to long-run growth, while it reduces bank solvency and creates systemic risk.

3 Testing the impact of financial architecture on technological change

Our interest is in the impact of "*financial architecture*" (FA) on "*technological change*" (TC). We estimate a model which captures the effect of several features of a country's financial system on the rate of technological change. First, we obtain the *technological change* for a sample of countries in different years by decomposing the Total Factor Productivity (we apply the Stochastic Frontier Analysis estimation) and then we study how this variable (TC) is affected by several features of countries' financial system, that is what we call *financial architecture* (FA) and, as already said, it does not refer exclusively to the market-bank orientation of a financial system (MB) but it includes also other aspects such as competitiveness, openness, capitalization, listing, etc. (FS).



More specifically, we regress technological change (TC) on financial architecture (FA) and different sets of independent variables, seizing various characteristics of the macroeconomic environment of the countries included in our sample (ME). Our model is the following:

$$TC_{it} = \alpha_{it} + \beta_1 MB_{it} + \beta_2 FS_{it} + \beta_3 ME_{it} + \varepsilon_{it} \quad [1]$$

The dependent variable in the regression, *technological change* (TC), is calculated on the basis of the stochastic frontier analysis (SFA) methodology described in paragraph 3.1. *Market-Bank orientation* (MB) is a continuous variable representing the degree of stock market orientation of a financial system constructed following the approach of Tadesse (2007; see paragraph 3.2).

Financial Structure (FS) variable includes the following factors:

- *foreign banks among total banks*: the percentage of the number of foreign owned banks over the number of the total banks in an economy[7] (expected sign: positive).
- *bank concentration*: the assets of three largest commercial banks as a share of total commercial banking assets[8] (expected sign: uncertain).
- *bank lending-deposit spread*: the difference between lending rate and deposit rate[9] (expected sign: negative).
- *stock price volatility*: the average of the 360-day volatility of the national stock market index (expected sign: uncertain).
- *number of listed companies*: number of domestically incorporated companies listed on the country's stock exchanges at the end of the year per 1,000,000 people[10] (expected sign: positive).
- *bank capitalization*: ratio of bank capital and reserves to total assets. Capital and reserves include funds contributed by owners, retained earnings, general and special reserves, provisions, and valuation adjustments. Total assets include all non-financial and financial assets[11].

7 A foreign bank is a bank where 50 percent or more of its shares are owned by foreigners (Claessens and van Horen, 2012).

8 Total assets include total earning assets, cash and due from banks, foreclosed real estate, fixed assets, goodwill, other intangibles, current tax assets, deferred tax assets, discontinued operations and other assets. The expected sign of this variable is uncertain since the higher bank concentration could be a result of higher bank efficiency hypothesis or simply stemming from an oligopolistic market structure. In the first case more efficient banks are able to gain larger market share and as a result the concentration will rise. In the second case the bank concentration is merely a result of a non-competitive market structure and hence bank can exert higher market power at borrowers detrimental (see Stigler, 1964; Demsetz, 1973; Berger, 1995).

9 Lending rate is the rate charged by banks on loans to the private sector and deposit interest rate is the rate offered by commercial banks on three-month deposits. Higher bank lending-deposit spread is associated with higher banks market power which is in turn a result of a lack of competitiveness.

10 It does not include investment companies, mutual funds, or other collective investment vehicles. Since equity capital only has a residual claim on corporate earnings, it can be used to finance projects with uncertain and long-term returns, such as research, product development, innovation or the opening of new markets. These characteristics make equity unique and the only standardised financial instrument dedicated to finance genuine innovation and value creation, which is associated with uncertainty and the very basis for economic progress (Knight, 1921).

11 Capital includes tier 1 capital (paid-up shares and common stock), which is a common feature in all countries' banking systems, and total regulatory capital, which includes several specified types of subordinated debt instruments that need not be repaid if the funds are required to maintain minimum capital levels (these comprise tier 2 and tier 3 capital). Due to differences in national accounting, taxation, and supervisory regimes, these data are not strictly comparable across countries.

Macroeconomic Environment (ME) contains the following set of variables:

- lagged real GDP per capita growth[12] (expected sign: positive).
- lagged output gap in percent of potential GDP: output gaps for advanced economies are calculated as actual GDP less potential GDP as a percent of potential GDP[13] (expected sign: positive).
- general government total expenditure: it consists of total expense and the net acquisition of nonfinancial assets (expected sign: uncertain).
- trade openness growth: it is the annual variation of trade openness, calculated as total trade, i.e. the sum of exports and imports of goods and services, relative to GDP. We use the annual variation instead of the annual level since it could better proxy the dynamics of countries' trade integration which is a long term phenomenon with several grades of stickiness (expected sign: positive).

Descriptive statistics for the control variables are presented in Appendix A.

3.1 Financial architecture

The Financial Architecture (FA) dimension is captured by two sets of variables defined as Market-Bank orientation (MB) and Financial Structure (FS). There is no uniformly accepted empirical definition of the market-bank orientation of a given country. We follow the approach of Tadesse (2007) and construct a continuous variable, MB, as an index of the degree of stock market orientation of a financial system. In particular, MB is based on three indices that measure the relative (i) size, (ii) activity and (iii) efficiency of the stock market in a given country with respect to those of the banking sector. Therefore the variable MB reflects the principal component of these three variables (PCA): *market size*, *market activity* and *market efficiency*. By construction, higher values of MB indicate a more market-oriented financial system.

Market size measures the relative size of stock markets to that of banks in the financial system. The size of the domestic stock markets is measured by the market capitalization of domestic stocks relative to the GDP of the country[14].The size of the banking sector is measured by the bank credit ratio defined as the claims of the banking sector against the private real sector as a percentage of GDP[15]. Therefore,

12 GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant 2005 U.S. dollars.

13 Estimates of output gaps are subject to a significant margin of uncertainty. For a discussion of approaches to calculating potential output, see Paula R. De Masi, "IMF Estimates of Potential Output: Theory and Practice", in Staff Studies for the World Economic Outlook (Washington: IMF, December 1997), pp. 40-46.

14 Stock market capitalization is defined as the total value of all listed shares in a stock market as a percentage of GDP.

15 It includes the financial resources provided to the private sector by domestic money banks as a share of GDP. Domestic money banks comprise commercial banks and other financial institutions that accept transferable deposits, such as demand deposits. This excludes claims of non-bank intermediaries, and credits to the public sector. *Market size* therefore combines the two size measures as a ratio of the capitalization ratio to bank credit ratio.

market size is the ratio between market capitalization and the claims of the banking sector. Larger values indicate more market orientation in terms of relative size.

Market activity measures the activity of stock markets relative to that of banks. It is denoted by the ratio of total value of stocks traded to bank credit ratio. Total value traded as a share of GDP measures stock market activity relative to economic activity; bank credit ratio (defined above) indicates the importance of banks in the economic activities of the private sector.

Market efficiency measures the relative efficiency of a country's stock markets with respect to that of its banks. Efficiency of stock markets is measured by the stock market turnover ratio, which is defined to be the total value of shares traded during the period divided by the average market capitalization for the period. High turnover is used as an indicator of low transaction costs[16]. Efficiency of banking is measured by bank overhead ratio, defined to be the ratio of banking overhead costs to banking assets. Market efficiency thus is the product of stock market turnover ratio and bank overhead ratio[17].

We take the principal component of the three series (*market size*, *market activity* and *market efficiency*) and compute the composite measure *MB*.

3.2 Estimating and decomposing TFP: stochastic frontier analysis

Productivity growth, in general, is composed by two parts, technological change (TC) and efficiency change (EC): stochastic frontier analysis allows us to distinguish between the two. This can be further understood by viewing output growth from the perspective of a frontier of production possibilities where countries can be operating either on or within the frontier, with the distance from the frontier reflecting inefficiency. Over time, a country's frontier can shift, indicating technological change, or a country can move towards or away from the frontier which represents efficiency changes. Moreover, a country can move along the frontier by changing inputs. So productivity growth can be seen as being made up of three components: efficiency change, technology change and input change with the first two components being the "productivity change" (Koop et al., 2000).

We limit our work to studying OECD countries because the stochastic frontier model assumes a common production technology frontier for all countries in the sample, and pooling developed and non-developed countries together would be conceptually erroneous.

16 A second measure of market liquidity used in the literature is Value Traded, defined as the value of trades of domestic shares on domestic exchanges divided by GDP. However, since financial markets are forward looking, Value Traded has one potential pitfall. If markets anticipate large corporate profits, stock prices will rise today. This price rise would increase the value of stock transactions and therefore raise Value Traded. Problematically, the liquidity indicator would rise without a rise in the number of transactions or a fall in transaction costs (Levine and Zervos, 1998).

17 Tadesse (2007) employs total value traded instead of stock market ratio. Demirguc-Kunt and Levine (2001) present measures using both value traded and stock market ratio and find no different rankings.

The approach adopted in this paper has been developed in the literature on technological efficiency and productivity, more specifically in the statistical and parametric branches of this literature, which is known as Stochastic Frontier Analysis (SFA). The focus of SFA is to obtain an estimator for one of the components of TFP, the degree of technological efficiency. Technological efficiency is estimated in addition to technological progress which in turn is captured (as usual) by a time trend and interactions of the regressors with time.

Frontier models are applied to both aggregate and individual data. They differ from the non-frontier models for the assumption that the observed production units do not fully utilize their existing technology. In presence of inefficiency, productivity measurement is affected and so will be productivity change, unless inefficiency does not vary over time. Since in many contexts it is relevant to provide evidence on the contribution of efficiency change to productivity change, a main advantage of these models is that they allow for the presence of time varying technological inefficiency in production. The main reason leading to the adoption of frontier models is then their capability to disentangle two main sources of productivity growth: technological change (TC) and efficiency change (EC). Technological progress (or change) is assumed to push the frontier of potential production upward, while efficiency change reflects the capability of productive units to improve production with a set of given inputs and available technology. An advantage of frontier models is that they can provide useful information to the policy maker for the design of productivity-enhancing policies.

The stochastic frontier model used in this article assumes the existence of technological inefficiency which evolves following a particular behaviour. This allows one to split productivity changes into (i) the change in technological efficiency (EC), which measures the movement of an economy towards (or away from) the production frontier, and (ii) technological progress (TC), which measures shifts of the production frontier over time.

Quantifying the ability of an economy or firm to convert inputs into output is a *conditio sine qua non* for empirical analysis in a number of research fields. What is usually needed is a measure of output differences which is not explained by different input choices and occurs, instead, through marginal product increases. This quantity, usually referred to as total factor productivity (TFP), is the essence of the economic notion of productivity[18]. To put it formally, what economists have in mind when they talk about productivity is a production function of the type

$$Y_{it} = A_{it}F(X_{it}) \qquad [2]$$

18 Aggregate studies are mainly concerned with identifying the role of TFP in growth dynamics, the main goal consisting of explaining the still wide differences in economic performance across countries. This literature started with the Solow growth theory, in which the pattern of productivity growth essentially mirrors that of the so-called technological progress (i.e. Solow residual). Known as *growth accounting*, this has been the first deterministic methodology proposed to estimate TFP and has been used to estimate TFP at both aggregate and sectoral levels. The first evidence dates back to the 1950s (Abramovitz, 1956; Solow, 1957) and, despite its age, still represents one of the most popular ways to estimate TFP.

relating the output (*Y*) of a generic unit (firm/industry/country) *i* at time *t* to a ($1 \times N$) vector of inputs (*X*) and the term *A* saying how much output a given unit is able to produce from a certain amount of inputs, given the technological level. The state of technology, embodied by the function *F*(.), is given and common to all i_t. Hence, the TFP index at time *t* is the ratio of produced output and total inputs employed:

$$\mathrm{TFP}_{it} = \mathrm{A}_{it} = \frac{\mathrm{Y}_{it}}{\mathrm{F}(\mathrm{X}_{it})} \tag{3}$$

The idea is quite simple, but giving it an operational content is not an easy task. In general, let us start with the following Cobb–Douglas specification of [2]:

$$\mathrm{Y}_{it} = \mathrm{A}_{it} \prod_{n=1}^{N} (\mathrm{X}_{n,it})^{\beta_n} \tag{4}$$

where $X_{n,it}$ is the amount of input *n* (with $n = 1, \ldots, N$), and β_n is the relevant production coefficient. Equation (4), which assumes Hicks-neutral technological change, expresses firm i'_s output at time *t* as a function of a bundle of *N* inputs times the TFP component A_{it}.

