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How important are capital controls in shaping innovation activity?

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ABSTRACT

This paper studies the role of capital controls in shaping innovation activity through the finance of R&D investment. The paper offers insights into the real effects of financial sector on the economy. It first asks whether capital controls shape innovation activity, both from the input (R&D) and output (patents) side. Based on a large dataset that includes 53 developed and emerging countries over the period 1996–2016 and a fixed effects identification and appropriate instrumentation strategy, results support a robust inverse U-shaped relationship between capital controls and R&D. Capital restrictions can be beneficial for R&D investment till a certain point and thereafter have detrimental negative effects, particularly for patents. Second, it asks whether the composition of restrictions of individual assets in the aggregate capital control index matters. We find equity-based finance restrictions greatly shape innovation activity, whereas controls on credit (bank) and direct investment assets exert no effect.

1. Introduction

Innovation is the essential driver of economic progress that benefits consumers, businesses and the economy as a whole (Romer, 1986; Grossman and Helpman, 1991). To the extent technological knowledge spills across firms and countries, innovation is also a key factor in shaping income inequality across regions and countries (Saxenian, 1994; Swann et al., 1998; Verspagen, 1999; Coe et al., 2009).

An important input of innovation is research and development (R&D), which highly depends on finance and therefore is susceptible to financial frictions. However, financing R&D activity is not always easy. From the perspective of investment theory, R&D has a number of characteristics that make it different from ordinary investment. It involves high probability of failure as the whole process is long, idiosyncratic and unpredictable with many future contingencies that are hard to foresee (Holmstrom, 1989; Brown and Petersen, 2009; Brown et al., 2012). It also has high adjustment costs (Hall et al., 1986; Lach and Schankerman, 1988); more than half of a firm's R&D spending includes both wages and salaries of highly educated scientists and engineers (Hall et al., 1986) and their efforts create an intangible asset, the firm's knowledge base from which profits in future years are generated. This resource base, however, disappears when researchers leave or are fired, as projects often take a long time between conception and commercialization, and therefore, firms tend to smooth their R&D spending over time to avoid having to lay off knowledge workers. A stable source of cash flow is, therefore, vital to perform R&D

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investments that must be sustained at a certain level in order to be productive. Further, innovative projects are usually difficult to evaluate, as information about their prospects is either sparse or hard to process. Banks and other debt-holders are often reluctant to lend when projects involve substantial R&D investment compared to investments in plant and equipment and prefer to use physical assets to secure loans. Bank finance is even harder for new entrants, startups and innovative firms that have unstable and limited amounts of internally generated cash flows to service debt (Hall and Lerner, 2010; Brown et al., 2012).

International capital mobility allows countries with limited savings to attract financing for productive investment projects and thereby provides a solution to firms funding gap. For many years, the prevailing view among economists has been that free capital mobility brings many potential welfare gains, such as reduction of the cost of capital (Stulz, 1999; Chari and Henry, 2004a), increase of investment (Rajan and Zingales, 1998; Forbes, 2007a), economic growth (Chari and Henry, 2004a, b, 2008), and international diversification gains for foreign investors (Adler and Dumas, 1983; French and Poterba, 1991; Brennan and Cao, 1997), whereas financial restrictions are nearly bad.[1] Other studies argue that capital controls are irrelevant when dealing with real economic crises and particularly with output and exchange rate fluctuations (Klein, 2012; Fernandez et al., 2013, 2015). However, this decades-long view has begun to shift, especially after the currency crisis in the middle of 2000 and the 2008 global financial crisis, and capital controls made an intellectual comeback becoming part of the policy discussion.

After long urging countries to free the movement of capital, the International Monetary Fund (IMF) surprised economic policy makers by endorsing and even recommending the imposition of capital controls, in some cases, when countries have few other options (Blanchard and Ostry, 2012).[2] The experience of a handful of advanced economies, which were entirely open to global capital flows and were hit hard by the global financial crisis, contributed to the reconsideration and implementation of capital controls by the IMF and policy makers.[3] Other prominent calls have gone further towards a greater acceptance of the use of capital controls as a regular policy tool (Jeanne et al., 2012; Rey, 2015). Some of these policy prescriptions are consistent with a new branch of theoretical research in which capital controls contribute to financial stability and macroeconomic management (Jeanne and Korinek, 2010; Bianchi, 2011; Benigno et al., 2013; 2014) and, therefore, restrictions to capital mobility are desirable, especially over the short run (Bhagwati, 1998; Rodrik, 2000).

Thus far, relevant research has mainly focused on the effects of capital controls on macroeconomic aggregates, namely exchange rates, inflation, public debt and economic growth (Schmidt, 2001; Klein, 2012; Mitchener and Wandschneider, 2015; Fernandez et al., 2013, 2015). The extent to which policymakers should limit foreign capital mobility remains a controversial issue as the empirical evidence is rather mixed, in general, and extremely thin on the relationship between capital controls and innovation activity. The financing of R&D, however, is an important channel that links the financial and real economy sector; financial barriers that affect R&D funding also affect economic growth.

This paper studies how capital controls shape countries' innovation activity. First, it aims to contribute to the evolving debate on the impact of international capital controls on economic growth focusing on the channel of innovation and particularly on R&D financing. We model R&D investment as a function of capital restrictions, among other controls, and by applying a fixed effects identification strategy and instrumentation techniques, we obtain the effect of capital controls on R&D investment. Then, we estimate a typical R&D-based endogenous growth model (Ha and Howitt, 2007; Ang and Madsen, 2011), where new knowledge (ideas) -the output of innovation production process, proxied by the number of patents (Jaffe, 1986)- are generated using existed technological knowledge and new R&D investment. Capital controls affect the generation of new ideas through the financing of the main input of innovation, the R&D investment.

To unfold their effects, the paper employs a new dataset that differentiates among asset categories, allowing thus a more detailed analysis than with most other capital control databases and indices. This aspect of the database allows us to further contribute to the recently emerged financial development and innovation literature and study the effects of restrictions on individual assets, namely equity and credit (debt), which are important channels of the financial sector and most relevant for firms to fund their innovation activity. Further, technology generated abroad can reach a country through foreign direct investment that takes the form of multinational enterprises (MNEs) and their affiliates. MNEs are a major force conducting cuttingedge research and consequently, limiting the openness of the local economy to MNEs, through controls on direct investment assets, may have potential consequences on innovation performance of the host country. Therefore, as access to finance is of upmost importance for nurturing technological innovation, as well as access to foreign advanced technology, a relevant question in this respect is that, should the government decide to restrict the international capital mobility, on what particular asset it should set controls on so that innovation activity would not be harmed.

[1] These views are best reflected in Dornbusch (1998) "Capital Controls: An Idea Whose Time is Gone.".

[2] Capital controls take the form of rules, taxes or fees associated with financial transactions that discriminate between domestic residents and those outside the country (OECD, 2019). They can be administrative or market-based measures. The former include outright prohibitions on foreign borrowing or lending, quantitative limits on these transactions, and the requirement that international capital transactions first receive government approval, while the latter include taxes on crossborder capital transactions, differential bank reserve requirements for resident and non-resident accounts, and the requirement that some proportion of capital inflows be deposited in a non-interest bearing account at a central bank.

[3] Iceland and Spain both experienced deep recessions when the foreign investment that had driven booms in their economies evaporated. Similar lessons were drawn during the Eurozone crisis. Greece and Cyprus, both facing sudden outflows over fears that their banks would fail, put strict restrictions of bank transfers to stop money from leaving. Even Swiss policymakers spoke of the possible use of controls on capital inflows as the franc strengthened against the euro and the dollar (Financial Times, 2012).

Our paper offers new insights into the real effects of financial sector and mainly contributes to two streams of literature. First, it relates to a literature strand that examines the effects of capital controls on a country's macroeconomic aggregates and performance.[4] This literature raises concerns about the effectiveness of capital controls and their potential costs pointing that capital controls tend to favor distortions in domestic policy (Alesina et al., 1993), limit the effectiveness of monetary policy (Mitchener and Wandschneider, 2015) and are prone to corruption (Schmidt, 2001).[5] In a similar vein, Klein (2012) finds little evidence of the efficacy of capital controls on the growth of financial variables, the real exchange rate, or GDP growth. In contrast, the study of Gupta et al. (2007) shows that the use of capital controls was associated with avoiding some of the worst growth outcomes associated with financial fragility. Other studies, however, find that the direction of the optimal responses of capital controls during a crisis will depend on the exchange rate regime (Devereux and Yu, 2019) and the implementation of both capital controls and managed exchange regimes can be optimal while maintaining domestic monetary policy sovereignty (Choi, 2019). Further recent evidence on the effectiveness of capital controls in insulating an economy from the international financial system and shifting capital flows to other countries, in a deflection effect generating multinational externalities on the welfare in other countries, is at best mixed (Boero et al., 2019; Fan et al., 2020). A thin micro-based evidence also delivers diverse findings as to the effects of capital restrictions on firm's real investment and financial activity.[6] Our paper focuses on innovation -the major driver of growth- and particularly investigates a very specific channel that links financial sector and economic growth; the finance of the most important input of innovation, R&D. Motivated by the lack of evidence on innovation performance, our paper contributes to the literature by studying the effect of international capital restrictions on a country's innovation input (R&D) and output (patents). Our study may abstract from heterogeneity at the firm level, which could be a potential caveat compared to event studies (Johnson and Mitton, 2003; Forbes, 2007a; Alfaro et al., 2017), but employs appropriate econometric estimation techniques and a rich database to perform a comprehensive analysis for a wide set of countries.

Second, our paper contributes to the emerging literature on finance and innovation. Moral hazard is present in R&D investments because of the separation of ownership (investors) from managers (those investing in R&D), generating principal-agent problems when goals are inconsistent.[7] Therefore, a central issue in the innovation-finance literature is the effect of different forms of financial development, namely direct or market-based (e.g., stock-market capitalization and bond-market capitalization) or arm's length finance versus intermediated (e.g., liquid liabilities and private credit) or relationship-based finance on innovation performance. Particularly, some argue that bank lending is most likely to support efforts of within-term monitoring and consequently private credit is the most direct means of monitoring and information revelation (Kerr and Nanda, 2015). Similarly, equity financing, especially when is more concentrated share ownership, bears strong incentives for investors to investigate and monitor the R&D programs of firms issuing stock. Others argue that a more diversified pool of investors, which may occur with both diffuse stock issuance and bond financing, also allows for greater diversity of opinions that can be beneficial for investment in new or uncertain technologies.[8] Our paper aims to contribute to this literature by exploiting an untapped aspect of the database we use that allows one to delve deeper into individual assets and estimate the separate effects of credit (debt) and equity restrictions on R&D financing and, in turn, on patents, for a large panel of countries across the world. We also remotely relate to the literature strand that studies knowledge diffusion via the channel of foreign direct investment (Grossman and Helpman, 1991; Aghion and Tirole, 1994; Maskus et al., 2012) as we also explore the effects of restrictions of direct investment on innovation. By using an untapped aspect of a newly developed database, our paper is able to distinguish the separate effect of controls of these aforementioned finance channels on both innovation input and output contributing thus to the debate on the relative importance of various types of finance channels on real economy.

Our empirical analysis is based on a sample of 53 countries, developed, emerging and developing, for which innovation data were available and with various degrees of capital restrictions over the period 1996–2016 with two key questions in mind: (i) How important are capital controls in shaping R&D activity? and (ii) What type of asset restriction, in particular, harms innovation the most?

The evidence we provide is straightforward. Financing constraints do matter for R&D investment. Contrary to nuance evidence on the impact of capital controls on macroeconomic aggregates, we document an unambiguous finding: a robust

[4] See Forbes (2007b) and Satyanath and Berger (2007) for extensive reviews of the theoretical and empirical literature.

[5] Eichengreen and Rose (2014) present a thorough discussion on capital controls in modern economies and suggest that such measures should be used as a last resort, only when first-best policies have been exhausted.

[6] For example, Harrison et al. (2004) show that by lifting capital controls countries experience the positive benefits predicted by economic theory. In contrast, Alfaro et al. (2017) study the effects of capital controls on firm-level stock returns and real investment. Bringing evidence from Brazil, they find that capital controls increased the cost of capital, reduced the availability of external financing and lower firm-level investment. Similarly, Forbes (2007a) examines the impact of capital controls, as opposed to the benefits of liberalization, using Chilean data from the 1990s and shows that, during the Chilean encaje, small traded firms experience significant financial constraints. A different perspective is offered from Johnson and Mitton (2003) who argued that despite the potential costs, the imposition of restrictions on capital flows limited cronyism in Malaysia, as capital resources were limited to politically connected and non-connected firms alike.

[7] Particularly relevant in this context is the tendency of risk-averse managers to invest too little in uncertain and longer-term R&D projects when, for example, shareholders and institutional owners might prefer more risk (Ang and Madsen, 2012).

