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The Effects of Prudential Regulation, Financial Development, and Financial Openness on Economic Growth

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Abstract

This paper studies the effects of prudential regulation, financial development, and financial openness on economic growth. Using both existing models and a new OLG framework with banking and prudential regulation in the form of capital requirements, the first part presents an analytical review of the various channels through which prudential regulation can affect growth. The second part provides a reduced-form empirical analysis, based on panel regressions for a sample of 64 advanced and developing economies. The results show that growth may be promoted by prudential policies whose goal is to mitigate financial risks to the economy. At the same time, financial openness tends to reduce the growth benefits of these policies, possibly because of either greater opportunities to borrow abroad or increased scope for cross-border leakages in regulation.

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1 Introduction

The relationship between financial development and growth has been the subject of an extensive literature.[1] A large body of evidence suggests that countries with better-developed financial systems tend to grow faster over long periods of time and that this effect is causal. To a significant extent, this growth benefit occurs because financial development helps to promote capital accumulation and a more efficient allocation of resources by improving the ability of financial intermediaries to mobilize and pool savings, alleviating financial constraints, improving risk-sharing, reducing agency costs, producing and disseminating information about investment opportunities, and facilitating long-term foreign capital inflows.

However, it is also increasingly recognized that financial development may lead to greater risks of financial crises (due to excessive growth in credit), adverse incentives to save (associated with weaker constraints on private borrowing), and inefficient allocation of labor to the financial sector (which hampers the expansion of innovation-driven, growth-promoting sectors). In particular, concerns with financial risks have regained importance in the aftermath of the Global Financial Crisis (GFC), which underscored the potentially adverse effects of weak regulation in a world where financial markets are closely interconnected. Some recent contributions have indeed emphasized that financial openness may translate into increased financial volatility, which may generate persistent effects on economic growth, and that coping with these increased risks may require the strengthening of prudential regulation.

The contribution of this paper to this ongoing debate is twofold. First, it provides an analytical overview of the various channels through which prudential regulation can affect economic growth. This is a critical aspect of the debate because, by and large, empirical studies and policy discussions have tended to focus on only one mechanism (the risk-taking effect of prudential regulation), without sufficient attention being paid to other, potentially equally important, channels. Second, it conducts an econometric analysis, using cross-country data, of the effects of prudential policies, financial development, and the degree of

[1] For an overview, see Levine (2005) and more recently Valickova et al. (2015), who conduct an instructive meta-analysis. Fernández and Tamayo (2017) provide a more focused discussion on the role of institutions, notably with respect to their role in enforcing property rights and trust in the terms of financial contracts.

financial openness, both individually and jointly, on economic growth. In doing so, we go beyond existing studies, such as Ma (2017) and Neanidis (2018), whose focus has been more narrowly defined in terms of the effects of prudential policies on growth, without accounting for the fact that financial development or financial openness could affect significantly this relationship.

Our analytical review highlights the fact that there are a number of channels (beyond the conventional mitigating effect on risk-taking) through which prudential regulation can affect growth. These channels may operate in opposite directions, making the net effect theoretically ambiguous. In turn, this ambiguity means that measuring the net impact of prudential regulation on growth is an empirical issue. At the same time, because our focus is on the net effect of prudential regulation on growth rather than any specific channel, we conduct our analysis using a reduced-form approach.

Our empirical results (which we view as provisional, given the limitations in available datasets) indicate that economies where prudential policy is used to tighten credit conditions—presumably to curb excessive credit growth and mitigate financial risks to the economy—tend to benefit from higher growth. At the same time, we find that financial openness tends to weaken this positive effect, possibly because openness provides greater opportunities to domestic financial institutions and nonfinancial agents to borrow abroad and insulate themselves from policy-induced changes in domestic financial market conditions. In addition, it is also possible that greater financial openness provides (as documented in some recent studies) more scope for leakages in prudential regulation across countries, thereby allowing financial institutions to circumvent changes in national regulatory policy measures.

The remainder of the paper is organized as follows. Section 2 provides a broad analytical overview of the various channels through which prudential regulation can affect economic growth, and how it can interact with financial development and financial openness. Part of the discussion is based on existing theoretical models, but part also is based on a new model, which is presented in a more detailed manner in Appendix A. Section 3 presents the empirical framework and Section 4 the econometric results. The last section provides some concluding remarks and discusses the broader policy implications of the analysis.

2 Analytical Background

One of the key lessons to emerge from the GFC is that prudential regulation and supervision must adopt a systemic (macroprudential) perspective to identify, and prevent the build-up of, weaknesses in the financial system. Indeed, there is now a broad consensus that the goal of macroprudential regulatory rules should be to mitigate the amplitude of the financial cycle, increase the resilience of the financial system, and limit disruptions to the provision of financial services that can adversely affect the real economy (Galati and Moessner (2013)).