In order to go from the firm to the industry, the simplest form of aggregation one can conceive is the Growth accounting measures, that is to measure TFP indirectly as the residual component of GDP growth that cannot be explained by the growth of the assumed inputs of production. Let us start the analysis from the standard Hicks-neutral specification described by (4). Taking logs (lowercase letters) and derivatives with respect to time (and dropping time dependence), the aggregate production function becomes:

$$\dot{y} = \dot{a} + \sum_{n=1}^{N} \beta_n \dot{x}_n \tag{5}$$

where $\dot{a}$ is the productivity, or TFP, growth rate and the β_ns are input marginal products. Thus, if we can compute the factors' growth rates and their marginal products, the TFP growth rate can be easily calculated as a residual, or Solow Residual (*SR*), from

$$\mathrm{SR} = \dot{a} = \dot{y} - \sum_{n=1}^{N} \beta_n \dot{x}_n \tag{6}$$

The rate of change of TFP represents the change in national income that is not explained by changes in the level of inputs used[19].

A way of estimating TFP – in macro as well as micro contexts – is based on stochastic frontier models. Originally proposed by Aigner et al. (1977), Meeusen and van den Broeck (1977) and Battese and Corra (1977), the estimation of stochastic

19 Assuming perfect competition and constant returns to scale, equation (5) becomes $\mathrm{SR} = \dot{a} = \dot{y} - \sum_{n=1}^{N} s_n \dot{x}_n$ where $s_n = wX/Y$ is the fraction of *Y* used to pay input *n*. Given the assumption that $\sum_n \beta_n = 1$, in the Cobb-Douglas case these input shares are constant over time and correspond to the exponents in the production function.

frontiers represents a well-established empirical tool, widely employed in the last three decades by scholars interested in efficiency analysis. On the other hand, its application to the study of TFP growth represents a more recent advance. As in the case of DEA (Data Envelopment Analysis), the existence of technological inefficiency (a discrepancy between observed and potential output) is assumed. This assumption allows one to decompose productivity changes into two parts: the change in technological efficiency (movements towards the frontier) and technological progress (the shift of the frontier over time). In contrast to DEA, the analysis is pursued in a stochastic context.

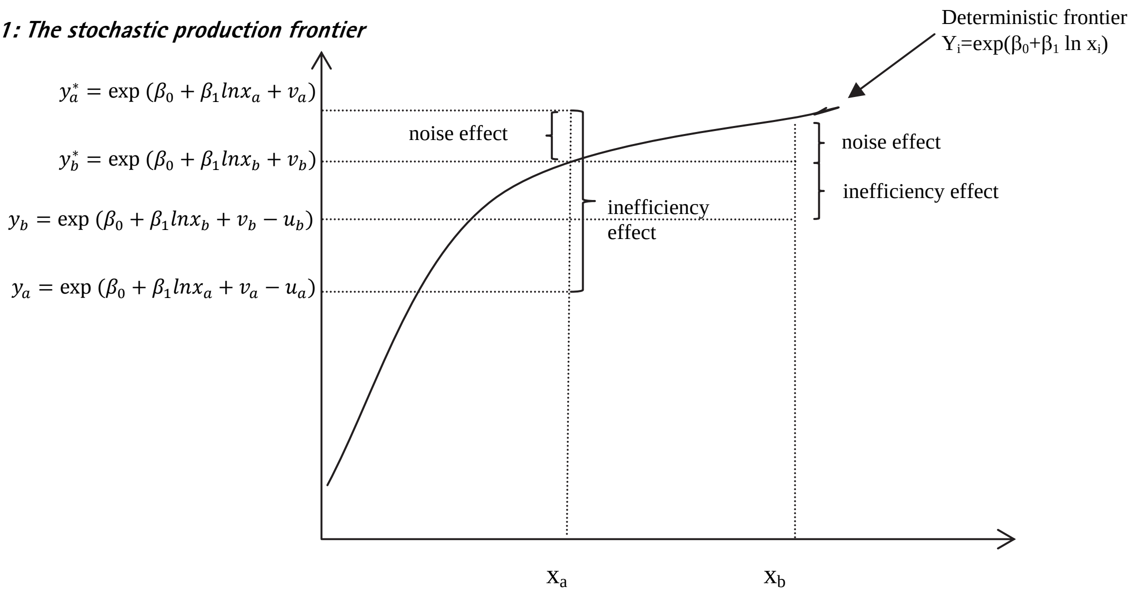
We first introduce a simple cross-section stochastic frontier model which gives the flavour of the departures of SFA from non-frontier models and focuses on the estimation of technological inefficiency. Then, we describe the stochastic frontier approach to the decomposition of TFP in a panel context proposed by Kumbhakar and Lovell (2000).

Given I producers each using $\boldsymbol{X} \in R_+^N$ inputs to produce a scalar output $Y \in R_+$, a frontier production model takes the following generic form:

$$Y_i = F(\boldsymbol{X}_i;\, \beta)\exp\,(v_i - u_i) \qquad [7]$$

where β is the vector of unknown parameters to be estimated that characterize the structure of the technology, $F(\boldsymbol{X}_i;\beta)$ defines a deterministic production frontier common to all *I* producers and the random error term v_i captures the effect of (producer-specific) external shocks on observed output Y_i. The stochastic production frontier $F(\boldsymbol{X}_i;\, \beta)\exp\,(v_i)$ defines maximum feasible output in an environment characterized by the presence of either favourable or unfavourable events beyond the control of producers (v_i). The error term $u_i \geq 0$ is introduced in the model in order to capture shortfall of Y_i from $F(\boldsymbol{X}_i;\, \beta)\exp\,(v_i)$, i.e. technological inefficiency (see Figure 1).

Figure 1: The stochastic production frontier



According to the output-oriented definition of technological efficiency (TE), we can write

$$TE_i = \frac{Y_i}{F(\boldsymbol{X}_i;\beta)\exp(v_i)} = \exp(-u_i) \leq 1 \qquad [8]$$

That is, producer *i* achieves maximum feasible output if and only if $TE_i = 1$; otherwise technological inefficiency occurs and $TE_i < 1$ measures the shortfall of Y_i from maximum feasible output in an environment characterized by the presence of noise. The log-linear version of (7) to be estimated with the ultimate objective of obtaining an estimate of technological efficiency is

$$y_i = \alpha + \boldsymbol{x}_i\beta + v_i - u_i \qquad [9]$$

Estimating technological efficiency defined in (8) requires the estimation of (7) in order to obtain estimates of the technology parameters β and to separate estimates of v_i and u_i. In turn, as Fried et al. (2008) point out, the price to pay for obtaining separate estimates of the two error components in [7] is indeed the imposition of distributional and independence assumptions in the estimated model[20].

In our paper we follow an alternative and more powerful approach which enables to explain how inefficiency changes for each *i* e for each t: this model takes into account the production environment[21]. A model for dealing with observable environmental variables is to allow them to directly influence the stochastic component of the production frontier. Kumbhakar et al. (1991) achieve this by assuming

$$y_i = \alpha + \boldsymbol{x}_i\beta + v_i - u_i \qquad [10]$$

and

$$u_i = \gamma'\boldsymbol{z}_i + \varepsilon_i; \qquad u_i \sim N^+(\boldsymbol{z}_i\gamma, \sigma_u^2) \qquad [11]$$

20 The conventional assumption of $v_i \sim N(0,\sigma_v^2)$ holds in frontier models, while variants of them have been developed in order to accommodate alternative distributional assumptions on u_i. In particular, Battese and Corra (1977) assumed u_i to follow a half-normal distribution $(u_i \sim N^+(0,\sigma_u^2))$, Meeusen and van den Broeck (1977) an exponential one, while Aigner et al. (1977) considered both assumptions. Later, Stevenson (1980) and Greene (1980a, b) assumed u_i to follow the more flexible truncated normal and gamma distributions, respectively. Either distributional assumption implies that the composed error $e_i = v_i - u_i$ in (7) is negatively skewed which prevents OLS estimation and makes maximum likelihood estimation necessary. OLS, as a matter of fact, neither provides consistent estimates of all β nor is able to deliver an estimate of technological efficiency. If the modal value of inefficiency is close to zero and relatively high efficiency is expected to be more likely than relatively low efficiency, then the half-normal distributional assumption on u_i will be appropriate, and indeed it is the most widely used in empirical applications. It is worth noting that the fact that the selection of a particular distribution for the $\mathrm{u_i}$ term is not grounded on an a priori justification represents a common criticism to frontier models.

21 The ability of manager to convert inputs into outputs is often influenced by exogenous variables that characterize the environment in which production takes place. When accounting for these variables, it is useful to distinguish between non-stochastic variables that are observable at the time key production decisions are made (e.g., degree of government regulation, type of firm ownership, age of the labour force) and unforeseen stochastic variables that can be regarded as sources of production risk (e.g., weather phenomena).

Random noise in the production process is introduced through the error component $v_i \sim iid\, N(0, \sigma_v^2)$ in equation (3); the second error component, which captures the effects of technological inefficiency, has a systematic component $\gamma' \boldsymbol{z}_i$ associated with the exogenous variables and a random component ε_i. Thus, the inefficiency effects in the frontier model have distributions that vary with $\boldsymbol{z}_i$ so they are no longer identically distributed[22]. The likelihood function is a generalisation of the likelihood function for the conventional model, as are measures of firm-specific and industry efficiency. The model has been generalised to the panel data case by Battese and Coelli (1992, 1995).

Given these assumptions, it is then possible to define the log-likelihood function to be maximized with respect to parameters $(\beta, \gamma, \sigma_v^2, \sigma_u^2)$ and to obtain consistent estimates of all parameters[23].

Once obtained maximum likelihood estimates of all parameters, technological efficiency has to be estimated for each of the i'_s observed production units. Jondrow et al. (1982) were the first to deliver a result. They noticed that the definition of technological efficiency in (8) involves the unobservable technological inefficiency component $\mathrm{u_i}$. This implies that "*even if the true value of the parameter vector β was known, only the difference $e_i = v_i - u_i$ could be observed*" (Coelli et al., 1998) and that the best prediction for $\mathrm{u_i}$ is the conditional expectation of $\mathrm{u_i}$, given the value of $\mathrm{e_i}$:

$$E(u_i|e_i) = \sigma_* \left[\frac{\phi(\frac{e_i\lambda}{\sigma})}{1-\Phi(\frac{e_i\lambda}{\sigma})} - \frac{e_i\lambda}{\sigma} \right] \qquad [12]$$

where $\mathrm{e_i = v_i - u_i}$, $\phi(.)$ is the density of the standard normal distribution, $\Phi(.)$ is the cumulative density function, λ is defined as above and $\sigma_*^2 = (\sigma_u^2 \sigma_v^2)\sigma^2$.