[8] The evidence is rather diverse with some studies to support a positive role of credit markets (Nanda and Nicholas, 2014) or private ownership (Bernstein, 2015) for innovation level and quality, while others point at the major role of external equity in financing R&D (Brown and Petersen, 2009; Brown et al., 2012; Hsu et al., 2014). The importance of both equity and credit markets to increase innovation level is documented by Bravo-Biosca (2007) with equity markets to be associated with more radical innovation, whereas Maskus et al. (2019) find that bond financing is particularly useful for allocating innovative capital where financial markets already efficiently fund R&D, permitting more arm's-length transactions. For a discussion on the the different types of financing innovation, consult, Kerr and Nanda (2015) and Maskus et al. (2019).

inverse U-shaped effect of capital restrictions on innovation activity. Capital controls do not impede R&D activity till a certain level, but thereafter, they have negative effects, which are particularly detrimental for the output of the innovation production, patents. Further, restrictions on different types of capital assets have also different implications for innovation, with capital controls on equity assets to be by far the most significant ones.

Our evidence certainly does not advocate the re-imposition of controls by countries that already have largely open capital accounts. In presence of macroeconomic and prudential policy challenges, countries which resort to capital control implementation should be cautious with the level of restrictions - particularly, on equity assets. Controls on these assets have the largest negative impact on R&D activity as well as on patents and serve as a transmission channel of the negative consequences of financial restrictions on the real economy. However, if there is high availability of venture capital investment, equity controls become of less importance.

The remainder of the paper proceeds as follows. Section 2 introduces the framework of our analysis. Section 3 presents the data. Section 4 discusses the results. Section 5 summarizes the findings and concludes.

2. Analytical framework

This section lays out the theoretical background, the specification(s) under estimation, and the econometric framework of our empirical analysis.

2.1. Theoretical background and empirical specification

The recent advancement of endogenous growth theory has been the emergence of R&D-based models of economic growth. At the very heart of these models is the technological knowledge (or ideas) production function that describes the evolution of technological knowledge creation.

A simplified version of endogenous growth models assumes that output, Y, in country i at time t is produced by using labor, L, and knowledge stock -accumulation of ideas that have been invented or developed by people- A. There are two sectors, the goods sector that produces output and the R&D sector that produces new knowledge. Labor is fixed, but it can be freely allocated to either of the two sectors, to produce output or to produce new knowledge.

New technological knowledge, ideas, are generated in the R&D sector. Then, $\dot{A}$ represents the flow of new knowledge or the number of new ideas generated in the economy at a point in time. New ideas are produced by researchers, L_A, according to the following production function:

$$\dot{A} = \tilde{\delta} L_A \tag{1}$$

where $\tilde{\delta}$ denotes (average) research productivity and is modeled as a function of the existing stock of knowledge (A) and the number of researchers (L_A) according to:

$$\tilde{\delta} = \delta \mathrm{A}^{\varphi} L_{\mathrm{A}}^{\lambda-1} \tag{2}$$

where $\delta > 0$, φ is the returns to scale in knowledge ($\varphi > 0$, ideas in the past may facilitate the discovery or creation of ideas in the present indicating a positive "spillover of knowledge" to future researchers; $\varphi < 0$, the most obvious ideas might have been discovered first and new ideas become harder to find over time), and λ is duplication parameter (0, if all innovations are duplications and 1, if there is no duplicating innovations) - all constant parameters.[9]

Taken together, equations (1) and (2) suggest the following knowledge (or ideas) production function:

$$\dot{A} = \delta \mathrm{A}^{\varphi} L_{\mathrm{A}}^{\lambda} \tag{3}$$

Dividing by the stock of knowledge, A, and by taking logs, equation (4) yields:

$$ln\left(\frac{\dot{A}}{A}\right) = (\varphi - 1)ln(A) + \lambda ln(L_A) \tag{4}$$

The parameter φ, as it has been noted above, is associated with the effect of the existing stock of knowledge, A (proxied by the past performance of patents), while L_A represents the efforts to acquire new technical knowledge through the intensity of domestic R&D expenditure. The growth rate of a country's innovation output, $ln\left(\frac{\dot{A}}{A}\right)$, could be proxied by the annual change of the (log) number of patent applications in the country. Two types of unobservable factors are considered: permanent and time-varying elements, assuming that $\upsilon_{i,t}$ has two orthogonal components, the fixed effects, ζ_i, and the white noice term, $\varepsilon_{i,t}$. Taking these into consideration, the resulting final estimating model adopts the following form:

[9] Overall, the restrictions imposed on φ and λ and existence of product proliferation relate to particular forms of knowledge production function and accordingly to different strands of endogenous growth theory. For a detailed discussion and empirical evidence on different 'generations' of endogenous growth theory models, consults Ha and Howitt (2007) and Ang and Madsen (2011).

$$\Delta lnPatents_{i,t} = \theta lnPatents_{i,t-1} + \lambda ln(R\&D/Q)_{i,t} + \zeta_i + \varepsilon_{i,t} \quad (5)$$

where, $\Delta lnPatents_{i,t}$ is the logarithmic transformation of the annual growth of patent applications[10] and $R\&D/Q$ represents private sector R&D expenditure over product variety (Q), which is proxied by the size of the economy's output (GDP). The latter, is a standard proxy for innovation input widely used in the literature (Feldman and Florida, 1994; Acs et al., 2002; Crescenzi et al., 2007).[11] It further captures the capacity of firms to 'absorb' innovation generated elsewhere (Cohen and Levinthal, 1989).

The realization, however, of R&D requires availability of (stable) funding. A number of studies have empirically documented that financial constraints have a detrimental impact on productivity growth (Aghion et al., 2010, 2012; Manaresi and Pierri, 2017; Duval et al., 2020). However, more recent studies show that negative shocks to credit can improve the allocation of resources by pushing the least productive firms to exit the market ('cleansing effect') so the remaining firms can improve their productivity and growth (Reis, 2013; Gopinath et al., 2017; Liu et al., 2019).

We model R&D investment as a function of past R&D performance, as innovation is cumulative and path-dependent, and also of financial restrictions (Bond and Meghir, 1994; Hsu et al., 2014). Specifically, we focus on restrictions on financial assets reflected on the strictness of capital controls (KC). To test for both negative and potential positive effects of the financial restrictions on innovation, as the literature has documented, capital controls enter in quadratic form as follows:

$$(R\&D/Q)_{i,t} = \beta_i + \beta_1 (R\&D/Q)_{i,t-1} + \beta_2 KC_{i,t-1} + \beta_3 KC^2_{i,t-1} + \beta_4 Z_{i,t-1} + \eta_{i,t} \quad (6)$$

where past performance of R&D ($(R\&D/Q)_{i,t-1}$) proxies for all past, relevant to innovation, policies and Z is a set of variables that describe the conditions which determine the rhythm at which a society adopts innovation and transforms it into real economic activity (Rodríguez-Pose, 1999). All variables are lagged one year to avoid potential endogeneity.

As access to finance is of upmost importance for nurturing technological innovation, an important question in this respect is that, should the government decide to restrict the international capital mobility, what particular asset should be restricted so that innovation activity would not be harmed? An advantage of the database we use is that provides information on capital restrictions for various individual assets that comprise the composite index of capital controls (KC) and therefore allows one to explore such issues. The pecking order theory (Ostry et al., 2010) has identified debt assets (short-term foreign and local) as the riskiest ones for a country's financial instability, followed by portfolio, and investment assets. The question is whether this order pertains when it comes to the riskiness of harming a country's innovation activity. We specifically focus on controls of credit (debt), equity, and direct investment assets and explore their individual effects both on R&D and patent activity.

According to the financial development literature, some of the important functions of the financial markets are to overcome information asymmetries, adverse selection, moral hazard problems and play an important role in facilitating risk taking, thereby, reducing a firm's cost of external capital. A central issue, therefore, is the effect of different forms of financial development, for example, direct or market-based or arm's length versus intermediated or relationship-based finance on innovation performance.

Arguably, equity financing of R&D could be more important for firms which are dependent on external finance as there are no collateral requirements and when additional equity is needed, equity financing would not increase a firm's financial distress (Brown et al., 2009). Also, under rational expectations, investors are able to extract the relevant yet noisy information from equilibrium prices (Grossman, 1976); therefore, investors feel more comfortable in relinquishing control of their savings (Levine, 2005). Further, equity markets facilitate the feedback effects of market security prices and therefore allow valuable information -which is scant and hard to comprehend for the case of innovative projects- about the prospects of firms' investment opportunities to affect managers' real investment decisions. Overall, equity financing, particularly if there is more concentrated share ownership, as occurs with institutional investors, bears strong incentives for investors to investigate and monitor the R&D programs of firms issuing stock.

Credit markets, in contrast, prefer to use physical assets instead of R&D investment to secure loans. This could be an obstacle for young, high-tech firms that own mainly intangible assets (for instance, knowledge assets that are generated by R&D investment and are partly embedded in human capital) to use debt to finance their innovation (Brown et al., 2009). Further, bank-serviced finance is hardly an option for firms that have unstable and limited amounts of internally generated cash flows to service debt (Brown et al., 2012). Also, banks, due to a lack of price signals, might continue financing firms, even for projects with negative returns (Rajan and Zingales, 2001) and therefore could inhibit the efficient flow of

[10] We measure the production output of new knowledge (ideas) using patents as observable as a well-grounded proxy for measuring technological innovations in the literature (Griliches, 1990; Trajtenberg, 1990; Eaton and Kortum, 1999). Let us note, however, that different industries have different propensities to patent and also not all new inventions are patented. In particular, process innovations have a significantly lower degree of patentability than product innovations. As a consequence, the use of a patent-based indicator as dependent variable may underestimate the effect of our explanatory variables on innovation in countries whose innovativeness is less measurable through patenting. However, the lack of comparable statistics on other measures of innovation, leaves no viable alternative. Measuring new knowledge indirectly by total factor productivity (TFP) comes also with some drawbacks: First, TFP combines knowledge as well as efficiency. For example, two economies with the same stock of knowledge may have quite different levels of TFP because one economy uses its resources more effectively than the other. Second, it is well known that the use of TFP is subject to measurement problems (Griliches, 1979; Aghion and Howitt, 1998).

[11] The variable $R\&D/Q$ could be a range of innovation-related indices depending on the endogenous growth paradigm. It could be the number of research workers (scientists) in Romer's model, or R&D spending (to GDP) in the semi-endogenous growth theory, or productivity-adjusted R&D input in the Schumpeterian (fully-endogenous) growth theory. Product variety (Q) is usually measured by the size of population or employment (Aghion and Howitt, 1998; Ha and Howitt, 2007) or by GDP (Krugman, 1989), or by the stock of trademarks (Madsen, 2008).

external finance to the most innovative projects (Beck and Levine, 2002). However, bank lending is likely to support efforts in upfront diligence and within-term monitoring and private credit could be the most direct means of monitoring and information revelation (Kerr and Nanda, 2015).

Bonds are regarded as the closest approximation to arm's-length finance among the aforementioned measures of financial development; this is not a sharp distinction from private equity, however. Bond financing is typically associated with unmonitored financing and may differ from bank loans and equity in this crucial element. Highly diffuse ownership, as is most typical of bond finance, are less innovative, implying that monitoring reduces moral hazard of this type and encourages investment in innovation (Francis and Smith, 1995).

All these different forms of financial development and their role in financing innovation are not always neatly compartmentalized, however (Allen et al., 2018). Eventually, it is an empirical issue and the literature offers diverse evidence on firms' strategies to fund innovation and the (level and quality of) innovation they perform. For example, Bernstein (2015) finds that going public significantly reduces firms' innovation quality. Meanwhile, Nanda and Nicholas (2014) show that bank distress, during the Great Depression, reduced both the quantity and quality of firm patenting, suggesting a positive role of credit markets in innovation. In contrast, Hsu et al. (2014) show that industries that are more dependent on external finance and that are more high-tech intensive exhibit a disproportionally higher innovation level in countries with better developed equity markets, while credit markets appear to discourage innovation in industries with these characteristics. Significant effects for varieties of both bank-based and market-based financial systems for financing innovation is also documented in Maskus et al. (2012) with the strongest effect for market-based (direct) forms of finance. Bravo-Biosca (2007) also supports the importance of both equity and credit markets to increase innovation level with equity markets to be associated with more radical innovation. Denis and Mihov (2003) find a negative relationship between R&D expenditures and the likelihood of issuing bonds. Firms that do issue bonds (relative to private credit) tend to be larger, more profitable, have a higher proportion of fixed assets, and spend less on R&D. In contrast, Altunbas et al. (2009) argue that bond markets may be particularly useful for financing activities that embody forward-looking expectations. Bond financing is found to particularly useful for allocating innovative capital where financial markets already efficiently fund R&D (Maskus et al., 2019).

Additionally to financing home-grown innovation, a country could adopt advanced technology through foreign direct investment (FDI) that takes the form of multinational enterprises (MNE) and their affiliates. Therefore, we further examine the effect of restrictions on foreign direct investment, which serves as a channel of technology diffusion across countries. FDI is an important vehicle in this respect as it supports more relationship-based R&D between parent enterprises and their affiliates with strong monitoring and managerial commitment and longer time horizons finance and less arm's-length lending which is important for innovation projects. Further, FDI may affect innovation capability of local indigenous firms through technological and managerial knowledge spillovers.[12]

To also address these issues, we replace the general index of capital controls (*KC*), in equation (6), with individual controls on financial credit and equity assets as well as on direct investment assets to obtain more insights about the effects of these types of controls on a country's innovation input (R&D) and output (patents).

A potential challenge we face, however, in our empirical attempt is to identify the causal effect of capital controls on innovation. We apply appropriate estimation techniques that are discussed in the next section.