Then, since $1 - \mathrm{u_i}$ is a first-order approximation to the infinity series $\exp(-\mathrm{u_i}) = 1 - \mathrm{u_i} + \mathrm{u_i^2}/2 - \mathrm{u_i^3}/3! \ldots$ they suggested to estimate technological efficiency defined in (7) as $\mathrm{TE_i} = \exp[-\mathrm{E(u_i|e_i)}] = 1 - \mathrm{E(u_i|e_i)}$.

Nishimizu and Page (1982) first worked out a decomposition of TFP change in order to obtain a measure of the contribution of technological efficiency change assuming constant returns to scale. Later, Kumbhakar (2000) refined their decomposition of TFP change also accounting for time-varying scale effects and changes of allocative inefficiency over time. Following Kumbhakar (2000), the Solow residual de-

22 The requirement that $u_i \geq 0$ requires that $\varepsilon_i \geq -\gamma' z_i$, which does not require $\gamma' z_i \geq 0$. However it is necessary to impose distributional assumptions on v_i and ε_i, and to impose the restriction $\varepsilon_i \geq -\gamma' z_i$, in order to derive the likelihood function.

23 Two alternative parameterizations of the log-likelihood function have been proposed by Aigner et al. (1977) and Battese and Corra (1977). Aigner et al. (1977) express the log-likelihood function in terms of the two parameters $\sigma^2 \equiv \sigma_u^2 + \sigma_v^2$ and $\lambda \equiv \sigma_u/\sigma_v$. On the other hand, Battese and Corra (1977) provide a parameterization of the log-likelihood function in terms of the variance parameter $\gamma \equiv \sigma_u^2/\sigma^2$. The latter parameterization of the log-likelihood function allows an easy way of testing the frontier model (8) versus its non-frontier version (with no inefficiency effects). Indeed, the parameter γ takes values between 0 and 1, with $\gamma = 0$ $(\gamma = 1)$ indicating that the deviations from the frontier are entirely due to statistical noise (technological inefficiency). For details on the test of the null hypothesis that $\mathrm{H_0}: \gamma = 0$ (no scope for the frontier model), see Coelli et al. (1998).

fined in (6) attainable within frontier models can be estimated and decomposed as follows. Consider the following production function:

$$Y_{it} = f(X_{it}, t; \beta) \exp(-u_{it}) \quad [13]$$

where *i =1, . . . ,N* producers are observed over *t = 1, . . . ,T* years, *Y, f(.)* and $\exp(-u_{it})$ are interpreted as above in this section and time is included as a regressor in the production function in order to capture technological change[24]. Omitting the *i* and *t* subscripts, taking logs and time derivatives:

$$\dot{y} = \frac{d \ln f(X,t)}{dt} - \frac{\partial u}{\partial t} \quad [14]$$

Totally differentiating *ln f(X, t)* with respect to time:

$$\frac{d \ln f(X,t)}{dt} = \frac{\partial \ln f(X,t)}{\partial t} + \sum_j \frac{\partial \ln f(X,t)}{\partial X_j} \cdot \frac{\partial X_j}{\partial t} = \frac{\partial \ln f(X,t)}{\partial t} + \sum_j \epsilon_j \cdot \dot{x}_j \quad [15]$$

and replacing (15) in (14) is then possible to obtain the following decomposition of output growth:

$$\dot{y} = \frac{\partial \ln f(X,t)}{\partial t} + \sum_j \epsilon_j \cdot \dot{x}_j - \frac{\partial u}{\partial t} \quad [16]$$

where $\partial \ln f(X,t)/\partial \ln X_j$ defines the output elasticity ϵ_j of input X_j at the frontier. Notice that equation (16) distinguishes three sources of output growth:

(i) $TC = \partial \ln f(X,t)/\partial t \Rightarrow$ exogenous technological change. That is, given a certain inputs use, if $TC > 0$ ($TC < 0$), exogenous technological change shifts the production frontier upward (downward);

(ii) $TEC = -\partial u/\partial t \Rightarrow$ technological efficiency change. TEC represents the rate at which an inefficient producer moves towards the frontier (technological efficiency declines over time if $TEC < 0$);

(iii) $\sum_j \epsilon_j \cdot \dot{x}_j \Rightarrow$ change in input use. It is worth noting that if inputs quantities do not change over time, then $\dot{y} = TC + TEC$.

Kumbhakar (2000) shows how to estimate the three components of TFP change in (16) in a translog production frontier model under the two alternative assumptions (i) $v_i \sim N(0, \sigma_v^2)$ and (ii) $u_i \sim N^+(z_i\gamma, \sigma_u^2)$ (time-varying inefficiency effects hypothesis), using the following translog production function:

$$y_{it} = \alpha_0 + \sum_j \beta_j x_{jit} + \beta_t t + \frac{1}{2}\sum_j \sum_k \beta_{jk} x_{jit} x_{kit} + \frac{1}{2}\beta_{tt} t^2 + \sum_j \beta_{jt} x_{jit} t + v_{it} - u_{it} \quad [17]$$

24 Technological change is not restricted to be neutral with respect to the inputs; neutrality requires that $f(X_{it}, t; \beta) = A(t) \cdot g(X_{it}; \beta)$.

The first variant of the model is based on the assumption that the temporal pattern of inefficiency is described by $u_i = \gamma' z_i + \varepsilon_i$. Given this, provided that $u_i \sim N^+(z_i\gamma, \sigma_u^2)$, $v_i \sim \text{iid } N(0, \sigma_v^2)$ and that v_{it} are independent of u_{it} for any *i* and *t*, it is possible to derive the log-likelihood function for (17) and to obtain maximum likelihood estimators of the technological parameters, all the parameters in γ, σ_v^2, σ_u^2. Then, estimates of u_{it} can be obtained by using (12). Finally, the technological change component of TFP change for each producer at each point in time can be computed on the basis of the following estimate:

$$TC = \beta_t + \beta_{tt}t + \sum_j \beta_{jt}x_j \qquad [18]$$

The technological change index between period *s* and *t* for the *i-th* country can be calculated directly from the estimated parameters. One first evaluates the partial derivatives of the production function with respect to time using the data for the *i-th* country in periods *s* and *t*. Then the technological change index between the adjacent periods *s* and *t* is calculated as the geometric mean of these two partial derivatives. That is:

$$\text{Technological change index} = \exp\left\{\frac{1}{2}\left[\frac{\partial \ln y_{is}}{\partial s} + \frac{\partial \ln y_{it}}{\partial t}\right]\right\} \qquad [19]$$

4 Data

Our sample contains data for 27 OECD member countries (Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Korea, the Netherlands, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, United Kingdom, United States) during the 1996-2010 period. Data are thoroughly described in Appendix A.

For the estimation of the technological change (TC), we estimate a translog production function by running the equation [17] where the dependent variable (y_{it}) is the log of real GDP and the independent variables are the log of the labour force and physical capital (x_{ijt}). The GDP and labour force data[25] are from OECD STAN database for Industrial Analysis. Due to the lack of data on physical capital stock across the countries, we decided to follow the methodology of Dhareshwar and Nehru (1994), i.e. to estimate capital stock as summation of past gross investment flows[26]. The summary statistics for the explanatory variables are reported in Table A1.

25 In particular, we use the civilian labour force which corresponds to total labour force excluding armed forces.

26 K is constructed as: $K_t = K_{t-1}(1-\theta) + I_t$, where K is capital stock, I investment and θ the rate of depreciation. θ is assumed as 6 percent along the lines of Hall and Jones (1999) and Bernanke and Gurkaynak (2001). Initial capital stocks are constructed by the assumption that capital and output grow at the same rate. Specifically, for countries

As already showed in paragraph 3.2 we follow the SFA approach in order to estimate and decompose the "productivity change" in its two main components: efficiency change (EC) and technological change (TC). We adopt the model proposed by Battese and Coelli (1995) which assumes that inefficiency, (u_{it}) in the model, is not identically distributed for all units observed and all the time, but instead follows a truncated normal distribution, the mean of which varies from unit to unit and year to year, depending on a series of explanatory variables ($\boldsymbol{z}_i$).

The explanatory variables for the efficiency term are *human capital* and *institutional variables*. Human capital is measured as the percentage of labour force with tertiary education (taken from OECD statistics). As institutional variables we build on the Worldwide Governance Indicators database developed by D. Kauffman et al. (2010) as part of the World Bank's Governance Matter project[27]. The indicators measure six dimensions of governance: Voice and Accountability, Political Stability and Absence of Violence/Terrorism, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption. The summary statistics for the efficiency explanatory variables are reported in Table A2.

In order to construct *Market-Bank orientation* (MB) we build on aggregate cross-country data extracted by the Global Financial Development Database[28]. As already recalled in paragraph 3.1, we follow the approach of Tadesse (2007) and construct a continuous variable, MB, which is the principal component of (i) *market size*, (ii) *market activity* and (iii) *market efficiency*. By construction, higher value of MB indicates a more market-oriented financial system. The summary statistics for the three variables used to build the MB variable are reported in Table A3.

With reference to *Financial Structure* (FS) variables we include: foreign banks among total banks, bank concentration[29], bank lending-deposit spread, bank capitalization, stock price volatility and number of listed companies (see Table A4 for related summary statistics).

Macroeconomic Environment (ME) includes the following set of variables: lagged real GDP per capita growth, lagged output gap in percent of potential GDP, general government total expenditure and trade openness (see Table A5 for descriptive statistics).

with investment data beginning in 1990 we set the initial capital stock $K_{1990} = I_{1990} / (g + \theta)$ where g is the 10 year growth rate of output (e.g., from 1980 to 1990).

27 See http://info.worldbank.org/governance/wgi/index.aspx#home.

28 The Global Financial Development Database is an extensive dataset of financial system characteristics for 203 economies. The database includes measures of (1) size of financial institutions and markets (financial depth), (2) degree to which individuals can and do use financial services (access), (3) efficiency of financial intermediaries and markets in intermediating resources and facilitating financial transactions (efficiency), and (4) stability of financial institutions and markets (stability).

29 See Cetorelli and Gambera (2001) for more details on bank concentration.

5 Econometric results

5.1 Estimates of technological change

As already recalled in section 3.2 the stochastic frontier model used in this paper assumes the existence of technological inefficiency (u_{it}) which evolves following a particular behaviour. This allows to split productivity changes into (i) the change in technological efficiency, which measures the movement of an economy towards (or away from) the production frontier, and (ii) the technological change (or technological progress), which measures shifts of the frontier itself over time.

The parameter estimates for the Translog stochastic frontier production function are reported in Table 1; for robustness reasons we run four alternative models which mainly differ from each other for the list of efficiency explanatory variables used. A total of 8 out of the 9 coefficients (excluding the constant) comprised in the frontier function are significantly different from zero at the 5 percent level. The three direct effects, two of the squared terms and the three cross products have coefficients significantly different from zero.

The impact of labour is negative and significant in all the specifications. It might be thought that countries more specialized in labour-intensive industries are also those less involved in innovative, knowledge-intensive, more productive sectors; therefore a higher use of labour could suggest a lower potential (or predicted) output. Capital, as expected, affects positively and significantly the predicted output in all the specifications. The results are robust across the alternative specifications[30].

As we apply the innovative approach firstly proposed by Battese and Coelli (1995), which allows to remove some restrictive assumptions on the inefficiency distributional proprieties, we are able to investigate the determinants of inefficiency, i.e. the factors that exert an impact on our sample inefficiency[31]. The explanatory variables for the inefficiency term are (i) *governance indicators* and (ii) *human capital*.

In order to assess whether efficiency is related to better governance, we use several indicators of government effectiveness of the World Bank (see Kaufmann et al., 2008) and test their contribution to efficiency. As measure of human capital we use the percentage of the labour force with tertiary education (taken from OECD statistics). The results are reported in Table 1. Since inefficiency in equation (9) is measured in terms of the distance from the frontier, a negative impact indicates an increase in efficiency (i.e. catching up toward the frontier). Therefore, for instance, a positive effect of improved government effectiveness in increasing technological efficiency is represented by a negative coefficient.

30 As pointed out by Berger and Mester (1987) some cautions should be applied in interpreting the signs of estimated parameters of the Translog production function. The Translog function (as opposed to the Cobb Douglas one) is intended to estimate the *theoretically optimal output* given a set of inputs and it comprises linear, quadratic and multiplicative effects of each input of production function, so it's not straightforward the economic interpretation of coefficients.

31 Since by construction the efficiency is equal to $Eff = (1 - u)$, where u is the inefficiency, we can interpret the signs of explanatory variables as follow: a negative coefficient affects negatively the inefficiency (so increase the efficiency); a positive coefficient of explanatory variables affects positively the inefficiency (so decrease the efficiency).

Governance explanatory variables: Government Effectiveness, Regulatory Quality and Rule of Law are significantly different from zero and with the expected sign in all specification, while Political Stability, Voice and Accountability and Control of Corruption are not significant. These results confirm the well-known empirical evidence showing the strong correlation between good governance and growth across countries. There is now a growing understanding that economic, political, legal and social institutions are essential to the economic success and failure of nations (see Acemoglu and Robinson, 2012). Particularly important elements of governance include the regulation of economic institutions (represented in our model by Government Effectiveness, Regulatory Quality and Rule of Law) which may create incentives for investment and technology adoption, for its businesses to invest, and for its workers the opportunity to accumulate human capital, thus engendering economic growth.

Human capital: we see that the coefficient of Tertiary Education is statistically significant with negative sign in all the specification, except the fourth one, confirming the idea that a better educated labour force reduces inefficiency.

Table 1. Production Function estimation results

	Model 1		Model 2		Model 3		Model 4	
	coefficient	*t* ratio	coefficient	*t* ratio	coefficient	*t* ratio	coefficient	*t* ratio
				Production Frontier				
Constant	-9.27	-4.03	-8.59	-3.88	-9.21	-3.90	-14.28	-14.34
Labour	-1.14	-2.29	-1.06	-2.05	-1.16	-2.14	-5.28	-5.82
Capital	2.70	6.07	2.58	5.90	2.70	5.71	5.07	9.99
Time	-0.27	-5.17	-0.27	-5.05	-0.27	-4.80	-0.58	-0.63
Labor2	-0.05	-0.80	-0.04	-0.66	-0.05	-0.79	-0.64	-1.52
Capital2	-0.16	-3.62	-0.15	-3.39	-0.16	-3.37	-0.48	-5.20
Time2	0.00	-2.14	0.00	-3.89	0.00	-2.13		
Labour*Capital	0.11	2.14	0.10	1.91	0.11	2.00	0.57	2.94
Capital*Time	0.02	4.93	0.02	4.73	0.02	4.41	0.05	0.70
Labour*Time	-0.02	-4.12	-0.02	-3.83	-0.02	-3.58	-0.05	-0.87
				Inefficiency model				
Constant	1.45	5.78	1.53	6.93	1.46	5.79	0.32	0.32
Tertiary edu	-0.04	-6.88	-0.04	-7.75	-0.04	-6.42	-0.01	-0.10
Voice and Accountability	-0.30	-1.42	-0.35	-1.80	-0.30	-1.43	0.16	0.16
Political Stability			-0.24	-0.27	0.06	0.10	-0.02	-0.02
Government effectiveness	-1.05	-4.97	-1.15	-6.02	-1.05	-5.28	-0.33	-0.35
Regulatory Quality	-0.17	-0.96	-0.21	-0.96	-0.17	-0.93	-0.20	-0.20
Rule of Law	-0.82	-3.49	-1.04	-4.73	-0.79	-3.17	-0.28	-0.29
Control of Corruption			0.38	1.55			-0.25	-0.26
	0.13	6.99	0.15	8.82	0.13	6.53	0.17	0.37
	0.93	63.21	0.94	80.55	0.93	61.61	0.93	12.40
Number of observations	405		405		405		405	
Log-likelihood	159.77		160.93		159.89		56.30	

Note: The estimates in the first panel are the parameters of the Translog production function while the estimates in the second panel are the parameters of the inefficiency model. σ^2 is the estimate of the standard deviation of the statistical noise. $\gamma = \sigma_u^2/\sigma^2$. Coelli et al. (1998) point out that if γ=0, the deviations from the frontier are entirely due to noise. All the data are in percentage values.

Table 2 shows the estimated *Technological change* (TC) – which represents the shift of a country's frontier during the time period ranging from 1996 to 2010 – for a subsample of countries among our 27 OECD countries[32]. Germany, USA and Italy are the countries with the best technological innovation performance during the 90s: they attain the higher values of *Technological change* variables, respectively 1.87 for Germany and USA and 1.84 for Italy. France, Norway and Spain follow with 1.78, 1.43 and 1.04. Hungary experienced a serious delay due to its deep transition to an open market system (-2.24).

Italy seems to perform better till the early 2000s (2004-2005) when it significantly slowed and was overtaken by many countries: in 2005 France reached an annual technological change (TC) equal to 2.15, higher than the 2.14 of Italy. In the same year (2005) the distance between Italy and Germany which was very close in the first year (1.84 versus 1.87 in 1996) widened to almost 30 basis points (2.14 versus 2.41 in 2005). In 2010 countries with best performances are USA (2.96) and Germany (2.52), followed by France and Italy (2.44 and 2.29).

Table 2. Technological change (TC)

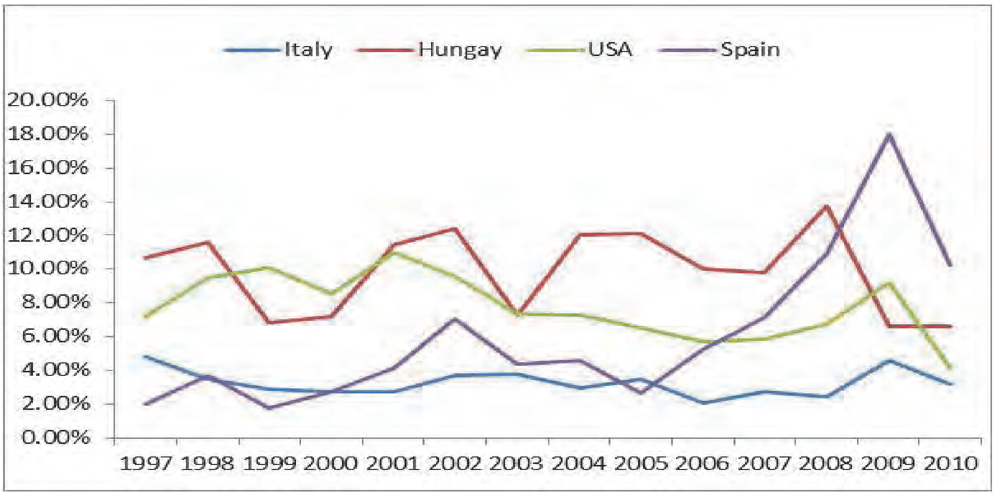
	Italy	France	Germany	Spain	Norway	USA	Hungary
1996	1.84	1.78	1.87	1.04	1.43	1.87	-2.24
1997	1.88	1.82	1.95	1.06	1.43	1.95	-2.13
1998	1.92	1.84	2.01	1.10	1.53	2.04	-2.01
1999	1.95	1.87	2.09	1.11	1.60	2.14	-1.95
2000	1.97	1.90	2.16	1.14	1.66	2.23	-1.87
2001	2.00	1.94	2.22	1.18	1.64	2.34	-1.76
2002	2.04	1.98	2.29	1.25	1.69	2.43	-1.63
2003	2.08	2.04	2.35	1.30	1.73	2.50	-1.56
2004	2.11	2.09	2.39	1.34	1.79	2.58	-1.44
2005	2.14	2.15	2.41	1.37	1.86	2.64	-1.32
2006	2.16	2.19	2.42	1.42	1.95	2.70	-1.22
2007	2.19	2.24	2.43	1.49	1.99	2.76	-1.12
2008	2.21	2.29	2.46	1.60	2.02	2.83	-0.99
2009	2.26	2.38	2.49	1.78	2.09	2.92	-0.92
2010	2.29	2.44	2.52	1.88	2.17	2.96	-0.85

Note: annual level of the estimated variable *TC* expressed in percentage

32 We present the results for the four biggest countries in the Euro area, USA, a Scandinavian country (Norway) and a former transition economy (Hungary). The estimated *TC* for the full list of countries is showed in Table B1 in Appendix B. Technological changes for the alternative models 2, 3 and 4 are reported in Appendix B, tables B3-B5. Table B1 in Appendix B shows results for Technological change (TC) for the whole sample of 27 countries. There is a wide variation in economic performances across countries. Average rates of technological change range from -3.1% per annum in Estonia to 2.5% per annum in the United States. Ranking countries by their average realized rates, we observe that, in general, in most advanced economies technological progress has been much faster than, for instance, in transition countries. This may be a signal of advanced countries' larger capacity to spur technological innovations.

Figure 2 plots the annual variation of TC for a subsample of countries. Indeed, it is important to consider not only the level but also the dynamics of *Technological Change* which provides useful insights on the speed of catching up in certain countries and on the prevailing stagnation path for others. Moving from the annual level of *Technological change* (TC) to the yearly and cumulative change of this variable we can shed light on some structural tendencies. The highest cumulative structural improvement in *Technological change* is that of Hungary (-0.85+2.24=1.39) and the lowest is that of Italy (2.29-1.84=0.45).

Figure 2. Annual variation of Technological Change



Efficiency scores, showed in Table 3[33], refer to the country's ability to reach the production frontier which means the distance between the actual output gained by a country (GDP), given a certain inputs endowment (Labour and Capital), and the maximum output that would have been reached given the characteristics (and the coefficients) of production function. The variation of efficiency levels in time is a qualifying point of the econometric method chosen as the most common models used do not allow the evaluation of this variation (Battese and Coelli 1995) or only permit the estimate of a trend or convergence parameter of the system, thus hindering any analysis of the time dynamic of the single units observed. Efficiency changes represent the movements a country does towards or away from the frontier.

Norway is the country by far most efficient followed by USA. They perform better than other countries during the whole time period considered, whit a slight decrease of efficiency only during the last years (2006-2010) probably due to the recent financial crisis[34].

France and Germany which start with an equivalent level of efficiency (92.10 and 92.35) in 1996 undertake two different paths: while France keeps to perform well till the onset of financial crisis (in 2008 the France's score was 94.53) and

33 Efficiency scores of the alternative models 2, 3 and 4 are reported in Appendix B, tables B6-B8.

34 Norway achieves its maximum score in 2006 (98.00) while USA in 2005 (96.72).

then declines to 91.58; German suffers a steady decrease during the nineties – probably due to the German industrial restructuring – and then it starts to rebuild its efficiency since 2004. A process that was abruptly interrupted by the insurgence of financial crisis in 2008.