2.1.1. Estimation

Our purpose is to estimate the effect of capital controls on R&D (equation (6)) and, through R&D, on patents (equation (5)). A way to do this is to treat both equations as a system and therefore apply Seemingly Unrelated Regression (SUR) estimation method. However, diagnostic tests (e.g., Breusch-Pagan test) support that error terms of both equations are uncorrelated and so we proceed in treating each equation separately. We begin by estimating equation (6) as the first stage of a two-stage estimation process - R&D acts as an endogenous variable in equation (5).

A potential challenge we face in our empirical attempt is to identify the causal effect of capital controls on R&D and, in turn, on patents. To confront this challenge, we take the following steps in our estimation approach. First, we allow for saturating sets of country- and time-specific fixed effects and country-specific time trends as several unobserved country characteristics might be correlated with both capital controls and innovation performance. Each of these effects control for different aspects and shocks in an economy. For example, the country fixed effects control for time-invariant characteristics and this implies identification from changes in capital controls on innovation activity. The year fixed effects control for annual unobserved shocks common to all countries in our sample while the country-specific time trends control for each country's domestic shock. Second, given all relevant control variables and fixed effects, omitted-variable bias is only possible in the presence of unobserved time-variant characteristics, which correlate with a change in both capital controls and innovation. To further insulate our analysis from the possibility of inconsistency and bias, and address concerns regarding endo-

[12] The literature identifies various ways through which FDI contributes to local innovation activity. First, R&D and other forms of innovation generated by foreign firms and R&D labs of MNEs increase contribute to the emergence of newer economies with more sophisticated technology generation (Athreye and Cantwell, 2007). Second, spillovers (knowledge transfers through the supply chain; skilled labour turnover; and demonstration effects) emanating from foreign innovation activities may affect the innovation performance in the region in which they locate (Grossman and Helpman, 1991; Griliches, 1992). Finally, in addition to greater R&D investments by MNEs and their affiliates, FDI may contribute to innovation capabilities by advanced practices and experiences in innovation management and thereby greater efficiency in innovation (Aghion and Tirole, 1994).

geneity, we additionally apply a two-step efficient generalized method of moments (GMM) estimator using appropriate instruments.

In equation (6), we instrument for our presumed endogenous variables: lagged R&D ($R\&D_{t-1}$) and capital controls (KC_{t-1} and CK_{t-1}^2). Among potential candidates are lagged values and differences of lagged values of the variables themselves. Going back in time, by taking lagged values, ensures that there is no feedback effect, as the past may influence the present but not the opposite. Additionally, we also use lagged values of institutions ($Institutions_{t-2}$ and $Institutions_{t-1}^2$) as commonly argued in the literature (Huang and Xu, 1999; La Porta et al., 2000; Coe et al., 2009). To further ensure the exogeneity of our instruments we construct the mean of the lagged value of the average R&D activity ($R\&D_{t-2}$) and capital controls (KC_{t-2}) of the neighboring countries. The political science literature discusses different channels that shape the behavior of neighboring countries: economic competition, common language, culture proximity, socialization, mimicking, coercion, spillovers and learning (Simmons and Elkins, 2004; Shipan and Volden, 2008; Buera et al., 2011). From an econometric point of view, R&D activity and capital controls of neighboring countries capture the exogenous source of variation in domestic R&D activity and domestic capital control policy.[13]

A set of instrument tests is performed to confirm that our instrumentation strategy is relevant. Specifically, we test the instrument validity by applying a Hansen J-test with the null hypothesis that the overidentifying restrictions are valid (i.e. that instruments are exogenous). To test for weak instruments (i.e., excluded instruments are correlated with the endogenous regressors, but only weakly), we report KleibergenPaap rk Wald F-statistics compared to their respective critical values. In addition, a Durbin-Wu-Hausman test for the exogeneity of the endogenous regressors is also reported, where a rejection of the null hypothesis indicates that instrumental variable techniques are required.

We also perform a set of diagnostic tests for the fitness of our specification. We apply a Kleibergen-Paap rk LM test under the null hypothesis that the model is underidentified (i.e., that the excluded instruments are correlated with the endogenous regressors). We use Arellano-Bond AR(1) to AR(3) tests, under the null hypothesis of no autocorrelation, to examine whether autocorrelation is present. We also test for crosssectional dependence across countries -caused by the presence of common factors, which are unobserved resulting in inefficient estimates (De Hoyos and Sarafidis, 2006)- by using the CD-test of Pesaran (2004) under the null hypothesis of no correlation. Finally, we evaluate the significance of quadratic term of capital controls (KC^2) by using a U test.

Equation (6) is estimated by using a two-step efficient GMM estimator (Baum et al., 2007) and thus, our instruments are less than the number of countries, avoiding a weak Hansen J-test.[14] The fitted values of equation (6) are then plugged into equation (5) and follow the same estimation process. To claim causal effects of capital controls on patents, we use again various fixed effects and GMM estimation using instruments for the endogenous variable ($lnPatents_{t-1}$) both in levels and differences of the lagged variable, as well as the two- period lagged values of institutions and the two-period lagged value of the average patents in the neighboring countries.

3. Data description and analysis

Our empirical analysis is based on annual data from 53 countries for the period 1996–2016. A list of all countries is presented in Table A.2 in the Appendix. We necessarily focus only on countries that report R&D expenditures and number of patent applications for the whole period of our investigation.

Our data come from a range of sources. Data on the input of innovation, research and development (*R&D*), and innovation output, patent applications (*Patents*), come from the World Bank, *World Development Indicators* (WDI).

Information on our capital controls index (*KC*) is derived from Fernandez et al. (2016), who developed a new dataset of capital restrictions for 100 countries over the period 1995 to 2017.[15] An attractive feature of this dataset is that offers a level of asset disaggregation that allows a more detailed analysis of capital controls than with most other capital controls indices.[16] Specifically, there is detailed information on restrictions of ten different categories of assets: equities (*eq*), bonds (*bo*), money market instruments (*mm*), collective investments (*ci*), derivatives (*de*), financial credits (*fc*), direct investment (*di*), commercial

[13] The average values of the same variable in neighboring countries has been conventionally used as an instrument in the literature in various contexts, for example, to instrument for domestic output and growth performance (Easterly and Ross, 1998; Cherif et al., 2018), fiscal reforms (Caselli and Reynaud, 2020), and energy subsidies (Ebeke and Ngouana, 2015) among other.

[14] By using system GMM, a great number of instruments is usually used, both in levels and in differences (Arellano and Bond, 1991; Arellano and Bover, 1995) for estimation. Roodman (2009) suggests that the difference and system GMM have been designed for few time-periods and many individuals. The dynamic bias becomes insignificant when a great number of time-periods exists and thus, it is more convenient to use a fixed-effects estimator. In the meanwhile, the number of instruments in difference and system GMM tends to explode increasing time-periods and thus in case the number of individuals is small, the cluster-robust standard errors and the Arellano-Bond autocorrelation test may be unreliable.

[15] Available at the NBER's International Finance and Macroeconomics Catalogue of Data Sources at https://www.nber.org/data/international-finance. Like other *de jure* capital control datasets, the Fernandez et al. (2016) is based on information in IMF's Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER) and builds on Schindler (2009), among other datasets, but it includes additional asset categories, more countries and a longer time period to existed databases. See Quinn et al. (2011) for a comprehensive survey for a wide range of indicators on financial openness.

[16] An alternative way to measure financial integration is to use *de facto* measures, i.e., quantity-based measures that rely on actual flows (a widely used *de facto* indicator is the Lane and Milesi-Ferretti (2007) index *TOTAL*, which is calculated as a country's aggregate assets plus liabilities relative to its GDP). *De facto* indicators are not free from limitations. An important one is the inconsistency of reporting and treating FDI across countries and over time. They may also fail to accurately reflect a government's policy stance. In addition, such measures do not capture the degree of enforcement of capital controls. See Kose et al. (2009) for a comparison between *de jure* and *de facto* indicators.

credits (*cc*), guarantees, securities and financial backup facilities (*gs*), and real estate (*re*) -definitions of these assets are presented in Table A.1 in the Appendix- that allows us to delve deeper into individual assets and examine certain hypotheses. Among these assets, we focus mainly on restrictions on equity (*eq*), credit (*fc*), and direct investment (*di*) assets.

Fig. 1 below visualizes the relationship between R&D and capital controls. To remove heterogeneity, we demean our data by subtracting from the observed values of R&D and capital controls their within-group means.

We observe that there is a non-monotonic relationship between R&D and capital controls index. To exclude the possibility this relationship is driven by extreme outliers, we drop the 1 per cent of the highest and lowest values of the (demeaned) capital controls and R&D expenditures from our sample -these values mostly refer to the beginning and ending years of our dataset.

Fig. 2 below shows the evolution of (aggregate, period average) capital control index and controls on equity (*eq*), credit (*fc*), and (*di*) assets. As the figure shows, till early 2000s, there is a dramatic decrease and thereafter a sharp increase of capital asset restrictions. It also appears that equity and debt asset restrictions followed a similar path with almost similar volatilities.

Data on an economy's sectoral composition, proxied by the share of employment in agriculture (*Agriculture Share*), are obtained from the WDI. From the same source, we also derive information of a country's social aspects relevant to innovation namely, human capital and labor market rigidity - the former, is proxied by the Human Development Index (*HDI*) and the latter, by the long-term unemployment ratio (*Unemployment*). A country's gross domestic product (GDP), to weight R&D investment, also comes from the WDI.

Finally, for our instruments, information on a country's neighbors -to construct instruments for a country's R&D, capital controls and patents, based on the performance of the surrounding countries- is retrieved from Ades and Chua (1997). In case a country is an island, neighboring countries are the nearby countries. Data on quality of institutions (*Institutions*) -to instrument for R&D and patents- come from the World Bank, Worldwide Governance Indicators (WGI). Among the six qualities of governance institutions, we focus on the 'rule of law' as it is very relevant to innovation activity (La Porta et al., 1998, 2000). Table 1 below provides summary statistics of the variables in our analysis.

On average, countries in our sample spend 1.36 % of their output (GDP) on R&D investment and produce about 32 thousand patents per year. Israel has the highest R&D spending while Peru the lowest. The leader in patent applications is the US while Cyprus is on the opposite side of the spectrum.

Further, countries, on average, are fairly open to free mobility of international capital as the index of capital controls is 0.30 (out of 1), while there are no large differences on the level and variation of equity, credit and direct investment restrictions. Focusing on statistics per country, reported in Table A.2 in the Appendix, heterogenous patterns emerge. The OECD countries, on average, tend to be more open (0.18) than the non-OECD (0.48). The highest capital restrictions are set by India (0.97) and China (0.96), followed by Malaysia (0.81) and Ukraine (0.80), while totally open to capital flows are Japan (0.0), Netherlands (0.0) and Panama (0.0). Over time, the vast majority of the countries have increased their controls on capital mobility - especially after the currency crisis in 2004. Countries seem to respond to macroeconomic and financial conditions by mainly adjusting controls on equity and to a lesser degree on debt (or direct investment) assets.

Concerning the rest of the variables, there is a wide heterogeneity in the sectoral production distribution across countries, as the unemployment ratio and the employment in agriculture indicate, while countries are fairly close to their potential when it comes to human development.

Episodic vs. Non-episodic countries.

Among the 53 countries in our sample, 38 of them (we label these as 'episodic') have changed their controls across all three (equity, credit, and direct investment) assets over the period of our sample more than once, with Argentina, Colombia and Kazakhstan to exhibit the highest frequency in using controls on these assets as instruments. Out of the remaining 15 countries (we labelled as 'non-episodic', as zero or one change in their capital controls at the most is reported), two of them have long-standing controls (China and India; labelled as "wall" economies) and 13 long-standing openness (labeled as "strictly open"). Table A2 in the Appendix offers an analytical exposition of the capital control status of all countries in our sample.

4. Empirical results

This section presents the results. We first examine the importance of capital controls on innovation. Then, we proceed to explore what particular controls, across different asset categories, matter most for innovation activity. We complete the section by presenting robustness analysis.

4.1. Do capital controls matter for innovation?

Table 2 summarizes estimates of the innovation input (*R&D*) equation (6) in Panel A and innovation output ($\Delta lnPatents$) equation (5) in Panel B. Columns (1) and (2) present OLS, while the rest of the columns, (3)-(6), report GMM estimates to address potential endogeneity issues. Columns (5) and (6), in particular, show estimates for a sub-set of our sample, the so-called'episodic' countries, i.e., countries with transitory capital controls. All specifications include country-year fixed effects, country-specific time trends and country-clustered robust standard errors to control for heteroscedasticity, while

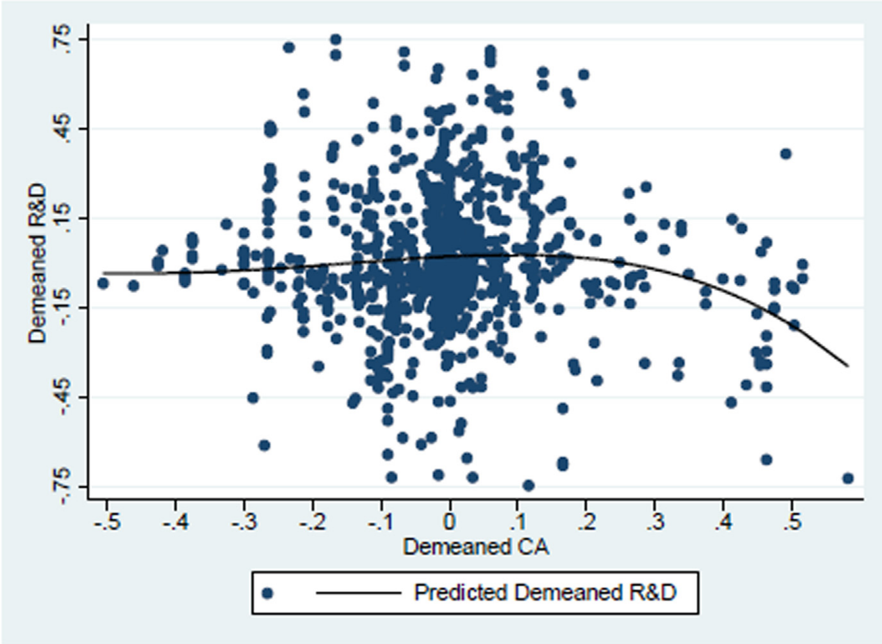

Fig. 1. R&D and capital controls (demeaned data).