Hungary shows the most impressive improvement in its efficiency score, ranging from 62.09 in 1996 to 80.62 in 2010, partly due to the well-known high speed catching up effect which benefits less developed-follower countries. Italy and Spain lag behind other countries and experienced a decrease in score efficiency respectively by roughly 6 and 10 percentage points (Italy shifts from 88.53 to 82.77 and Spain from 89.48 to 79.99). They seem to be affected by a relentless decline which becomes more pronounced starting from 2002-2003.

Table 3. Efficiency scores

	Italy	France	Germany	Spain	Norway	USA	Hungary
1996	88.53	92.10	92.35	89.48	97.77	95.63	62.09
1997	88.33	92.02	92.13	89.17	97.79	96.61	63.21
1998	87.61	92.76	91.45	89.16	97.78	96.77	65.12
1999	86.85	92.77	91.21	88.67	97.78	96.82	66.11
2000	87.08	92.83	91.38	88.44	97.87	96.76	67.42
2001	86.54	92.50	91.03	87.87	97.81	96.61	69.22
2002	85.35	92.19	90.54	87.45	97.82	96.60	71.38
2003	84.04	92.01	86.68	86.62	97.79	96.60	72.98
2004	84.31	94.34	90.44	81.06	97.94	96.70	76.00
2005	83.93	92.89	90.52	80.12	97.99	96.72	78.19
2006	84.34	94.62	90.95	79.91	98.00	96.65	80.66
2007	84.78	92.67	91.33	80.01	97.96	96.63	80.92
2008	83.68	94.53	86.73	79.92	97.82	96.55	82.42
2009	80.87	91.15	88.48	79.52	97.70	95.22	78.68
2010	82.77	91.58	86.09	79.99	97.69	95.69	80.62

Note: the scores are in percentage, so 100 means that the country is on the frontier and therefore reaches a maximum efficiency.

5.2 Robustness check

We check to see if our results are robust to a partially different sample, including a smaller number of countries for a longer period (1996-2011). Data for robustness check are also from OECD STAN database for Industrial Analysis. Table 4 presents the estimate results obtained on the restricted sample: (i) the initial rate of *technological change* (TC), (ii) the country ranking based on the initial value of *technological change*; (iii) cumulative growth rate of *technological change* between the initial year, *t*, and the final year of the sample, *T;* (iv) the country ranking speed based on cumulative growth rate of TC[35]. As far as initial country ranking is concerned, we do not observe significant differences with respect to the baseline sample: Norway

35 Full results are available upon request.

and Finland confirm their primacy. What is more interesting is the cumulative growth rate of technological change (TC) in the considered period: Hungary and Czech Republic confirm their success in the transition process with cumulative rates higher than 9%. In the last positions of the ranking, we find Italy and Belgium, whose performance with reference to *technological change* (and hence innovation) has been poor as indicated by a cumulative growth rate of *technological change* lower than 3%.

Italy slips back from the 6th position in 1996 to the 9th one in 2011, even worse does Belgium which moves back from the 3th position in 1996 to the last one in 2011.

Table 4. Robustness check

Rate of technological change in t=1	Country ranking	Cumulative growth rate of technological innovation (between t and T)	Country ranking speed
6.88	Norway	9.23	Hungary
6.44	Finland	9.13	Czech Republic
6.31	Belgium	8.01	Denmark
6.08	Austria	7.34	Unitet States
5.30	Denmark	6.58	Sweden
4.77	Italy	5.28	Norway
4.60	Sweden	3.16	Austria
2.27	Czech Republic	2.92	Finland
2.25	United States	2.87	Italy
1.83	Hungary	2.41	Belgium

Note: All the data are in percentage values.

5.3 Estimating the impact of financial architecture on technological change

To investigate the impact of *financial architecture* (FA) on *technological change* (TC) we run country fixed-effects[36] unbalanced panel regressions both in good times (2002-2007) and crisis periods (1998-2010) [Eq. 1]. Due to the fact that the 1998-2010 period includes two financial crisis – the dot-com crisis in 2001 and the biggest financial crisis since the second world war from 2008 to 2010 – our model implemented in the full sample cannot perform properly. Indeed, financial variables are strongly affected by two different breaks caused by the crisis as shown by Figure B1 in Appendix B. Therefore, we concentrate on good times.

Table 5 shows results that are robust across several panel data specifications, in good times, i.e. between 2002 and 2007 and for 25 countries[37]. A larger role

36 We perform the Hausman specification test in order confirm our theoretical preference for a fixed-effects model (we believe that country differences matter and are persistent along time). The Hausman test rejects the hypothesis that difference in coefficients are not systematic with a p-value=0.000 (Chi2 test statistic=48.42) so confirming our choice.

37 Australia, Austria, Belgium, Canada, Czech Republic, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Korea, the Netherlands, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, United Kingdom, United States.

of *financial architecture* (FA) variables seems to be clearly associated with higher levels of *technological change* (TC): both the positive sign and statistical significance of the coefficients of *Market-Bank orientation* (MB) and many of the variables comprised in the *Financial Structure* (FS) are unchanged across different specifications.

Estimated coefficients for MB (*Market-Bank orientation*) are always positive and statistically significant which means that a more market oriented financial system spurs innovation technology. Therefore our results seem to confirm the expected higher effectiveness of market-oriented financial systems in allocating resources to innovative firms which operate on the technological frontier. On the contrary, bank-oriented financial systems are more focused on the incumbents firms, specialized on the mature industrial sector.

Higher concentration (FS_1) and lending spreads (FS_5), both indicators of the degree of competitiveness in the banking sector, are statistically significantly associated with lower technological change. One explanation is that higher spreads and higher concentration – either showing a degree of market power exerted by banks in a monopolistic market – enable banks to earn higher profits, and as a result they may be less motivated to take risk financing riskier and more innovative firms who mostly affect the country's technological innovation.

Table 5. Fixed-effects panel estimation in good times (2002-2007)

		(1)	(2)	(3)	(4)	(5)	(6)
BM	Bank-Market orientation	0.0013** (2.34)	0.0013** (2.61)	0.0017*** (2.86)	0.0015*** (2.66)	0.0008* (1.71)	0.0014** (2.03)
FS_1	Concentration	-0.003* (-1.94)	-0.0039** (-2.60)	-0.0037** (-2.52)	-0.004*** (-2.67)	-0.0033 (-2.48)	-
FS_2	Foreign	0.0217*** (7.32)	0.0206*** (7.33)	0.0200*** (7.02)	0.0199*** (7.07)	0.0116*** (4.26)	0.0118*** (3.78)
FS_3	Volatility	-0.0091*** (-4.45)	-0.0099*** (-5.11)	-0.0100*** (-5.15)	-0.0102*** (-5.31)	-0.0080*** (-4.88)	-0.0098*** (-3.97)
FS_4	Listed companies	-	-	-	0.00004* (1.68)	0.00004 (0.120)	0.00002 (0.248)
FS_5	Lending-deposit spread	-	-	-	-	-	-0.0364* (-1.94)
FS_6	Bank capitalization	-	-	-	-	-	-0.0014*** (-3.25)
ME_1	Gdp	0.0259** (2.61)	0.0221** (2.35)	0.0266** (2.62)	0.0309*** (2.98)	-	-
ME_2	Trade openess growth	-	0.1082*** (3.75)	0.1101*** (3.82)	0.1161*** (4.03)	0.1053*** (4.29)	0.11286*** (4.40)
ME_3	Public expenditure	-	-	0.00952 (1.17)	0.0104 (1.29)	-	-
ME_4	Otuput-gap	-	-	-	-	0.0364*** (6.00)	0.0301*** (3.40)
	Costant	0.0042** (2.27)	0.0051*** (2.84)	0.0007 (0.17)	-0.0008 (-0.18)	0.0103 (5.32)	0.004 (1.64)
	Observation	132	132	132	132	126	74
	R^2	0.53	0.59	0.6	0.61	0.73	0.81

Note:***significant at 99%; **significant at 95%; significant at 90%.

A larger share of foreign banks (FS_2) in the domestic banking sector is positively associated with higher technological change. This result, which is robust in the different specifications, signals that higher levels of financial globalization may be associated with more technological progress. A higher presence of foreign banks in a domestic market could boost technological change in two ways: (i) foreign banks which enter a domestic market try to gain market share by financing more opaque and riskier firms that are characterized by innovative and high return project investment (firms mostly constrained by domestic banks; (ii) a financial system which shows a non-negligible presence of foreign banks is likely to be well interconnected with a broader financial and industrial area and therefore could easily absorb technological innovation from more advanced economies (via Foreign Direct Investment, international trade, etc.).

Bank capitalization (FS_6) is negatively associated with technological change suggesting that an excessive level of capital buffers may hinder the lending activities and therefore the financing of technological progress. Again, borrowing firms specialized on more innovative technology are those with riskier project and therefore their lending exposures absorb more banks' prudential capital.

Stock price volatility (FS_3) affects negatively technological progress. One explanation is that an increase in stock market volatility raises the compensation that shareholders demand for bearing idiosyncratic risks. Hence, the cost of equity increases and as a result the investments in technological progress – which are mostly funded by market – are negatively affected.

A higher number of listed companies (FS_4) is positively, though not always significantly, associated with technological progress indicating the importance of having a well-developed domestic capital market. More easily innovative firms can go public more entrepreneurial projects will succeed, with technological spill over effects on the whole economy.

Macroeconomic environment variables (ME) are GDP, output gap, public expenditure and trade openness growth. GDP (ME_1) shows the expected positive sign in all specifications and is always statistically significant: countries with higher per capita GDP growth are those with higher speed in technological change reflecting a wider availability of resources devoted to investments in knowledge-intensive sectors. *Output gap* (ME_4), which has the same economic meaning of GDP, is estimated in alternative of GDP and presents always the right sign and maximum statistical significance.

Public expenditure (ME_3) expected to affects positively the technological change. It is envisioned as an extra-input in the countries' production function, which is the complementary effect exerted by governments in providing private sector with public goods like infrastructures, educations, public research, etc. The variable presents the right sign (positive) but is never significant, probably due to the fact that in the national accounting standard the gross variable *public expenditure* is overwhelmed by the current expenditure component which doesn't refer to the public

R&D activities or other infrastructural investments which are those solely related to technological change.

When we include data up to 2011, i.e. all the years of the so-called big crisis, we lose most of the results obtained in good times. *Market-Bank orientation* (MB), output gap, concentration and volatility maintain the sign but lose statistical significance. Trade openness growth, which was positive in good times, becomes negative, even if not significant: this may signal that a higher level of international integration is associated with poor outcomes during crisis periods, due to the higher contagion pulses countries absorb from abroad (Gentile and Giordano, 2013). A larger capital buffer is negatively associated with technological progress indicating the potential problems related to pro-cyclical effects of capital requirements. Table 6 shows the results only for one model specification. Full results are available upon request.

Table 6. Fixed-effects panel estimation in the whole sample, including bad times (1998-2010)

		(1)
BM	Bank-Market orientation	0.0018 (1.39)
FS_1	Concentration	-0.0036 (-0.97)
FS_2	Foreign	0.0181*** (3.98)
FS_3	Volatility	-0.0001 (0.01)
FS_4	Bank capitalization	-0.1319*** (-4.27)
FS_5	Listed companies	-0.0001 (-1.28)
ME_1	Trade openness growth	-0.0575 (-1.50)
ME_2	Output gap	-0.165 (-1.50)
	Constant	0.0118** (2.28)
	Observations	82
	R^2	0.56

Note:***significant at 99%; **significant at 95%; significant at 90%.