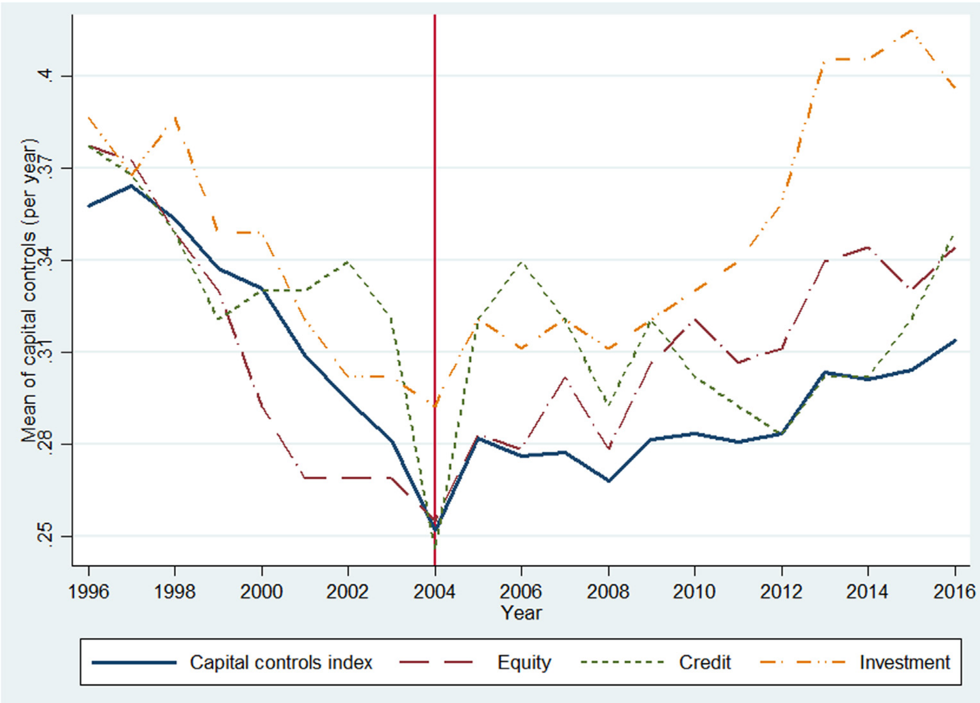

Fig. 2. Development of capital asset restrictions.

t-values are reported in parentheses. Diagnostic tests (CD test) reported at the bottom part of Table 2 confirm absence of cross-sectional dependence. Finally, Table 2 closes with a summary of the effects of capital controls on innovation (R&D and patents).

We begin with analyzing OLS estimates reported in column (1), Panel A. It appears that capital controls and innovation input (*R&D*) exhibit an inverse U-shaped relationship, as both estimates of the linear and squared terms of the capital con-

Table 1
Summary Statistics, years 1996–2016.

Variables	Observations	Mean	St. Dev.	Min	Max
Patents	1,101	32,133	105,856	3	1,338,503
R&D	1,074	1.36	1.01	0.05	4.43
KC	1,113	0.30	0.31	0	1
KC_{Equity}	1,113	0.31	0.37	0	1
KC_{Credit}	1,113	0.32	0.42	0	1
$KC_{Investment}$	1,113	0.35	0.42	0	1
Unemployment	1,113	7.48	4.88	0.40	33.47
AgricultureShare	1,113	12.53	13.29	0.13	61.44
HDI	1,112	0.80	0.10	0.43	0.95
Instruments					
$Patents_{BorderCountry}$	1,113	44,197	126,020	16	1,338,503
$R\&D_{BorderCountry}$	1,104	1.23	0.78	0.04	4.39
$KC_{BorderCountry}$	1,113	0.36	0.26	0	1
Institutions	1,113	70.56	25.58	9	100

Note: *R&D* is ratio of GDP; *Patents* is count (non-negative integer); *KC* is an IMF-constructed index of financial capital restrictions (ranges from 0 to 1; where 0 denotes open and 1 closed to international finance economies); KC_{Equity}, KC_{Credit} and $KC_{Investment}$ are restrictions on individual assets, of equity, credit and direct investment, respectively - correlation among the three ranges from 0.63 (KC_{Credit} and $KC_{Investment}$) to 0.76 (KC_{Equity} and $KC_{Investment}$). *Unemployment* is a ratio (unemployed to labor force); *AgricultureShare* is ratio of employment in agriculture to total employment; *HDI* is the Human Development Index, which proxies for human capital and ranges between 0 and 1; $R\&D_{Neighbor}$, $KC_{Neighbor}$ and $Patents_{Neighbor}$ are the average values of R&D/GDP, capital controls and number of patents of the neighboring countries, respectively and serve as instruments; *Institutions* refers to the quality of governance and particularly to the quality of the rule of law and serves as an instrument.

trols index (*KC*) are statistically significant. In addition, the diagnostic *U* test, at the bottom part of Table 2 confirms the existence of an inverse U-shaped relationship (Lind and Mehlum, 2010). The value of capital controls (*KC*) for which the maximum response of R&D to capital controls is occurring is 0.497 (on a scale of 0 to 1), which is the outcome of the first derivate of R&D in equation (6) with respect to capital controls (*KC*) set equal to zero, yielding $KC = -\beta 2/(2^*\beta 3)$. The mean value of capital controls below this maximum response is 0.117 and the mean value of capital controls above this maximum response is 0.749. A unit change in capital controls -till the value of 0.497- relates with an increase in R&D by about 0.12 per cent, while after the value of 0.497, a unit change in capital controls associates with a decline in R&D by about 0.08 per cent, as the lower part of Table 2 reports. As for the remaining estimates of socio-economic variables in the control set *Z* we find that human capital (*HDI*), long run unemployment (*Unemployment*) and the employment in the agricultural sector (*AgricultureShare*) are insignificantly different from zero and cannot be argued to carry a particular sign.[17]

Then, we turn our attention to the relationship between capital controls and innovation output, proxied by the annual change in the log transformation of patent applications ($\Delta lnPatents$). After estimating equation (6), we obtain the fitted values of R&D and place them in equation (5). Estimates are reported in column (2), Panel B. Both past accumulated knowledge, proxied by the lagged value of patents, and current innovation investment, proxied by the fitted values of R&D, strongly associate with the generation of new ideas. The negative and lower than one coefficient of past knowledge (*lnPatents*) suggests a process of convergence in patenting activity. Less innovative countries have, during the period of analysis, been able to reduce the technological gap with more advanced countries as documented in the literature (Rodríguez-Pose and Cataldo, 2014). The effect of R&D on a country's innovation capability is also close to what the literature reports (Bottazzi and Peri, 2003; Peri, 2005; Drivas et al., 2016). Capital controls, through the channel of R&D, relate to patents in the following way: before the value of *KC* for which the maximum response of R&D to *KC* is occurring (i.e., 0.497), a unit increase of capital controls relates to a 31 per cent increase of patents, while after 0.497 relates to a 26 per cent decrease.

A common concern, however, when dealing with policy variables, such as capital controls, and economic outcomes, such as innovation performance, is endogeneity. Innovation may be influenced by capital controls and in turn innovation performance, which shapes economic growth may influence restrictions set on capital flows. Further, both variables could be influenced by institutions and other policies not included in the model. We address endogeneity and omitted variable bias with GMM estimation.

To find appropriate instruments, we were guided by the literature (Easterly and Ross, 1998; La Porta et al., 2000; Rodríguez-Pose and Cataldo, 2014; Cherif et al., 2018). In equation (6), we instrument for the lagged value of R&D ($R\&D_{t-1}$) and capital controls KC_{t-1}, KC^2_{t-1}) using two-period lagged values of domestic R&D, first differences of domestic R&D, the average R&D of the neighboring countries, institutions and squared terms of institutions, domestic country's capital controls and their squared terms, as well as the average capital controls of the neighboring countries, respectively. To make sure that our instruments are valid and, further, there are not other serious issues with instrumentation and the fitness of the model, we perform a number of diagnostic tests. For instance, several precautions are taken in order to avoid the problem of

[17] Further analysis in sections that follow show that agricultural share does appear to be negatively related to R&D in Table 4 and Table A3, the level of human development shows some indication of being positive in Table 4, while long term unemployment appears to have little effect (insignificant and coefficient is around 0) in any of these aforementioned Tables.

Table 2
Capital Controls (*KC*) and Innovation (*R&D* and *Patents*) Estimates.

	All countries				Episodic countries	
	OLS (1)	OLS (2)	GMM (3)	GMM (4)	GMM (5)	GMM (6)
Panel A	**Estimates of eq. (6): Innovation Input (dep. var.: $R\&D_t$)**					
$R\&D_{t-1}$	0.785***		0.797***		0.808***	
	[27.839]		[7.684]		[5.969]	
KC_{t-1}	0.154**		0.374***		0.484***	
	[1.974]		[2.887]		[3.545]	
KC^2_{t-1}	−0.155*		−0.375***		−0.512***	
	[−1.960]		[−2.801]		[−3.337]	
$Unemployment_{t-1}$	−0.002		−0.002		−0.000	
	[−1.148]		[−0.811]		[−0.096]	
$AgricultureShare_{t-1}$	0.001		−0.001		−0.003	
	[0.464]		[−0.571]		[−1.238]	
HDI_{t-1}	−0.014		0.546		1.010*	
	[−0.033]		[1.106]		[1.783]	
Panel B	**Estimates of eq. (5): Innovation Output (dep. var.: $\Delta lnPatents_t$)**					
$lnPatents_{t-1}$		−0.449***		−0.668***		−0.685***
		[−10.181]		[−7.603]		[−6.919]
$lnR\&D_t$		0.279***		0.404**		0.477*
		[3.976]		[2.105]		[1.763]
Observations	1020	1010	911	712	651	507
Number of countries	53	53	53	53	38	38
Within R-squared	0.650	0.240	0.527	0.261	0.519	0.302
Total R-squared	0.995	0.992	0.995	0.995	0.995	0.994
Year effects	Y	Y	Y	Y	Y	Y
Country effects	Y	Y	Y	Y	Y	Y
Country-specific-time-trends	Y	Y	Y	Y	Y	Y
Clustered standard errors	Country	Country	Country	Country	Country	Country
Pesaran (CD) test	0.228	0.218				
U test	0.044		0.008		0.003	
Hansen J-test			0.898	0.179	0.673	0.502
K-P rk Wald			11.677	24.753	7.327	23.355
Durbin-Wu-Hausman			0.022	0.005	0.003	0.016
K-P rk LM (p-value)			0.001	0.002	0.007	0.006
Arellano-Bond AR-1	0.012	0.182	0.102	0.271	0.178	0.288
Arellano-Bond AR-2	0.221	0.194	0.453	0.241	0.521	0.241
Arellano-Bond AR-3	0.118	0.465	0.228	0.085	0.316	0.216
	Summary Effects of *KC*					
KC^*	0.497		0.499		0.473	
before KC^*	0.118	0.314	0.286	0.538	0.327	0.662
after KC^*	−0.078	−0.258	−0.187	−0.487	−0.244	−0.609

Notes: Dependent variable in columns (1), (3) and (5) is *R&D/GDP*, while in columns (2), (4) and (6) is $\Delta lnPantents$; Table A.2 in the Appendix lists all countries (episodic and non-episodic) of our sample; (*), (**), (***) are significance level at the 10 %, 5 % and 1 %, respectively. Clustered standard errors with countries, country and year fixed effects and country-specific time trends are included in all specifications; *t*-values are reported in parentheses.
Diagnostics: Hansen J-test (p-value) examines whether instruments are valid (null); Kleibergen-Paap (K-P) rk Wald (F-statistic) tests whether instruments are weak (null), with critical values varying between 5.34 and 24.58, and 4.44 and 13.95 for the eq. (5) and eq. (6), respectively; Durbin-Wu-Hausman (p-value) tests whether instrumental variables techniques are required (null); Kleibergen-Paap (K-P) rk LM statistic (p-value) tests whether the estimated equation is underidentified (null); Arellano-Bond for AR(1) to AR(3) (p-value) test for no autocorrelation (null). Instruments used in eq. (5): $\Delta 5 lnpatents_{t-2}$, $lnpatents_{t-2}$, and the average of $lnPatents_{t-2}$ of neighboring countries (for $lnpatents_{t-1}$). Instruments used in eq. (6): $\Delta R\&D_{t-2}$, the average $R\&D_{t-2}$ of neighboring countries, $Institutions_{t-2}$ and $Institutions^2_{t-2}$ (for $R\&D_{t-1}$) and KC_{t-2}, KC^2_{t-2} and the average of KC_{t-2} of neighboring countries (for KC_{t-1} and KC^2_{t-1}). KC^*: value for which the maximum response of *R&D* to *KC* occurs.

instrument proliferation. Our instruments are exogenous (Hansen J-test) and do not suffer from weak identification problem (Kleibergen-Paap (K-P) rk Wald F-statistic). Further, the instrumental variable technique is necessary (Durbin-Wu-Hausman test), while our model is not under-identified (Kleibergen-Paap (K-P) rk LM test) and does not suffer from at least first to third order serial correlation (Arellano-Bond for AR(1) to AR(3) tests).

Columns (3) and (4) present GMM estimates in analogous way to columns (1) and (2). The inverse U-shaped relationship of capital controls and R&D investment still pertains, while the size of the coefficients of capital controls as well as their statistical significance have increased; so has the importance of the diagnostic *U* test, at the bottom part of Table 2, which provides support to an inverse U-shaped relationship between R&D and capital controls. The maximum value of capital restrictions remains unaltered and around 0.50, but their effect on R&D before and after the value of 0.50 is now doubled. The fitted values of innovation input (R&D) from equation (6) convey the exogenous component of capital controls -due to instrumentation when we estimate equation (5) and so we are able to discuss the impact of capital controls on patents, via their effect on R&D. If restrictions on capital increase by one unit, the positive effect on patents growth is almost 54 per cent, till capital controls reach the value of 0.50, and thereafter, any further increase of controls results in a 49 per cent decrease of patent applications.

While some countries have long-standing strong controls or long-standing openness to foreign capital flows, others re-introduce transitory controls when events seem to warrant their use. Episodic capital controls relax during tranquil times, to enable an economy to benefit from international capital, but increase in the threat of capital inflows that may cause an unwanted appreciation or a destabilizing asset market boom. These episodic controls are usually targeted toward particular categories of assets, are less distortionary and inefficient than broad, long-standing controls (Klein, 2012). Columns (5) and (6) of Table 2 report estimates of capital controls on innovation activity of episodic countries.

As one can note, the estimated maximum value of capital controls for which the maximum response of R&D to capital controls is occurring is very close to the values reported in columns (3) and (4) for the whole sample. The coefficients of both capital controls and capital controls square although appear to be bigger (in absolute terms) for episodic economies; performing, however, a typical *z*-test we find this difference to be statistically insignificant.[18]

We further tested our model for the 15 non-episodic countries and we find no statistically significant effects of capital controls on R&D or patents.[19]Apparently, the group of episodic countries drives the results of the whole sample as these countries use capital controls as policy tools to maneuver their economies; consequently, our finding about the effects of capital control on innovation activity mainly pertain to this specific group of countries.

Nevertheless, we would like to note here that the group of non-episodic includes 15 economies with 13 of them to have long-standing openness (strict open countries) and two of them (China and India) long-standing controls to international capital flows (wall countries) (consult Table A.2 in the Appendix). The strictly open countries enjoy high level of economic development (most of them are OECD members) and financial stability and are also top performers of innovation activity. As this group does not rely on capital controls, as a policy tool, to protect or enhance their economic performance, we cannot advocate their use. Even if the imposition (of a certain level) of capital controls would benefit innovation activity, as it is the case with the 'average' episodic country, such imposition may create more distortions in other aspects of the economy. The wall group consists of two strong emerging economies, China and India, characterized by large internal markets, low wages and strong technical education system – attributes that make both economies attractive destinations of location for foreign investment. Shielding their economy from financial turmoil (capital market speculation, excessive risk-taking, economic overheating, overvalued exchange rates, and the ever-present threat of a "sudden stop," where short-term speculative flows can quickly exit a country with little warning, causing a country's currency, banking system, and economy to crash) has been and still is one their priorities.[20] Sheltering, however, behind strict capital controls forever in an interconnected world may become a serious hindrance for achieving long-term economic growth. Relaxing capital controls to enhance innovation as a policy advice for China based on our finding without performing any addition country-specific analysis would be a reckless advice. Fully opening the Chinese financial system will require keen attention to prioritizing other important reforms and to designing a strong and flexible set of cross-border financial regulations. Such regulations will be important to preventing and mitigating financial fragility. Similarly, any advocation for more open Indian economy to foreign flows should first ensure the system's resilience to foreign shocks. Based on our current analysis, we refrain from making policy recommendations for the wall economies as to the level of capital controls they should implement. A detailed firm-level analysis could perhaps shed more light into sectors' special characteristics and competitive.

To sharpen the robustness of our results, we explore couple of issues. To exclude the possibility that our results are driven by extreme outliers, we drop the 1 per cent of the highest and lowest values of the aggregate index of capital controls and R&D expenditures from our sample. These values mostly refer to the beginning and ending years of our dataset without affecting the dynamic performance of our model (equation (5)). Results do not show any change. Overall, results have remained robust in different specifications, variable definitions and time splits.

[18] We use the *z*-test for the difference between two regression coefficients with null hypothesis the difference of the two regression coefficients to be not statistically different from zero.$Z = \frac{b_1 - b_2}{\sqrt{SEb_1^2 + SEb_2^2}}$where b_1 and b_2 are regression coefficients and *SE* their corresponding standard errors. A z-score above 1.96 (in absolute terms) would reject the null hypothesis at a 5% level of significance. We test the coefficient of *KC* for R&D for the episodic countries (0.484) and that for all countries (0.374) and find a *z* score of 0.58 (< 1.96). We also test for the coefficient on KC^2 for R&D for the episodic countries (−0.512) and that for all countries (-0.375) and find a *z* score of 0.67 (< 1.96). We, therefore, reject the null hypothesis and accept that there is no statistical difference between the estimates of *KC* (and KC^2) between specifications (3) and (5) of Table 2.

[19] Results, not reported here for brevity, are available upon request. The fact that in non-episodic economies the innovation process is not affected by capital controls is rather simple; since capital controls in these countries do not change over the sample period, they cannot statistically explain any variation of R&D activity in these economies.

[20] However, the use of strong capital controls in China and India stemmed from different reasons. China's main driver of growth has been the focus on domestic market, or internal circulation, i.e., to mainly grow without overreliance on international trade or external circulation. China's growth model mainly relies on state investment. By implementing capital controls, domestic savings stay within the borders, and savings are placed with banks. Though the government control, the banks channel the savings to the industries the government aim to develop.India's imposition of capital controls was rather a policy of last resort, as India's authorities deemed them necessary, after massive foreign capital inflows since 1991, the year of India's "great opening" (see a discussion in Patnaik and Shah, 2012). In the prospect of a speculative crash in the Indian stock market, a sharp downturn in India's export economy, exceedingly risky inflows of international loans to India's private sector, and the inability to use interest rates to regulate capital flows, the Securities and Exchange Board of India and the Reserve Bank of India decided to enact strong capital controls, beginning in June of 2007, to head off these risks.

4.1.1. Sensitivity: exploring the role of domestic financial development

Guided by the voluminous finance-growth literature (Schumpeter, 1911) and a newly grown literature that focuses particularly on finance-innovation nexus (Brown et al., 2009, 2012; Ayyagari et al., 2011; Hsu et al., 2014), we further explore whether the level of financial development can act as a moderator of the (negative particularly) effects of restrictions on capital.

We employ various measures of domestic financial development -all included in the control set, Z of the R&D equation (6)- with each one of them to capture different aspects of the level of development in the financial sector. More specifically, we used eight measures of domestic financial development all drawn primarily from the World Bank's World Development Indicators, the IMF's International Financial Statistics, and the databases associated with Beck et al. (2000). For example, the Financial Development index (*FD*) is an aggregate of the Financial Institutions (*FI*) and Financial Markets (*FM*) indices which summarizes how developed financial institutions and markets are in terms of their depth (size and liquidity), access (ability of individuals and companies to access financial services), and efficiency (ability of institutions to provide financial services at low and with sustainable revenues at the level of activity of capital markets) as in Devereux and Yu (2020) as well as the ratio of private credit from deposit money banks to the private sector (*PC*), which represents the overall development in private banking markets (Chinn and Ito, 2006; Maskus et al., 2019). As our focus is primarily on the development of equity markets which is quite important for innovation activity (Brown et al., 2009, 2012; Ayyagari et al., 2011; Hsu et al., 2014), we additionally employ four variables as near proxies: the stock market capitalization (*SMKC*) and private bond market capitalization (*PBMC*) as in Maskus et al. (2019), as well as the total value of stocks traded (*SMTV*) and stock market turnover ratio (*SMTO*) as in Chinn and Ito (2006). We consider SMKC as the measure of the size of equity markets and *SMTV* and *SMTO* as measures of the activeness of equity markets.

Estimates of the effect of the level of domestic financial development are shown in Table 3 below. Columns (1) to (8) include all aforementioned different measures of financial development.

All different measures of domestic financial level are found statistically insignificant in all our specifications related to the innovation input, R&D.[21] Therefore, we cannot robustly conclude whether the level of domestic financial development is an intermediator for countries' international financing restrictions. Recent literature (Hsu et al., 2014; Maskus et al., 2012, 2019) has regressed innovation activity against the level of a country's domestic finance and its sectors' external dependency among other determinants and report some statistically significant effects. Other studies find mixed evidence of a weak or U-shaped relationship (Trinugrohoa et al., 2021). In our case, our model, which directly stems from endogenous growth theory (R&D-based models of economic growth), comprises of a system of two equations, (5) & (6) - with the latter to be a dynamic equation with the level of past knowledge (proxied by R&D) to be found highly significant. This is perhaps the main reason of the statistical insignificance of the estimates of the domestic financial development measures. According to the literature, the size and depth of an economy's financial system positively relate to real income, employment, and output (King and Levine, 1993; Levine and Zervos, 1998; Rajan and Zingales, 1998; Beck et al., 2000; Beck and Levine, 2002; Black and Strahan, 2002), which, in turn, shape the level of innovation (R&D) activity. Therefore, the realized (past) level of R&D acts here as a "catch-all" variable that is shaped from the macroeconomic environment (proxied here by long-run employment, agriculture share and human capital; all of them determinants of GDP) as well as from the financial performance (proxied here by various measures) of an economy. The use of appropriate econometric techniques (GMM estimation) ensures the consistency of our estimates, avoiding thus potential endogeneity and omitted variable bias problems.

We further tested for potential non linearities, i.e., whether the effect of capital controls vary given a country's level of domestic financial development (Hsu et al., 2014; Maskus et al., 2012, 2019) or by the level of innovation-related institutions, as strong intellectual property rights may be particularly important where financial markets are relatively less developed (Maskus et al., 2019). Estimates of the interaction terms reported in columns (9) and (10) are found statistically insignificant.

Thus far, thin empirical evidence has documented mixed findings on the relationship of capital controls and macroeconomic aggregates (exchange rate, financial vulnerability, output growth) supporting a monotonic (negative or positive) relationship, which in most cases is rather weak (Satyanath and Berger, 2007; Klein, 2012), while there has been no concrete evidence on innovation and capital controls. Our results robustly document that there is an inverted U-shaped relationship between the two. The steepness, however, may vary, depending on sector and firm characteristics; for example, high technology firms, either nascent or established could be more sensitive to financial restrictions. Our findings corroborate with recent evidence in the literature that some level of financial (credit) restrictions may improve the allocation of resources as more credits are channeled to firms that perform productive and growth-enhancing research (Reis, 2013; Gopinath et al., 2017; Liu et al., 2019). However, if restrictions become too high, they may have a detrimental impact on innovation as screening costs will be high and risky but high-impact, promising projects may not be realized (Aghion et al., 2009). Our results show that the effect of capital controls on innovation is not uniform but varies depending on the level of restrictions. Effects may differ across sectors, but on average, we find that restrictions on aggregated capital control index of no higher than 0.47 do not obstruct innovation activity; however, any further protection from international capital flows may cause serious harm to innovation performance. Our results certainly, do not advocate the implementation of capital controls in countries that already have largely open capital accounts for a long period. Nevertheless, countries that do main-

[21] Consequently, we do not report estimates of innovation output, equation (5).

Table 3
Domestic Financial Development estimates.