6 Conclusions

Since the beginning of the global financial crisis many structural changes – including crisis intervention measures and evolving regulatory reform agenda – have occurred in the financial system. The changing structures for financial intermediation can be expected to affect economic growth, its volatility and financial stability. However, while there is a quite extensive literature analysing the relation between financial development (generally measured by the size of the financial system) and growth, less theoretical and empirical work exists on the effect of financial structure on several dimensions of economic performance: resilience to financial crisis (stability), technological change, income inequality, competitiveness, social mobility, etc.

Two financial systems can allocate the same amount of resources but the way they do it (the features of financial system) affects seriously the final output, particularly from a social desirability perspective. Only measuring the size or depth of financial systems allows getting a rough idea of what are the underlying forces in places in spurring long-run growth, especially for advanced economies.

From a policy point of view, it is crucial to understand how different financial structures have interacted with economic outcomes in the past in order to assess the expected changes probably resulting by the evolving reforming agenda.

In this paper we contribute to this literature by exploring the impact of financial architecture (FA) on technological change (TC). The hypothesis we test is whether a larger role of financial markets with respect to banks is associated with a higher rate of technological change. Doing this, we address the key determinant of growth, i.e. technological progress that crucially determines the success of an economy. There is a lot of empirical evidence clearly showing that economies characterised by higher level of technological progress have generally more competitive and globalized companies and, as a result, higher GDP growth rates and lower unemployment levels. This is particularly important for mature economies of advanced countries challenged by the competition from emerging markets.

We find that a well-functioning domestic capital market has a positive and significant effect on technological progress: financial systems more market-oriented, whit higher presence of foreign banks, more competitive (less concentrated and with lower bank spreads), with higher companies' propensity to go public and less volatile stock market, are those economies which experience a higher technological progress.

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Appendix A

The dataset

Table A1. Data description for Technological change estimation[1]

	GDP[1]		Capital Stock[2]		Labour force[3]	
	mean	sd	mean	sd	mean	sd
Australia	501.0	111.6	4.81	1.10	9,119.1	1,162.3
Austria	220.8	30.9	2.99	0.89	3,759.4	186.2
Belgium	274.5	34.2	3.10	0.47	4,012.6	280.6
Canada	816.8	150.7	3.85	0.78	14,774.5	1,566.4
Czech Rep.	90.9	17.7	2.85	0.46	4,817.0	102.4
Denmark	178.7	22.1	4.07	0.66	2,696.6	80.1
Estonia	8.2	3.0	11.08	3.49	639.5	75.1
Finland	135.4	24.7	2.22	1.03	2,309.9	148.4
France	1,554.6	177.9	3.05	0.48	24,404.9	1338.8
Germany	2,115.8	183.8	3.57	1.66	36,128.0	1,926.6
Greece	163.6	30.8	6.87	1.66	4,097.5	315.2
Hungary	81.5	12.0	5.38	0.84	3,815.9	179.6
Iceland	14.2	2.4	8.01	2.23	152.8	14.5
Ireland	114.4	53.3	8.43	1.11	1,609.4	347.7
Israel	92.3	21.3	4.53	2.40	2,255.5	356.9
Italy	1,333.9	107.5	2.44	0.75	21,383.4	1,105.2
Korea	612.7	176.4	7.36	3.73	21,308.5	1,772.4
Netherlands	460.5	70.3	3.68	0.71	7,584.9	784.9
Norway	204.0	35.5	3.05	1.22	2,214.2	177.5
Poland	209.4	57.7	11.66	3.77	14,877.0	713.2
Portugal	139.4	18.1	4.40	1.64	4,826.6	296.9
Slovak Rep.	41.9	11.7	5.53	1.35	2,186.7	112.3
Slovenia	24.2	5.6	-4.35	0.94	912.3	45.6
Spain	774.5	144.1	4.94	1.05	15,674.9	2,909.9
Sweden	245.2	42.0	8.23	2.09	4,226.1	220.9
UK	1,508.4	278.7	4.99	0.90	27,132.3	1,366.1
US	9,033.5	1,665.7	4.35	1.33	132,773.8	9,337.1

[1] Euro billions. [2]Average rate of growth of capital stock between 1990 and 2010. [3]Thousands of Civilian Labour Force which corresponds to total labour force excluding armed forces.

Table A2. Explanatory variables for the efficiency term

Variable	Short explanation	Source
Tertiary education	It is the proportion of labor force that has a tertiary education, as a percentage of the total labor force.	World Bank (World Development Indicators database)
Voice and accountability	Reflects perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media. It ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance	WGI database
Political Stability and Absence of violence /Terrorism	Reflects perceptions of the likelihood that the government will be destabilized or overthrown by unconstitutional or violent means, including politically-motivated violence and terrorism. It ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance	WGI database
Government effectiveness	Reflects perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies. It ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance	WGI database
Regulatory quality	Reflects perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development. It ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance.	WGI database
Rule of law	Reflects perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence. It ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance).	WGI database
Control of corruption	Reflects perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests. It ranges from approximately -2.5 (weak) to 2.5 (strong) governance performance.	WGI database

Source: World Bank.

Table A3. Data description for Financial Architecture

	architecture size		architecture activity		architecture efficiency		financial architecture	
	mean	st dev	mean	st dev	mean	st dev	mean	st dev
Australia	1.106	0.163	0.796	0.175	0.011	0.006	1.135	0.160
Austria	0.226	0.127	0.099	0.074	0.006	0.003	0.193	0.115
Belgium	0.838	0.212	0.316	0.125	0.004	0.001	0.671	0.156
Canada	0.991	0.218	0.720	0.177	0.016	0.006	1.024	0.185
Czech Republic	0.598	0.183	0.370	0.190	0.014	0.007	0.579	0.222
Denmark	0.580	0.483	0.607	0.606	0.009	0.002	0.720	0.657
Estonia	0.494	0.284	0.155	0.180	0.009	0.016	0.380	0.223
Finland	1.910	1.285	1.693	0.773	0.008	0.003	2.160	1.080
France	0.872	0.203	0.781	0.229	0.010	0.002	0.995	0.225
Germany	0.427	0.082	0.522	0.184	0.016	0.004	0.584	0.139
Greece	1.050	0.830	0.682	0.772	0.014	0.005	1.032	0.955
Hungary	0.653	0.318	0.541	0.319	0.035	0.015	0.732	0.376
Iceland	0.535	0.223	0.338	0.265	0.010	0.007	0.521	0.260
Ireland	0.431	0.267	0.215	0.138	0.002	0.002	0.379	0.228
Israel	0.844	0.255	0.438	0.178	0.012	0.004	0.758	0.244
Italy	0.510	0.243	0.579	0.219	0.027	0.012	0.673	0.259
Korea, Rep.	0.757	0.218	1.619	0.455	0.034	0.012	1.486	0.356
Netherlands	0.694	0.303	0.855	0.351	0.012	0.009	0.945	0.355
Norway	0.707	0.163	0.715	0.280	0.015	0.004	0.863	0.271
Poland	0.762	0.245	0.293	0.109	0.015	0.005	0.620	0.193
Portugal	0.308	0.111	0.208	0.102	0.010	0.006	0.311	0.125
Slovak Republic	0.141	0.057	0.034	0.033	0.011	0.015	0.107	0.033
Slovenia	0.415	0.148	0.062	0.032	0.005	0.004	0.273	0.091
Spain	0.627	0.163	1.034	0.352	0.005	0.004	1.020	0.314
Sweden	1.443	0.979	1.563	0.590	0.015	0.003	1.820	0.896
United Kingdom	0.940	0.340	0.965	0.286	0.018	0.010	1.156	0.211
United States	2.433	0.538	4.372	1.250	0.060	0.021	4.214	0.769

Source: calculations on Global Financial Development Database, World Bank.

Table A4 Financial structure variables

		foreign banks	bank concentration	lending-deposit spread	bank capitalization	stock price volatility	listed companies
Australia	mean	41.00	71.04	4.19	5.89	15.02	77.48
	st dev	3.59	13.22	0.79	0.93	5.86	10.06
Austria	mean	3.60	67.02	3.60	5.55	21.70	11.60
	st dev	2.26	10.13	0.24	0.94	9.54	1.25
Belgium	mean	39.80	84.13	4.72	3.52	18.53	16.93
	st dev	3.84	3.78	0.46	0.74	6.40	3.26
Canada	mean	42.07	69.31	3.34	4.48	18.26	94.86
	st dev	1.10	13.72	0.56	0.53	7.17	32.61
Czech Republic	mean	53.27	68.61	4.53	5.75	23.30	7.00
	st dev	9.48	3.82	0.29	0.49	7.54	6.92
Denmark	mean	6.80	81.84	4.81	5.58	20.70	37.80
	st dev	4.04	2.59	0.11	0.66	6.05	3.96
Estonia	mean	45.13	96.85	4.13	10.92	24.45	12.91
	st dev	24.97	2.03	1.67	2.77	13.57	2.95
Finland	mean	14.87	96.71	3.37	7.26	30.58	25.84
	st dev	4.24	3.65	0.51	1.88	11.94	2.40
France	mean	6.67	60.90	3.85	5.35	23.71	13.51
	st dev	0.72	4.22	0.33	1.18	7.29	1.47
Germany	mean	11.93	72.26	6.45	4.25	24.02	8.64
	st dev	1.49	3.34	0.35	0.22	7.25	1.51
Greece	mean	50.50	73.33	5.76	7.38	27.48	27.63
	st dev	9.24	12.25	1.30	1.83	9.07	2.76
Hungary	mean	81.53	71.19	3.01	8.96	28.96	4.88
	st dev	8.58	5.80	1.47	0.58	9.48	0.73
Iceland	mean	n.a.	100.00	6.89	8.31	n.a.	123.11
	st dev	n.a.	0.00	0.94	2.56	n.a.	81.34
Ireland	mean	86.27	76.52	3.77	5.47	21.61	15.07
	st dev	3.77	9.81	1.18	0.99	9.05	3.82
Israel	mean	11.47	75.36	3.60	5.97	21.18	90.45
	st dev	3.42	2.32	0.82	0.74	4.51	10.31
Italy	mean	5.67	58.34	5.12	7.28	23.05	4.82
	st dev	2.47	13.61	0.28	0.80	8.21	0.23
Korea, Rep.	mean	18.09	86.70	1.66	6.96	30.55	32.37
	st dev	7.52	20.91	0.41	2.51	10.00	4.33
Netherlands	mean	47.27	82.58	1.09	4.22	24.00	11.38
	st dev	4.15	9.72	0.96	0.78	8.61	3.72
Norway	mean	1.00	93.10	2.19	6.66	25.25	41.06
	st dev	0.00	3.01	0.29	0.56	9.13	3.44

- cont. -

Table A4 Financial structure variables (cont.)

		foreign banks	bank concentration	lending-deposit spread	bank capitalization	stock price volatility	listed companies
Poland	mean	60.80	60.53	4.99	7.79	28.01	8.19
	st dev	13.98	11.64	1.28	0.50	6.78	4.19
Portugal	mean	24.53	82.40	3.33	6.05	17.23	6.67
	st dev	6.42	12.64	0.77	0.36	6.32	3.26
Slovak Republic	mean	70.07	70.30	4.46	8.34	21.45	55.27
	st dev	22.19	11.36	1.35	1.61	5.11	40.26
Slovenia	mean	25.80	63.08	4.58	8.87	16.52	36.98
	st dev	9.51	8.53	1.06	1.32	7.27	19.14
Spain	mean	5.60	74.13	2.06	6.90	23.78	60.08
	st dev	1.06	7.57	0.15	0.85	7.46	25.03
Sweden	mean	1.73	94.49	3.40	5.17	25.72	32.24
	st dev	0.46	0.93	0.49	0.53	7.15	3.15
United Kingdom	mean	50.33	48.76	2.73	6.70	18.38	38.08
	st dev	4.64	13.54	n.a.	1.61	6.32	5.40
United States	mean	21.33	28.11	n.a.	9.65	20.22	19.61
	st dev	5.23	5.45	n.a.	0.95	7.49	5.28

Source: calculations on Global Financial Development Database, World Bank.

Table A5 Macroeconomic environment variables

		GDP per capita	Output gap	General government expenditure	Trade openness
Australia	mean	2.11	0.07	35.02	2.49
	st dev	1.18	0.54	1.41	0.57
Austria	mean	1.71	0.07	51.92	6.56
	st dev	2.01	1.69	2.26	1.34
Belgium	mean	1.43	0.09	50.46	13.95
	st dev	1.83	1.16	1.63	3.01
Canada	mean	1.55	0.32	41.49	4.72
	st dev	2.05	1.78	2.55	0.39
Czech Republic	mean	2.85	0.72	43.30	5.03
	st dev	3.22	2.97	2.26	2.13
Denmark	mean	0.97	0.24	55.04	6.43
	st dev	2.46	1.84	2.48	1.05
Estonia	mean	5.71	0.58	37.17	5.80
	st dev	7.10	6.31	4.21	1.36
Finland	mean	2.44	0.82	51.70	5.88
	st dev	3.67	2.70	3.79	0.96
France	mean	1.09	-0.54	53.51	4.03
	st dev	1.76	1.84	1.49	0.49
Germany	mean	1.06	-0.30	47.03	5.15
	st dev	2.13	1.64	1.70	1.09
Greece	mean	2.62	1.71	46.57	2.48
	st dev	2.33	4.83	3.02	1.09
Hungary	mean	2.63	0.69	49.32	5.36
	st dev	3.11	2.89	1.68	1.86
Iceland	mean	2.35		44.64	5.55
	st dev	3.73		2.30	1.15
Ireland	mean	3.85	0.81	38.26	9.17
	st dev	5.21	2.86	8.72	0.68
Israel	mean	1.65		47.96	3.83
	st dev	2.43		3.50	0.57
Italy	mean	0.45	0.71	48.67	3.38
	st dev	2.30	1.73	1.74	0.67
Korea, Rep.	mean	3.79		19.58	3.85
	st dev	3.90		2.41	0.85
Netherlands	mean	1.82	0.24	46.81	10.18
	st dev	2.24	1.64	2.06	2.22
Norway	mean	1.62	0.32	44.27	5.70
	st dev	1.99	1.25	2.99	0.80

- cont. -

Table A5 Macroeconomic environment variables (cont.)

		GDP per capita	Output gap	General government expenditure	Trade openness
Poland	mean	4.54	0.64	44.25	2.59
	st dev	1.95	2.14	2.29	1.01
Portugal	mean	1.45	0.22	44.41	3.54
	st dev	2.24	1.51	3.00	0.56
Slovak Republic	mean	4.33	0.92	33.89	4.83
	st dev	3.79	2.61	4.48	2.42
Slovenia	mean	3.28	0.75	42.17	6.68
	st dev	3.68	3.19	2.08	1.75
Spain	mean	1.84	0.54	40.69	3.01
	st dev	2.29	2.10	2.73	0.46
Sweden	mean	1.96	0.48	55.47	6.21
	st dev	2.75	2.15	3.36	0.94
United Kingdom	mean	1.96	1.03	55.47	3.52
	st dev	2.60	1.78	3.36	0.33
United States	mean	1.51	-0.37	55.47	1.58
	st dev	2.04	2.45	3.36	0.16

Source: calculations on World Economic Outlook, International Monetary Fund.

Appendix B

Table B1. Technological change (percentage values)

	mean	min	max	st dev	1996	2010
Australia	1.50	1.04	2.05	0.31	1.04	2.05
Austria	1.57	1.22	1.78	0.18	1.22	1.78
Belgium	1.62	1.37	1.89	0.17	1.37	1.89
Canada	1.55	1.22	2.03	0.26	1.22	2.03
Czech Republic	-0.32	-0.73	0.03	0.24	-0.73	0.03
Denmark	1.22	0.69	1.85	0.35	0.69	1.85
Estonia	-3.05	-4.71	-1.70	0.99	-4.71	-1.70
Finland	1.13	0.89	1.48	0.19	0.92	1.48
France	2.06	1.78	2.44	0.21	1.78	2.44
Germany	2.27	1.87	2.52	0.21	1.87	2.52
Greece	-0.22	-1.14	0.54	0.54	-1.14	0.54
Hungary	-1.53	-2.24	-0.85	0.45	-2.24	-0.85
Iceland	0.53	-0.33	1.29	0.50	0.30	1.29
Ireland	1.62	0.87	2.59	0.54	0.87	2.59
Israel	0.16	-0.01	0.42	0.10	-0.01	0.42
Italy	2.07	1.84	2.29	0.14	1.84	2.29
Korea	0.64	-0.06	1.18	0.37	-0.06	1.18
Netherlands	1.44	1.12	1.83	0.22	1.12	1.83
Norway	1.77	1.43	2.17	0.23	1.43	2.17
Poland	-1.34	-3.17	-0.06	0.96	-3.17	-0.06
Portugal	0.95	0.55	1.56	0.36	0.60	1.56
Slovak Republic	-0.22	-1.04	0.53	0.48	-1.04	0.53
Slovenia	2.33	1.69	3.02	0.44	3.02	1.69
Spain	1.34	1.04	1.88	0.26	1.04	1.88
Sweden	1.37	0.26	2.29	0.63	0.26	2.29
United Kingdom	1.32	0.79	1.87	0.34	0.79	1.87
United States	2.46	1.87	2.96	0.35	1.87	2.96

Note: All the data are in percentage values.

Table B2. Efficiency levels (percentage values)

	mean	min	max	st dev	1996	2010
Australia	94.34	93.43	94.83	0.39	93.43	94.17
Austria	90.73	87.05	93.41	2.16	87.06	92.95
Belgium	94.32	93.06	95.09	0.55	94.48	93.06
Canada	95.56	95.16	95.88	0.24	95.27	95.40
Czech Republic	50.68	40.84	64.22	8.72	41.37	64.22
Denmark	96.73	96.02	97.05	0.27	96.93	96.23
Estonia	87.66	81.16	91.38	2.74	87.58	85.13
Finland	94.58	90.00	96.62	1.95	90.00	96.44
France	92.73	91.15	94.62	1.04	92.10	91.58
Germany	90.09	86.09	92.35	2.06	92.35	86.09
Greece	89.63	87.93	92.31	1.55	87.93	89.67
Hungary	73.00	62.09	82.42	7.12	62.09	80.62
Iceland	93.05	84.70	97.08	3.02	96.99	84.70
Ireland	94.15	89.66	96.81	2.28	89.66	95.11
Israel	87.86	81.79	94.28	4.63	81.79	93.85
Italy	85.27	80.87	88.53	2.18	88.53	82.77
Korea	60.46	50.13	73.59	7.41	51.23	73.59
Netherlands	95.09	94.24	95.87	0.45	95.16	95.59
Norway	97.83	97.69	98.00	0.10	97.77	97.69
Poland	57.91	54.64	61.65	2.18	61.65	60.70
Portugal	49.94	48.19	52.38	1.09	49.59	48.96
Slovak Republic	45.83	39.60	54.87	5.45	39.60	54.87
Slovenia	31.11	22.79	40.91	6.40	22.79	40.91
Spain	84.49	79.52	89.48	4.34	89.48	79.99
Sweden	94.88	91.98	96.14	1.11	96.14	93.42
United Kingdom	96.39	95.74	97.05	0.41	95.74	96.52
United States	96.44	95.22	96.82	0.49	95.63	95.69

Note: the scores are in percentage, so 100 means that the country is on the frontier and therefore reaches a maximum efficiency.

Robustness checks

Table B3. Technological innovation (model 2)

	mean	min	max	st dev	1996	2010
Australia	1.40	0.93	1.94	0.31	0.93	1.94
Austria	1.49	1.15	1.70	0.18	1.15	1.70
Belgium	1.54	1.29	1.81	0.17	1.29	1.81
Canada	1.43	1.10	1.91	0.26	1.10	1.91
Czech Republic	-0.42	-0.84	-0.06	0.24	-0.84	-0.06
Denmark	1.15	0.62	1.79	0.35	0.62	1.79
Estonia	-3.11	-4.78	-1.74	0.99	-4.78	-1.74
Finland	1.07	0.82	1.42	0.20	0.86	1.42
France	1.93	1.65	2.32	0.21	1.65	2.32
Germany	2.13	1.73	2.38	0.21	1.73	2.38
Greece	-0.31	-1.24	0.46	0.55	-1.24	0.46
Hungary	-1.64	-2.34	-0.95	0.46	-2.34	-0.95
Iceland	0.54	-0.33	1.30	0.51	0.33	1.30
Ireland	1.57	0.82	2.54	0.54	0.82	2.54
Israel	0.09	-0.08	0.34	0.10	-0.08	0.34
Italy	1.94	1.71	2.17	0.14	1.71	2.17
Korea	0.50	-0.20	1.04	0.37	-0.20	1.04
Netherlands	1.34	1.02	1.73	0.22	1.02	1.73
Norway	1.72	1.37	2.12	0.23	1.38	2.12
Poland	-1.49	-3.33	-0.19	0.97	-3.33	-0.19
Portugal	0.86	0.46	1.48	0.37	0.51	1.48
Slovak Republic	-0.29	-1.12	0.47	0.49	-1.12	0.47
Slovenia	2.31	1.66	3.01	0.45	3.01	1.66
Spain	1.21	0.92	1.76	0.26	0.92	1.76
Sweden	1.29	0.17	2.22	0.64	0.17	2.22
United Kingdom	1.18	0.64	1.74	0.34	0.64	1.74
United States	2.28	1.69	2.78	0.36	1.69	2.78

Note: the estimated variable Technological Change is expressed in percentage.

Table B4. Technological innovation (model 3)

	mean	min	max	st dev	1996	2010
Australia	1.53	1.06	2.09	0.32	1.06	2.09
Austria	1.61	1.25	1.82	0.18	1.25	1.82
Belgium	1.66	1.40	1.93	0.18	1.40	1.93
Canada	1.58	1.24	2.07	0.26	1.24	2.07
Czech Republic	-0.33	-0.75	0.04	0.24	-0.75	0.04
Denmark	1.26	0.71	1.90	0.36	0.71	1.90
Estonia	-3.10	-4.80	-1.72	1.01	-4.80	-1.72
Finland	1.17	0.92	1.52	0.20	0.95	1.52
France	2.10	1.81	2.49	0.22	1.81	2.49
Germany	2.31	1.90	2.56	0.21	1.90	2.56
Greece	-0.22	-1.16	0.56	0.56	-1.16	0.56
Hungary	-1.57	-2.28	-0.87	0.46	-2.28	-0.87
Iceland	0.57	-0.31	1.34	0.51	0.34	1.34
Ireland	1.67	0.90	2.65	0.55	0.90	2.65
Israel	0.17	0.00	0.44	0.10	0.00	0.44
Italy	2.11	1.87	2.33	0.14	1.87	2.33
Korea	0.64	-0.07	1.19	0.38	-0.07	1.19
Netherlands	1.47	1.14	1.86	0.23	1.14	1.86
Norway	1.82	1.47	2.23	0.24	1.48	2.23
Poland	-1.38	-3.25	-0.07	0.98	-3.25	-0.07
Portugal	0.97	0.57	1.60	0.37	0.61	1.60
Slovak Republic	-0.21	-1.06	0.55	0.50	-1.06	0.55
Slovenia	2.40	1.74	3.11	0.45	3.11	1.74
Spain	1.36	1.06	1.92	0.26	1.06	1.92
Sweden	1.41	0.27	2.34	0.65	0.27	2.34
United Kingdom	1.33	0.79	1.90	0.34	0.79	1.90
United States	2.49	1.89	3.00	0.36	1.89	3.00

Note: the estimated variable Technological Change is expressed in percentage.