Dependent variable: $R\&D_t$	(1) Financial development (FD)	(2) Financial market (FM)	(3) Financial institutions (FI)	(4) Stock market capitalization (SMKC)	(5) Domestic credit to private sector (*PC*)	(6) Stock market turnover (*SMTO*)	(7) Stock market traded value (*SMTV*)	(8) Private bond market capitalization (*PBMC*)	(9) Non-linear effects	(10)
$R\&D_{t-1}$	0.802***	0.800***	0.777***	0.865***	0.769***	0.868***	0.844***	0.617***	0.806***	0.767***
	[8.073]	[7.792]	[8.078]	[9.232]	[8.126]	[9.535]	[8.975]	[4.881]	[8.215]	[5.907]
KC_{t-1}	0.380***	0.387***	0.359***	0.452***	0.406***	0.452***	0.473***	0.748***	0.219	0.567
	[2.877]	[2.973]	[2.688]	[3.611]	[2.925]	[3.508]	[3.582]	[2.783]	[1.027]	[1.259]
KC^2_{t-1}	−0.385***	−0.395***	−0.340**	−0.475***	−0.389***	−0.460***	−0.486***	−0.707**	−0.337**	−0.703**
	[−2.702]	[−2.872]	[−2.404]	[−3.117]	[−2.659]	[−3.052]	[−3.155]	[−2.470]	[−2.471]	[−2.423]
$Unemployment_{t-1}$	−0.002	−0.002	−0.001	−0.003*	−0.003	−0.003	−0.002	−0.003	−0.002	0.004
	[−0.854]	[−0.873]	[−0.598]	[−1.798]	[−1.373]	[−1.409]	[−1.135]	[−1.283]	[−0.840]	[1.370]
$AgricultureShare_{t-1}$	−0.001	−0.001	−0.001	0.001	−0.001	0.000	−0.000	−0.004	−0.001	−0.005
	[−0.462]	[−0.251]	[−0.453]	[0.396]	[−0.423]	[0.058]	[−0.011]	[−1.095]	[−0.335]	[−1.313]
HDI_{t-1}	0.588	0.553	0.240	−0.431	0.211	−0.412	−0.320	−0.473	0.570	0.178
	[1.124]	[1.098]	[0.477]	[−0.734]	[0.427]	[−0.666]	[−0.542]	[−0.739]	[1.064]	[0.250]
FD_{t-1}	−0.059	−0.083	0.229	−0.000*	0.000	−0.000	−0.000	0.001	−0.114	−0.264
	[−0.508]	[−1.447]	[1.372]	[−1.796]	[0.239]	[−0.283]	[−0.210]	[1.600]	[−0.914]	[−0.939]
RL_{t-1}										0.003
										[1.303]
$FD_{t-1}{}^{*}\ KC_{t-1}$									0.250	0.649
									[0.804]	[0.903]
$RL_{t-1}{}^{*}\ KC_{t-1}$										−0.005
										[−0.904]
KC*	**0.493**	**0.490**	**0.527**	**0.476**	**0.522**	**0.491**	**0.487**	**0.529**	**–**	**–**
Observations	911	911	911	859	867	856	866	516	911	673
Within R-squared	0.527	0.528	0.533	0.509	0.531	0.496	0.503	0.393	0.523	0.412
Year effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Country effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Country-specific-time-trends	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Clustered standard errors	Country	Country	Country	Country	Country	Country	Country	Country	Country	Country
P-value *U* test	0.012	0.007	0.030	0.006	0.024	0.007	0.005	0.042	0.152	0.104
p-value Kleibergen-Paap rk LM	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.070
Kleibergen-Paap rk Wald F stat	10.658	10.915	9.877	11.632	13.766	12.114	12.001	9.236	10.339	10.632
p-value Arellano-Bond AR-1	0.091	0.100	0.106	0.126	0.072	0.120	0.139	0.393	0.091	0.443
p-value Arellano-Bond AR-2	0.439	0.449	0.427	0.415	0.394	0.399	0.139	0.221	0.420	0.323
p-value Arellano-Bond AR-3	0.209	0.220	0.203	0.193	0.171	0.211	0.251	0.224	0.209	0.302
p-value Durbin-Wu-Hausman test	0.019	0.020	0.038	0.010	0.038	0.008	0.010	0.026	0.015	0.199
p-value Hansen test	0.896	0.898	0.918	0.853	0.841	0.826	0.846	0.614	0.867	0.897

Notes: Dependent variable is *R&D/GDP*, *FD* is the Financial Development and *RL* refers to the Rule of Law. *, **, *** are significance level at the 10 %, 5 % and 1 %, respectively. Clustered standard errors with countries, country and year fixed-effects, and country-specific time trends are included in all specifications; t-values are reported in parentheses.
Diagnostics: Hansen J-test (p-value) examines whether instruments are valid (null); Kleibergen-Paap (K-P) rk Wald (F-statistic) tests whether instruments are weak (null), with critical values varying between 4.44 and 13.95; Durbin-Wu-Hausman (p-value) test whether instrumental variable techniques are required (null); Kleibergen-Paap (K-P) rk LM statistic (p-value) tests whether the estimated equation is under-identified (null); Arellano-Bond for AR(1) to AR(3) (p-value) test for no autocorrelation (null). Instruments used: $\Delta R\&D_{t-2}$, the average $R\&D_{t-2}$ of neighboring countries, $Institutions_{t-2}$, $Istitutions^2_{t-2}$, CA_{t-2}, CA^2_{t-2}, the average CA_{t-2} of neighboring countries. KC^*: value for which the maximum response of *R&D* to *KC* occurs.

tain high level of capital controls should be cautious about their limitations and their potential negative effects on innovation performance.

In summary, our results have shown that the aggregate level of capital controls index is relevant and important for innovation. The composition of this index may also be of policy relevance, as controls on different capital assets may have different implications for innovation activity. This begs the question of whether there are asset restrictions that are more harmful for innovation than others. The section that follows explores this issue.

4.2. What asset restrictions matter most for innovation?

So far, we have estimated the aggregate effect of the composite index of capital controls on both R&D and patent activity. Motivated by the financial development and innovation literature, in this section, we focus on individual assets that act as tools for firms to cover their financial needs. Thereby, we replace the aggregate index of capital controls with individual indices of equity and credit asset controls. Additionally, to the aforementioned options, FDI could also be a major vehicle of technological knowledge transmission and funding as it supports strong relationship between parent enterprises and their affiliates through monitoring and managerial commitment, longer time horizons finance and less arm's-length lending which is important for innovation projects. Therefore, we further examine the effect of restrictions on foreign direct investment, which serves as a channel of technology diffusion across countries.

The effects of restrictions on the aforementioned channels on funding a country's innovation activity are depicted in Table 4. More specifically, the table summarizes estimates of equations (6) and (5) in Panel A and B, respectively. Columns (1) to (6) present GMM estimates of equity (*eq*), credit (*fc*), and direct investment (*di*) asset restrictions on R&D (Panel A) and patents (Panel B) for all countries in our sample, while in columns (7) to (12) we limit our attention to the group of episodic countries. All specifications include country-year fixed effects, country-specific time trends, country-clustered robust standard errors and *t*-values are reported in parentheses. The bottom part of Table 4 reports diagnostic tests as well as a summary of the effects of capital controls on R&D and patent applications.

Estimates in columns (1) to (4) show that equity and credit asset restrictions have completely different effects on R&D and patents; equity restrictions are found to greatly shape innovation activity whereas credit restrictions do not exert any impact. Particularly, equity restrictions could be beneficial for R&D investment till a certain level (around 0.46) and thereafter have detrimental negative effects, particularly for patents.[22] This finding is also consistent when we limit our analysis for the group of episodic countries, where the effects of equity restrictions on both R&D and patents is even larger.

Prior research has demonstrated that firms first tap internal funds in order to maintain control rights over their innovations (Aghion et al., 2004; Hall and Lerner, 2010). As they need additional capital to fund R&D expenditures; however, they turn to external funds, first accessing bank credit and then equity markets.[23] Innovative firms, however, may be less able to take advantage of credit markets to externally fund their innovations for various reasons such as their small asset tangibility, as they rely on high human capital investment which cannot be collateralized and the nature of the project they want to finance; for instance, bank lending decisions are typically made by a single bank manager, who forms an opinion about the potential returns of a relatively well defined project and may be less likely to finance highly uncertain projects. Equity-based financing, in contrast, relies on a wide variety of opinions, with this diversity allowing for investment in risky R&D investments (Allen and Gale, 2000). This line of thinking is consistent with our results, which underline the importance of restrictions on equity-based source of financing innovation activity.

Turning our attention to restrictions on direct investment assets, we find no effect at all at both aspects of innovation. Arguably, FDI could be just as important source of financing innovation activity as the other two. The close relationships that are often established between multinational firms and their subsidiaries reduce the need for tangible assets as collateral to support R&D investments, allowing subsidiaries to access the internal credit resources of the multinational parent (Desai et al., 2004; Maskus et al., 2012). Our empirical evidence, however, does not seem to align with this line of argumentation or existed evidence (Maskus et al., 2012) in this respect. Perhaps, our findings may be picking up an average effect that could be further explored if more detailed data were available on the type of foreign direct investment.

The rest of control variables pertain their significance as before, with the (decrease of the) share of agricultural sector employment and especially the (increase of the) human development to be particularly important contributors to innovation. Further, all diagnostic tests about the validity of our instruments and fitness of the specifications confirm that our instrumentation strategy is relevant and our specifications do not suffer from any bias or endogeneity or cross-sectional dependence.

4.2.1. Sensitivity: exploring the role of venture capital

Next, we explore whether the importance of equity controls alters, depending on the availability of venture capital (VC), which is financing mainly for startup companies and small businesses. The funding for this financing usually comes from wealthy investors, investment banks, and any other financial institutions. Venture capital involves active investors that can help companies to reduce the time to bring a new product to the market (Hellmann and Puri, 2000), pursue more influ-

[22] A similar finding emerges when we broad up, for robustness analysis, the set of equity to further include restrictions of other equity (collective investment, *ci*, derivatives *de*, and real estate, *re*) related assets.

[23] See Myers and Majluf (1984) regarding this pecking-order logic for general investments. Harris and Raviv (1991) offer a useful review.

Table 4
Individual Asset Controls and Innovation Estimates.

	All countries							Episodic countries				
	Equity (eq)			*Credit (fc)*		*Investment (di)*		*Equity (eq)*	*Credit (fc)*	*Investment (di)*		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A	**Estimates of eq. (6): Innovation Input (dep. var.: *R&D$_t$*)**											
R&D$_{t-1}$	0.856***		0.852***		0.779***		0.872***		0.920***		0.893***	
	[8.816]		[8.555]		[6.865]		[7.113]		[7.773]		[6.604]	
KC$_{t-1}$	0.336**		0.350		0.412		0.404***		0,427		0.435	
	[2.515]		[1.447]		[1.405]		[2.874]		[1.745]		[1.440]	
KC^2_{t-1}	−0.368**		−0.286		−0.350		−0.457***		−0.351		−0.379	
	[−2.455]		[−1.047]		[−1.171]		[−2.860]		[−1.266]		[−1.209]	
Unemployment$_{t-1}$	−0.001		−0.002		−0.002		0.001		0.000		0.002	
	[−0.447]		[−0.767]		[−0.540]		[0.480]		[0.161]		[0.511]	
AgricultureShare$_{t-1}$	−0.004*		−0.005*		−0.001		−0.005**		−0.008***		−0.003	
	[−1.811]		[−1.950]		[−0.582]		[−2.469]		[−2.839]		[−0.951]	
HDI$_{t-1}$	0.694		0.604		0.521		1.301**		1.145		1.250*	
	[1.389]		[0.943]		[0.891]		[2.160]		[1.400]		[1.869]	
Panel B	**Estimates of eq. (5): Innovation Output (dep. var.: *ΔlnPatents$_t$*)**											
lnPatents$_{t-1}$		−0.679***		−0.663***		−0.689***		−0.692***		−0.684***		−0.707***
		[−7.766]		[−7.823]		[−7.866]		[−7.123]		[−7.208]		[−7.102]
lnR&D$_t$		0.464***		0.395**		0.437**		0.603***		0.536**		0.585**
		[2.904]		[2.455]		[2.480]		[2.651]		[2.381]		[2.153]
Observations	911	712	911	712	911	712	651	507	911	507	911	507
Number of countries	53	53	53	53	53	53	38	38	38	38	38	38
Within R-squared	0.50	0.28	0.48	0.28	0.51	0.26	0.47	0.31	0.43	0.31	0.46	0.30
Year effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Country effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Country-specific-time-trends	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Clustered standard errors	Country	Country	Country	Country	Country	Country	Country	Country	Country	Country	Country	Country
Hansen J-test	0.820	0.166	0.657	0.163	0.158	0.158	0.800	0.453	0.675	0.431	0.086	0.467
K-P rk Wald	6.796	24.791	1.124	25.703	0.854	25.605	6.650	23.927	1.211	24.802	0.729	24.958
Durbin-Wu-Hausman test	0.015	0.032	0.039	0.039	0.327	0.032	0.001	0.048	0.003	0.053	0.018	0.044
K-P rk LM (p-value)	0.002	0.002	0.147	0.002	0.404	0.001	0.002	0.008	0.178	0.007	0.508	0.006
Arellano-Bond AR-1	0.078	0.247	0.073	0.269	0.100	0.233	0.117	0.275	0.088	0.291	0.132	0.246
Arellano-Bond AR-2	0.339	0.220	0.326	0.212	0.590	0.253	0.420	0.204	0.310	0.209	0.482	0.258
Arellano-Bond AR-3	0.172	0.066	0.156	0.074	0.274	0.076	0.234	0.189	0.180	0.195	0.257	0.205
	Summary Effects of *KC*											
*KC**	0.457						0.442					
*before KC**	0.297	0.624					0.334	0.842				
*after KC**	−0.230	−0.584					−0.274	−0.793				

Notes: Dependent variable in odd columns is *R&D/GDP*, while in even columns is Δ*lnPantents*; Table A.2 in Appendix lists all countries (episodic and non-episodic) of our sample; Definitions of Equity (*eq*), Credit (*fc*) and Direct Investment (*di*) assets are provided in Table A.1 in Appendix (*), (**), (***) are significance level at the 10 %, 5 % and 1 %, respectively. Clustered standard errors with countries, country and year fixed effects and country-specific year trends are included in all specifications; *t*-values are reported in parentheses.

Diagnostics: Hansen J-test (p-value) examines whether instruments are valid (null); Kleibergen-Paap (K-P) rk Wald (F-statistic) tests whether instruments are weak (null), with critical values varying between 5.34 and 24.58, and 4.44 and 13.95 for the eq. (5) and eq. (6), respectively; Durbin-Wu-Hausman (p-value) tests whether instrumental variables techniques are required (null); Kleibergen-Paap (K-P) rk LM statistic (p-value) tests whether the estimated equation is underidentified (null); Arellano-Bond for AR(1) to AR(3) (p-value) test for no autocorrelation (null). Instruments used in eq. (5): $\Delta 5 lnpatents_{t-2}$, $lnpatents_{t-2}$, and the average of $lnPatents_{t-2}$ of neighboring countries (for $lnpatents_{t-1}$). Instruments used in eq. (6): $\Delta R\&D_{t-2}$, the average $R\&D_{t-2}$ of neighboring countries, $Institutions_{t-2}$ and $Institutions^2_{t-2}$ (for $R\&D_{t-1}$) and KC_{t-2}, KC^2_{t-2} and the average of KC_{t-2} of neighboring countries (for KC_{t-1} and KC^2_{t-2}). KC^*: value for which the maximum response of *R&D* to *KC* occurs.

ential innovations (Kortum and Lerner, 2000), arrange subsequent financing and assist with recruiting managers (Hellmann and Puri, 2000; Bottazzi et al., 2008).

As an exercise, we split the countries of our sample into two groups based on the availability of venture capital and particularly on an index that measures "how easy is it for entrepreneurs with innovative but risky projects to find venture capital" and ranges between 1(=extremely difficult) and 7(=extremely easy).[24] Countries which belong to the top 25 per cent of the distribution of venture capital index are classified as 'high-VC', while the rest as 'low-VC' countries.[25]

Then, we re-estimate the effects of restrictions on equity assets for both groups of countries. We expect when other sources of funding are available, such as venture capital investment, for innovative firms especially at the early stages of their technology development- controls on equity should matter less.[26] Results are shown in Table 5 below, where columns (1) and (2) report GMM estimates of equations (5) and (6), in Panels A and B, respectively, for high venture capital (high-VC), while columns (3) and (4), in similar fashion, for low venture (low-VC) countries.

The finding that emerges confirms our expectations: results may differ across industries but, on average, controls on equity assets do not have significant effects on innovation for the case of high-VC countries while they are of great importance for the case of the low-VC countries. Apparently, when innovative technologies are in their gestation period, their trajectories are far from defined, and success is highly uncertain, it is venture capital that fills firms' finance gaps; consequently, for countries that have firms at this stage of development with high availability of venture capital, financial constraints play little role in shaping innovation activity.

Furthermore, as in recent years the offshoring of firms' research and development functions (still not very high but it) is increasing rapidly (Gersbach and Schmutzler, 2011; Hall, 2011), for robustness purposes, we have also considered to control for countries that receive a large share of their general expenditure of R&D from abroad and revaluate the effects of equity constraints on innovation activity. In doing so, we split our sample into countries with high R&D funded from abroad (top 25 % percentile of sample distribution) versus low R&D funded and replicated our analysis.[27] Results, available upon request, have remained qualitatively unaltered with only the controls on equity to have a heavier tall (max of 0.32) on R&D and patent activity for the group of countries which received R&D funding from abroad.

Overall, our results corroborate with studies that point to the importance of equity-based finance as a major channel of funding innovation activity (Brown and Petersen, 2009; Brown et al., 2012; Hsu et al., 2014).[28] Specifically, our findings support that restrictions on debt (or direct investment) assets do not matter for innovation activity, while controls on equity greatly do. Countries that face macroeconomic or prudential policy challenges may resort in setting controls on debt assets -which are riskier than equity assets or on direct investment to financially stabilize a country without harming its innovation activity (Ostry et al., 2010). Even for countries which maintain high or extensive restrictions, the composition of the asset restrictions matters - particularly the level of restrictions on equity assets. However, countries that have high availability of venture capital, equity asset controls may play an insignificant role. Although the extant literature on venture capital and innovation provides mixed evidence, our finding aligns with recent evidence on the role of venture capital in fostering innovation for countries that have a considerable (relative to their R&D) amount of venture capital (Popov and Roosenboom, 2012).

5. Conclusion

The recent financial crisis has rejuvenated the debate about the free movement of capital. Controls on capital flows have been receiving increasing support in policy circles, among researchers and in the general economic debate. Theoretical research provides rationales for the imposition of episodic controls at the time of surging capital inflows, or at a time when the economy is booming. However, the empirical evidence on their effectiveness is rather reluctant while causation is far from established.

The paper aimed to contribute to the evolving debate on the effects of international capital controls on economic growth through the channel of R&D financing. R&D is an important input of innovation and a major driver for long-run economic growth. Knowledge asset, created by R&D investment, is intangible, partly embedded in human capital, and ordinarily very specialized to the particular firm in which it resides. As most of the R&D expenditure is the wages and salaries of highly educated scientists and engineers, liquidity constraints, or excess sensitivity to cash flow shocks can be detrimental for the financing of longrun innovative projects. Failure of financing promising and innovative project would result in a smaller

[24] Information on venture capital availability index comes from the World Economic Forum *Global Competitiveness Index*. Available at: https://reports.weforum.org/global-competitiveness-index-2017–2018/.

[25] The high-VC group includes 14 countries: Australia, Canada, Finland, Hong Kong, Israel, Malaysia, Netherlands, New Zealand, Norway, Singapore, Sweden, Switzerland, United Kingdom, and United States. Half of them (Finland, Israel, Singapore, Sweden, Switzerland, and United States) are world's top performers in R&D expenditure.

[26] Similar expectations rise for coefficients of debt and direct investment restrictions. However, as we find no effect of these asset restrictions on innovation, we focus only on equity restrictions controlling for the presence of venture capital investment by splitting our sample into high- and low-VC countries.

[27] Information on the share of expenditure in R&D funded from abroad is available from the UNdata: https://data.un.org. Countries that belong to the top 25%, in which the R&D funded from abroad performs>11.5% in terms of their total general R&D are: Austria, Bulgaria, Cyprus, Greece, Ireland, Israel, Latvia, Malta, Panama, Singapore, South Africa, Ukraine, United Kingdom. However, due to missing data, we were not able to fully explore this issue; yet, we made an effort to vaguely address it by using only the information available.

[28] We have also examined the effect of controls of the remaining assets, i.e., bonds (*bo*), money market (*mm*), commercial credits (*cc*), and guaranties and securities (*gs*) on innovation performance. Estimates, as shown in Table A.3 in the Appendix, are found to be statistically insignificant.

Table 5
Equity Asset Controls and Innovation Estimates in High (Low) Venture Capital (VC) Countries.

	High-VC countries		Low-VC countries	
	(1)	(2)	(3)	(4)
Panel A	**Estimates of eq. (6): Innovation Input (dep. var.: $R\&D_t$)**			
$R\&D_{t-1}$	0.653***		0.916***	
	[4.154]		[8.279]	
KC_{t-1}	0.372		0.262**	
	[1.170]		[2.181]	
KC^2_{t-1}	−0.727		−0.280**	
	[−1.343]		[−2.007]	
$Unemployment_{t-1}$	−0.013		0.000	
	[−1.544]		[0.106]	
$AgricultureShare_{t-1}$	−0.004		−0.0.004*	
	[−0.273]		[−2.281]	
HDI_{t-1}	0.315		0.988*	
	[0.319]		[1.790]	
Panel A	**Estimates of eq. (5): Innovation Output (dep. var.: $\Delta lnPatents_t$)**			
$lnPatents_{t-1}$		−1.061***		−0.654***
		[−9.391]		[−7.272]
$lnR\&D_t$		0.815***		0.528**
		[3.897]		[2.490]
Observations	241	190	670	522
Number of countries	14	14	39	39
Within R-squared	0.534	0.080	0.461	0.270
Year effects	Y	Y	Y	Y
Country effects	Y	Y	Y	Y
Country-specific-time-trends	Y	Y	Y	Y
Clustered standard errors	Country	Country	Country	Country
Hansen J-test	0.596	0.493	0.656	0.146
K-P rk Wald F-statistic	1.327	5.473	4.605	23.817
Durbin-Wu-Hausman test	0.928	0.389	0.036	0.072
K-P rk LM	0.681	0.085	0.007	0.003
Arellano-Bond AR-1	0.279	0.220	0.163	0.303
Arellano-Bond AR-2	0.608	0.533	0.679	0.229
Arellano-Bond AR-2	0.712	0.155	0.189	0.170
	Summary Effects of Equity Controls, KC_{eq}			
KC^*_{eq}			0.468	
before KC^*_{eq}			0.231	0.665
after KC^*_{eq}			−0.177	−0.630

Notes: Dependent variable in columns (1) and (3) is *R&D/GDP*, while in columns (2) and (4) is $\Delta lnPantents$; Table A.2 in Appendix lists all countries (episodic and non-episodic) of our sample; 'High-VC' countries: Australia, Canada, Finland, Hong Kong, Israel, Malaysia, Netherlands, New Zealand, Norway, Singapore, Sweden, Switzerland, United Kingdom, and United States, while 'Low-VC' group contains the rest, 40 countries; Definition of Equity (*eq*) asset provided in Table A.1 in Appendix; (*), (**), (***) are significance level at the 10 %, 5 % and 1 %, respectively. Clustered standard errors with countries, country and year fixed effects and country-specific year trends are included in all specifications; *t*-values are reported in parentheses. Diagnostics: Hansen J-test (p-value) examines whether instruments are valid (null); Kleibergen-Paap (K-P) rk Wald (F-statistic) tests whether instruments are weak (null), with critical values varying between 5.34 and 24.58, and 4.44 and 13.95 for the eq. (5) and eq. (6), respectively; Durbin-Wu-Hausman (p-value) tests whether instrumental variables techniques are required (null); Kleibergen-Paap (K-P) rk LM statistic (p-value) tests whether the estimated equation is underidentified (null); Arellano-Bond for AR(1) to AR(3) (p-value) test for no autocorrelation (null). Instruments used in eq. (5): $\Delta 5lnpatents_{t-2}$, $lnpatents_{t-2}$, and the average of $lnPatents_{t-2}$ of neighboring countries (for $lnpatents_{t-1}$). Instruments used in eq. (6): $\Delta R\&D_{t-2}$, the average $R\&D_{t-2}$ of neighboring countries, $Institutions_{t-2}$ and $Institutions^2_{t-2}$ (for $R\&D_{t-1}$) and KC_{t-2},
KC^2_{t-2} and the average of KC_{t-2} of neighboring countries (for KC_{t-1} and KC^2_{t-1}). KC^*_{eq}: value for which the maximum response of *R&D* to KC_{eq} occurs.

increase of new technological knowledge and generation of new ideas, which, in turn, would result to lower economic growth.

Our paper offers new insights into the real effects of financial restrictions. First, we ask whether capital controls shape innovation activity, both from the input and output side. To evaluate their role, we model R&D investment as a function of capital restrictions, among other controls, and by applying a fixed effects identification strategy and instrumentation techniques, we are able to obtain the effect of capital controls on R&D. Then, we estimate a typical R&D-based endogenous growth model, where new knowledge -the output of innovation production process- is proxied by the annual growth of patents while new investment in knowledge -the input of innovation production process- is R&D.

Our results support a robust inverse U-shaped relationship between capital controls and domestic R&D. On average, capital restrictions can be beneficial till a certain point, and thereafter have negative effects on R&D and even more so on patents. Countries that already maintain (high and extensive) restrictions on most categories of flows should be cautious to further increase their capital controls; otherwise, they could harm their innovation and consequently, future growth perspectives.

Second, we ask whether the composition of restrictions of individual assets, in the aggregate capital control index, matters for innovation. A benefit of a new dataset we employ is that it allows one to differentiate between controls on individual assets. Motivated by a recently emerging literature on financial development and innovation, we assess the impact of restrictions on equity and credit assets, which both consist well-established channels of the financial sector. Also motivated by another literature that stresses the potential benefits of external knowledge diffusion on a country's innovation performance through the presence of multinational companies, we further examine direct investment restrictions. Our results support that controls on debt (credit) assets have no effect while equity controls, after a level, are damaging for R&D and especially for patents. Our results highlight the major role of equity-base channel for the financing of innovation activity. In countries, however, where there is high availability of venture capital even equity controls cannot harm innovation. Finally, controls on direct investment have no impact at all.

Summing up, our results do not advocate, by any means, the re-imposition of controls by countries that already have largely open capital accounts. Capital controls are a legitimate part of the toolkit to manage capital inflows in certain circumstances. A decision on their use should reflect a comparison of the distortions and implementation costs that they may impose and the benefits from regaining macroeconomic policy control, reducing financial fragility and supporting (or at least not damaging) innovation. For the latter, our findings underline that both the aggregate index of capital controls as well as the composition of asset restrictions greatly matter for innovation activity.