Table B5. Technological innovation (model 4)

	mean	min	max	st dev	1996	2010
Australia	-0.77	-1.73	0.36	0.64	-1.73	0.36
Austria	0.14	-0.63	0.57	0.39	-0.63	0.57
Belgium	0.19	-0.29	0.74	0.36	-0.29	0.74
Canada	-1.05	-1.70	-0.02	0.53	-1.70	-0.02
Czech Republic	-4.43	-5.40	-3.62	0.55	-5.40	-3.62
Denmark	-0.38	-1.59	1.09	0.80	-1.59	1.09
Estonia	-9.06	-12.89	-5.90	2.27	-12.89	-5.90
Finland	-0.46	-0.98	0.31	0.42	-0.86	0.31
France	-0.26	-0.84	0.59	0.46	-0.84	0.59
Germany	-0.09	-1.00	0.43	0.47	-1.00	0.43
Greece	-4.09	-6.16	-2.35	1.22	-6.16	-2.35
Hungary	-7.05	-8.63	-5.47	1.04	-8.63	-5.47
Iceland	0.28	-1.82	1.93	1.18	0.20	1.93
Ireland	0.91	-0.58	3.08	1.15	-0.58	3.08
Israel	-2.74	-2.99	-2.29	0.18	-2.99	-2.29
Italy	-0.13	-0.60	0.35	0.29	-0.60	0.35
Korea	-3.47	-5.04	-2.28	0.81	-5.04	-2.28
Netherlands	-0.77	-1.39	0.09	0.46	-1.39	0.09
Norway	1.04	0.29	1.90	0.50	0.33	1.90
Poland	-7.73	-11.98	-4.78	2.22	-11.98	-4.78
Portugal	-1.51	-2.43	-0.10	0.82	-2.23	-0.10
Slovak Republic	-3.55	-5.46	-1.84	1.10	-5.46	-1.84
Slovenia	3.07	1.53	4.71	1.06	4.71	1.53
Spain	-1.61	-2.08	-0.42	0.51	-2.08	-0.42
Sweden	-0.40	-2.92	1.68	1.43	-2.92	1.68
United Kingdom	-2.08	-3.25	-0.82	0.75	-3.25	-0.82
United States	-0.75	-2.04	0.40	0.79	-2.04	0.40

Note: the estimated variable Technological Change is expressed in percentage.

Table B6. Efficiency levels (model 2)

	mean	min	max	st dev	1996	2010
Australia	93.99	92.91	94.55	0.45	92.91	93.75
Austria	89.86	85.78	92.93	2.43	85.79	92.34
Belgium	94.32	93.13	95.11	0.52	94.46	93.13
Canada	95.33	94.88	95.71	0.29	94.90	95.14
Czech Republic	51.25	41.12	65.14	8.97	41.63	65.14
Denmark	96.63	95.80	96.96	0.32	96.87	96.01
Estonia	88.31	81.87	92.00	2.73	87.80	85.84
Finland	94.42	89.00	96.66	2.23	89.00	96.45
France	92.84	91.58	94.81	1.03	92.37	91.99
Germany	89.13	85.16	91.47	2.09	91.47	85.16
Greece	90.44	88.84	92.92	1.43	88.84	90.37
Hungary	74.27	62.89	83.87	7.35	62.89	82.08
Iceland	92.36	82.52	96.96	3.52	96.89	82.52
Ireland	93.94	88.53	96.64	2.48	88.53	94.58
Israel	88.23	82.01	94.63	4.67	82.01	94.18
Italy	85.52	81.21	88.60	2.08	88.60	83.15
Korea	60.99	50.38	74.37	7.58	51.52	74.37
Netherlands	94.87	93.93	95.72	0.50	94.89	95.39
Norway	97.79	97.60	97.96	0.11	97.73	97.60
Poland	59.02	55.70	62.62	2.19	62.62	61.86
Portugal	49.98	48.16	52.66	1.24	48.50	48.91
Slovak Republic	46.10	39.81	55.10	5.48	39.81	55.10
Slovenia	30.46	22.07	40.31	6.43	22.07	40.31
Spain	84.79	79.96	89.49	4.13	89.49	80.37
Sweden	94.53	91.00	96.04	1.36	96.04	92.66
United Kingdom	96.35	95.61	97.05	0.45	95.61	96.48
United States	96.44	95.40	96.93	0.47	95.40	95.93

Note: the scores are in percentage, so 100 means that the country is on the frontier and therefore reaches a maximum efficiency.

Table B7. Efficiency levels (model 3)

	mean	min	max	st dev	1996	2010
Australia	94.29	93.33	94.77	0.40	93.33	94.16
Austria	90.57	86.78	93.35	2.24	86.81	92.93
Belgium	94.32	93.18	95.11	0.52	94.47	93.18
Canada	95.54	95.12	95.86	0.24	95.23	95.41
Czech Republic	50.91	40.88	64.83	8.91	41.40	64.83
Denmark	96.71	96.00	97.03	0.27	96.90	96.22
Estonia	87.98	81.92	91.69	2.66	87.62	85.90
Finland	94.46	89.84	96.61	2.00	89.84	96.39
France	92.68	91.14	94.55	1.03	91.99	91.58
Germany	89.92	86.08	92.21	2.03	92.21	86.08
Greece	89.82	88.03	92.52	1.59	88.03	90.07
Hungary	73.49	62.22	83.17	7.36	62.22	81.55
Iceland	92.98	84.77	97.06	3.01	96.97	84.77
Ireland	94.08	89.50	96.78	2.32	89.50	95.08
Israel	88.04	81.90	94.46	4.66	81.90	94.08
Italy	85.26	81.01	88.49	2.11	88.49	82.96
Korea	60.75	50.24	74.22	7.57	51.35	74.22
Netherlands	95.04	94.16	95.85	0.48	95.09	95.59
Norway	97.82	97.68	97.99	0.10	97.76	97.68
Poland	58.43	55.05	62.10	2.26	62.10	61.47
Portugal	49.99	48.33	52.39	1.05	49.58	49.13
Slovak Republic	45.95	39.59	55.21	5.56	39.59	55.21
Slovenia	31.10	22.80	41.01	6.42	22.80	41.01
Spain	84.63	79.85	89.46	4.20	89.46	80.35
Sweden	94.83	91.89	96.10	1.12	96.10	93.37
United Kingdom	96.38	95.70	97.05	0.43	95.70	96.54
United States	96.41	95.20	96.79	0.49	95.60	95.69

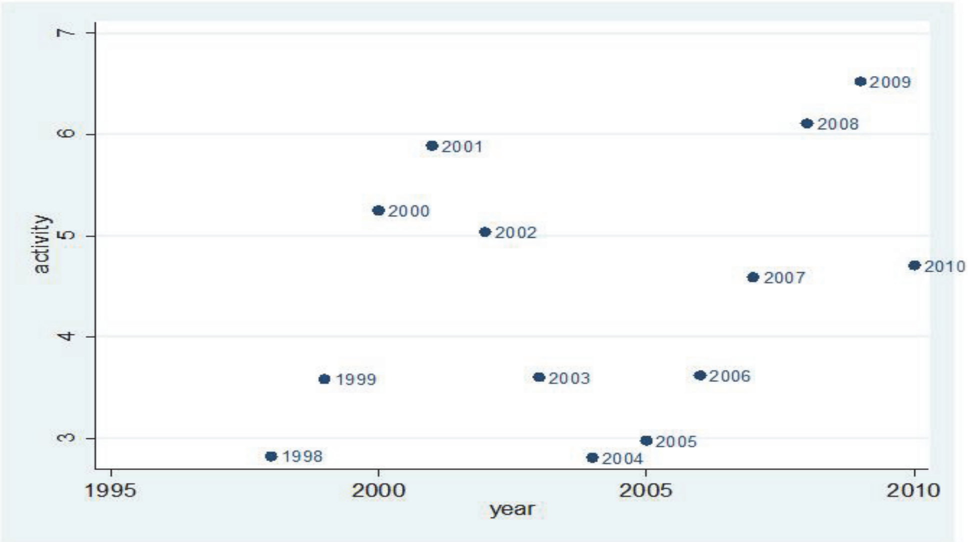
Note: the scores are in percentage, so 100 means that the country is on the frontier and therefore reaches a maximum efficiency.

Table B8. Efficiency levels (model 4)

	mean	min	max	st dev	1996	2010
Australia	86.33	81.00	89.14	2.67	81.00	81.79
Austria	82.24	75.35	85.75	3.17	75.35	80.54
Belgium	87.80	82.91	89.53	1.77	87.21	82.91
Canada	88.64	82.91	91.13	2.69	82.91	85.41
Czech Republic	52.54	36.65	68.96	11.96	36.65	68.96
Denmark	92.39	88.54	93.70	1.69	91.23	88.54
Estonia	72.16	60.14	83.15	6.86	60.14	71.76
Finland	86.53	76.10	91.86	4.54	76.10	88.65
France	84.80	78.59	87.20	2.65	82.30	78.59
Germany	79.14	73.55	81.42	2.47	79.53	73.55
Greece	86.97	77.53	91.74	4.31	77.53	87.11
Hungary	80.63	58.54	91.78	11.63	58.54	90.79
Iceland	84.28	71.37	96.88	8.00	95.37	76.03
Ireland	88.37	76.36	94.30	5.66	76.36	89.82
Israel	78.66	63.55	91.00	9.28	63.55	89.00
Italy	80.95	74.09	84.10	3.07	81.87	74.71
Korea	66.45	52.36	78.26	9.13	52.58	78.26
Netherlands	88.65	86.06	90.59	1.32	86.06	87.33
Norway	96.26	94.33	96.81	0.72	96.32	94.33
Poland	87.94	82.79	95.77	4.12	95.77	82.79
Portugal	46.73	43.40	49.63	2.04	43.40	43.94
Slovak Republic	41.95	31.99	51.79	6.45	31.99	49.90
Slovenia	37.52	35.75	39.85	1.16	39.85	36.12
Spain	79.14	72.50	82.08	2.85	76.90	72.50
Sweden	86.90	77.47	89.62	3.98	86.64	78.51
United Kingdom	94.39	91.36	95.81	1.31	91.36	93.45
United States	92.16	87.21	94.03	2.14	91.56	87.48

Note: the scores are in percentage, so 100 means that the country is on the frontier and therefore reaches a maximum efficiency.

Figure B1. Market activity in the United States



Note: This graph provides a clear evidence of how financial crises affect some variables. For example, the variable activity (but the same reasoning applies for other variables) which measures the financial system's activity level is driven by the two crises which occurred in the time period considered (dotcom bubble and Lehman´s failure). Using this variable in a second stage regression in order to detect the effect of financial activity on technological change would have distorted the results due to exogenous shocks which have led this explanatory variable.

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