Micro level evidence could further shed more light as to what type of firms and sectors are more vulnerable to capital restrictions concerning their innovation patterns. Given firms' external dependence of finance, one could explore what type of innovation (product, process, radical, incremental) is mostly affected.

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CRediT authorship contribution statement

Alexandros Bechlioulis: Formal analysis, Investigation, Methodology, Software. **Claire Economidou:** Conceptualization, Investigation, Project administration, Supervision. **Dimitrios Karamanis:** Investigation, Validation, Visualization. **Dimitrios Konstantios:** Data curation, Resources, Investigation.

Data availability

Data will be made available on request.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix. Asset Definition and Grouping

See Tables A1-A3.

Table A1
Asset Categories of Capital Control Index.

Asset category	Definition
Equity (*eq*)	Includes transactions involving shares and other securities of a participating nature if they are not affected for the purpose of acquiring a lasting economic interest in the management of the enterprise concerned.
Bonds (*bo*)	Refers to bonds and other securities with an original maturity of more than one.
Money market (*mm*)	Refers to securities with an original maturity of one year or less and includes short-term instruments, such as certificates of deposit and bills of exchange. The category also includes treasury bills and other short-term government paper, bankers' acceptances, commercial papers, interbank deposits, and repurchase agreements.
Collective investment (*ci*)	Includes share certificates and registry entries or other evidence of investor interest in an institution for collective investment, such as mutual funds, and unit and investment trusts.
Derivatives (*de*)	Includes operations in rights, warrants, financial options and futures, secondary market operations in other financial claims, swaps of bonds and other debt securities, and foreign exchange without any other underlying transaction.
Financial credits (*fc*)	Includes credits other than commercial credits granted by all residents, including banks, to nonresidents, or vice versa.
Direct investment (*di*)	Refers to investments for the purpose of establishing lasting economic relations both abroad by residents and domestically by nonresidents. These investments are essentially for the purpose of producing goods and services, and, in particular investments that allow investor participation in the management of the enterprise. The category includes the creation or extension of a wholly owned enterprise, subsidiary, or branch and the acquisition of full or partial ownership of a new or existing enterprise that results in effective influence over the operations of the enterprise.
Commercial credits (*cc*)	For operations directly linked with international trade transactions or with the rendering of international services.
Guaranties andsecurities (*gs*)	Provided by residents to nonresidents, and vice versa, which includes securities pledged for payment or performance of a contract such as warrants, performance bonds, and standby letters of credits and financial backup facilities that are credit facilities used as a guarantee for independent financial operations.
Real estatetransactions (*re*)	Representing the acquisition of real estate not associated with direct investment, including, for example, investments of a purely financial nature in real estate or the acquisition of real estate for personal use.

Source: Fernandez et al. (2016).

Table A2
List of Countries and Capital Controls.

			Capital controls index			Asset restrictions						Changes
			(1996–2003)	(2004–2016)	(1996–2016)	Equity		Credit		Investment		
						(+)	(−)	(+)	(−)	(+)	(−)	
Country	Membership	Type	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Argentina	Non-OECD	E	0.30	0.78	0.58	5	2	2	0	4	2	15
Australia	OECD	E	0.31	0.25	0.27	2	2	1	1	0	0	6
Austria	OECD	E	0.05	0.21	0.14	1	0	2	1	0	0	4
Belgium	OECD	E	0.03	0.12	0.08	3	2	2	1	0	0	8
Brazil	Non-OECD	E	0.68	0.55	0.61	2	2	2	1	1	1	9
Bulgaria	Non-OECD	E	0.33	0.06	0.18	0	1	0	1	0	1	3
Canada	OECD	N-E	0.05	0.05	0.05	0	0	0	0	0	0	0
China	Non-OECD	N-E	0.98	0.95	0.96	0	0	0	0	0	0	0
Colombia	Non-OECD	E	0.70	0.61	0.65	3	2	2	4	2	2	15
Cyprus	Non-OECD	E	0.80	0.21	0.46	1	3	2	2	1	1	10
Czech Republic	OECD	E	0.20	0.32	0.27	2	3	2	2	1	0	10
Denmark	OECD	N-E	0.07	0.05	0.06	0	0	0	0	0	0	0
Ecuador	Non-OECD	E	0.32	0.24	0.27	2	1	1	1	0	0	5
Egypt	Non-OECD	E	0.15	0.17	0.16	2	0	0	0	0	0	2
Finland	OECD	E	0.05	0.20	0.13	2	1	2	1	1	0	7
France	OECD	E	0.09	0.05	0.07	1	2	0	0	0	0	3
Germany	OECD	E	0.03	0.30	0.18	1	1	1	0	2	0	5
Greece	OECD	E	0.00	0.20	0.11	3	1	1	0	2	0	7
Hong Kong	Non-OECD	N-E	0.00	0.03	0.02	0	0	0	0	0	0	0
Hungary	OECD	E	0.40	0.11	0.24	1	2	0	1	0	1	5
Iceland	OECD	E	0.18	0.67	0.46	2	1	1	0	2	0	6
India	Non-OECD	N-E	0.99	0.95	0.97	0	0	0	0	0	0	0
Ireland	OECD	N-E	0.05	0.05	0.05	0	0	0	0	0	0	0
Israel	OECD	E	0.19	0.05	0.11	0	2	0	1	1	1	5
Italy	OECD	N-E	0.03	0.03	0.03	0	0	0	0	0	0	0
Japan	OECD	E	0.01	0.00	0.00	0	0	0	0	1	1	2
Kazakhstan	Non-OECD	E	0.62	0.44	0.51	3	3	2	3	0	1	12
Korea	OECD	E	0.59	0.13	0.33	1	1	0	1	3	2	8
Latvia	OECD	E	0.07	0.06	0.07	1	1	1	1	1	1	6

Table A2 (*continued*)

			Capital controls index			Asset restrictions						Changes
			(1996–2003)	(2004–2016)	(1996–2016)	Equity		Credit		Investment		
						(+)	(−)	(+)	(−)	(+)	(−)	
Malaysia	Non-OECD	E	0.79	0.82	0.81	1	1	0	0	0	0	2
Malta	Non-OECD	E	0.66	0.08	0.33	0	4	0	1	0	2	7
Mexico	OECD	E	0.58	0.59	0.58	2	1	1	1	0	1	6
Netherlands	OECD	N-E	0.00	0.00	0.00	0	0	0	0	0	0	0
New Zealand	OECD	N-E	0.10	0.10	0.10	0	0	0	0	0	0	0
Norway	OECD	N-E	0.02	0.08	0.05	0	0	0	0	0	0	0
Pakistan	Non-OECD	E	0.79	0.68	0.73	3	1	0	0	1	0	5
Panama	Non-OECD	N-E	0.00	0.00	0.00	0	0	0	0	0	0	0
Peru	Non-OECD	N-E	0.00	0.01	0.01	0	0	0	0	0	0	0
Poland	OECD	E	0.86	0.64	0.73	1	2	1	2	0	0	6
Portugal	OECD	E	0.06	0.25	0.17	3	2	1	1	2	1	10
Romania	Non-OECD	E	0.67	0.09	0.34	0	3	0	1	1	1	6
Russia	Non-OECD	E	0.80	0.46	0.61	1	3	2	3	0	0	9
Singapore	Non-OECD	E	0.17	0.13	0.14	2	2	1	0	0	0	5
Slovenia	OECD	E	0.46	0.30	0.37	1	2	1	1	1	2	8
South Africa	Non-OECD	E	0.62	0.64	0.63	1	1	0	0	1	0	3
Spain	OECD	N-E	0.03	0.01	0.02	0	0	0	0	0	1	1
Sweden	OECD	E	0.06	0.06	0.06	2	2	1	1	0	0	6
Switzerland	OECD	E	0.05	0.25	0.16	2	1	2	1	0	0	6
Thailand	Non-OECD	E	0.70	0.77	0.74	1	1	2	1	1	2	8
Turkey	OECD	E	0.30	0.53	0.43	3	1	1	0	1	2	8
Ukraine												
United Kingdom												
United States												
Ukraine	Non-OECD	E	0.83	0.77	0.80	1	1	2	2	0	0	6
United Kingdom												
United States												
United Kingdom	OECD	N-E	0.00	0.02	0.01	0	0	0	0	1	0	1
United States	OECD	N-E	0.13	0.15	0.14	0	1	0	0	0	0	1
Total						**62**	**62**	**39**	**37**	**31**	**26**	**257**

Note: In column "Type", we split countries into Episodic (E) and Non-Episodic (N-E). The latter group contains countries which have changed the composite index of capital controls (*KC*) only one time, at the most, over the sample period of our analysis (particularly for the equity, credit and direct investment assets), which corresponds to 25 % of the total number of countries with the zero or maximum one changes in their capital controls. Among the Non-Episodic group some countries are either "walls" (with long-standing capital restrictions, not allowing international flows, i.e., *KC* close to 1) or on the opposite side "strictly open" (allowing unrestricted capital flows, i.e., *KC* close to 0).

Table A3
Estimates of Various Individual Asset Controls and R&D Activity.

	bo	*mm*	*ci*	*de*	*cc*	*gs*	*re*
$R\&D_{t-1}$	0.897***	0.954***	0.941***	0.923***	0.867***	0.884***	0.904***
	[9.845]	[11.646]	[11.079]	[10.058]	[8.564]	[8.762]	[7.620]
KC_{t-1}	0.195	0.113	0.159	0.152	0.054	−0.029	0.241
	[1.387]	[1.117]	[1.289]	[1.170]	[0.599]	[−0.291]	[1.320]
KC^2_{t-1}	−0.130	−0.043	−0.155	−0.150	−0.068	−0.019	−0.206
	[−1.237]	[−0.350]	[−1.261]	[−1.253]	[−0.738]	[−0.245]	[−1.322]
$Unemployment_{t-1}$	−0.000	−0.000	0.001	−0.000	0.002	0.001	0.002
	[−0.043]	[−0.044]	[0.304]	[−0.035]	[0.569]	[0.379]	[0.578]
$AgricultureShare_{t-1}$	−0.005***	−0.003*	−0.004**	−0.003	−0.004*	−0.004*	−0.004*
	[−2.594]	[−1.712]	[−2.375]	[−1.477]	[−1.869]	[−1.649]	[−1.813]
HDI_{t-1}	0.389	0.313	0.221	0.158	0.102	0.208	0.093
	[0.768]	[0.646]	[0.444]	[0.330]	[0.206]	[0.391]	[0.180]
Observations	769	771	771	771	771	771	771
Within R-squared	0.47 4	0.446	0.451	0.470	0.487	0.479	0.477
Year effects	Y	Y	Y	Y	Y	Y	Y
Country effects	Y	Y	Y	Y	Y	Y	Y
Country-specific-time-trends	Y	Y	Y	Y	Y	Y	Y
Clustered standard errors	Country	Country	Country	Country	Country	Country	Country
P-value *U* test	0,294	–	0,137	0,121	–	–	0,174
p-value Kleibergen-Paap rk LM	0,000	0,049	0,047	0,000	0,000	0,000	0,000
Kleibergen-Paap rk Wald F statistic	8,310	3,809	3,267	10,138	9,048	10,189	7,520

(*continued on next page*)

Table A3 (*continued*)

	bo	*mm*	*ci*	*de*	*cc*	*gs*	*re*
p-value Arellano-Bond AR-1	0,266	0,273	0,285	0,295	0,272	0,294	0,302
p-value Arellano-Bond AR-2	0,254	0,218	0,228	0,238	0,350	0,348	0,302
p-value Arellano-Bond AR-3	0,098	0,122	0,124	0,129	0,146	0,162	0,138
p-value Durbin-Wu-Hausman test	0,059	0,009	0,089	0,170	0,270	0,197	0,362
P-value Hansen test	0.552	0.511	0.468	0.410	0.417	0.437	0.348

Notes: See Table A.1 for variables' definition. *, **, *** are significance level at the 10 %, 5 % and 1 %, respectively. Robust standard errors, country-year fixed-effects and country-specific time trends are also reported.
Diagnostic tests: The null hypothesis of the *U* test is that a monotone or U-shape relation exists. The null hypothesis of the Kleibergen-Paap rk LM statistic is that the equation is underidentified. The Kleibergen-Paap rk Wald F statistic measures weak instruments, with critical values varying between 4.44 and 16.10. If the F-statistic value is higher or close to respective critical values we do not suffer from weak instrument problem. The Arellano-Bond tests no autocorrelation problem, with a null hypothesis of no autocorrelation. The Durbin-Wu-Hausman test shows that a rejection of the null hypothesis indicates that endogenous regressors' effects on the estimates are meaningful, and instrumental variables techniques are required. The null hypothesis of the Sargan-Hansen test is that the instruments are valid instruments.
Instruments used are: $R\&D_{t-2}$, $R\&D_{t-2}$ *of border − countries average*, *Rule of law*$_{t-2}$, *Control of corruption*$_{t-2}$, KC_{t-2}, KC^2_{t-2}, KC_{t-2} *of border − countries average*. Per case, we also include instruments of each *KC* component, e.g., $bonds_{t-2}$,.$bonds^2_{t-2}$

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