Consistent with that perspective, much of the recent debate has focused almost exclusively on the benefits of prudential regulation in terms of mitigating financial risks and the procyclicality of the financial system, dampening short-run fluctuations in credit and output, and promoting economic stability in general. By contrast, the growth effects of regulation have received only scant attention.[2]

However, understanding these effects is essential because a potential trade-off may arise: although regulatory policies can help to promote growth by reducing the procyclicality of the financial system and the risk of financial crises, they could also be detrimental to economic growth beyond the short term. To identify these effects, we consider four channels through which prudential regulation could indeed affect longer-run growth: an effect on risk-taking and incentives to lend and borrow, an effect on bank intermediation costs, an effect on the size of the financial sector, and a broader effect through the distribution of income and wealth. We focus our discussion mostly on capital and liquidity requirements, given the role that they played in recent regulatory reforms.

2.1 Effect on Risk-Taking

The first, and most discussed, channel through which prudential regulation can affect economic growth in the long run is through its impact on risk-taking and incentives to borrow

[2] A study by the Basel Committee on Banking Supervision (2010), as well as others, did discuss the possibility that stronger regulation could generate short-term costs in terms of slower credit growth and weaker activity—while at the same recognizing that there are potential long-term benefits in terms of financial stability. However, the quantitative exercises performed in most of these contributions do not provide proper microfoundations with respect to how regulation affects the possibility of default and the probability of occurrence of a financial crisis. As discussed next, these are important channels through which prudential regulation can affect long-run growth.

and lend.[3] To the extent that higher capital adequacy ratios, for instance, increase bankers' *skin in the game*, they may reduce risk-taking by improving incentives to screen and monitor borrowers, and to exercise due diligence. In turn, this can mitigate excessive credit growth and reduce the amplitude of the financial cycle and the degree of output volatility. Moreover, if reduced volatility (or, more generally, a more stable economic environment) makes it easier for entrepreneurs to perceive and respond to relative price signals, as well as assess risks and returns associated with their decisions, investment may increase, thereby promoting growth. Another positive effect on growth may be due to the fact that, if an increase in capital requirements is perceived by households as making the banking system safer, they may choose to reallocate their portfolios toward deposits.[4] In turn, a sustained increase in core bank resources can help to promote lending and economic growth.

Nevertheless, these positive effects can be mitigated or offset in several ways. First, it is possible that the shift to less risky activities leads to an excessive focus on short-term loans (such as financing of durable consumption goods), trade finance, or the holding of safe government bonds, which may contribute less significantly to promoting longer-run growth. Second, an increase in capital requirements may raise the cost of credit (due to banks passing on to borrowers the higher cost of issuing and holding equity), which may dampen the demand for investment loans. Theoretically, therefore, the net effect of the risk-taking channel of prudential regulation on growth is in general ambiguous.

Formally, the effect of prudential regulation on risk-taking and growth can be illustrated in the model developed in Agénor and Pereira da Silva (2017), in which mitigating risks to the financial system takes the form of eliminating a specific *type* of credit (loans to risky borrowers) rather than the *amount* of credit that banks provide.[5] In the model, the economy is populated by a continuum of risk-neutral agents who live for two periods (adulthood and old age), final goods producers, and a financial regulator. Individual agents are all endowed with one period of time in adulthood and are of two types: households and

[3] This channel has also been shown to be fairly significant at shorter horizons as well. Using annual data for a group of 61 countries covering the period 1990-2012, Altunbas et al. (2018) for instance found that capital requirements have a significant impact on bank risk-taking.

[4] In Agénor (2018*a*), this effect on deposits occurs because prudential regulation (in the form of reserve requirements) operates as partial deposit insurance. See the discussion in the next subsection.

[5] In turn, their analysis dwells in part on Collard et al. (2017), who focus on short-run fluctuations in production.

entrepreneurs. Households consist of a fixed number of individuals. When young (period t) each household member sells his labor endowment of unity in return for a wage w_t. At the end of period t, a fixed fraction $\varkappa \in (0,1)$ of household members are randomly selected to become *bankers*, who join together to form a bank, while a fraction $1-\varkappa$ becomes *depositors*. Thus, with the number of households normalized to unity, $\varkappa$ is also the share of bankers in the economy.

Each household divides $(1-\varkappa)w_t$ between period-t consumption and saving via deposits, whereas $\varkappa w_t$ is used as equity to start the bank. Optimization yields the supply of deposits d_t as

$$d_t = \frac{\Lambda}{1+\Lambda}(1-\varkappa)w_t - (\frac{1}{1+\Lambda})\frac{R^E}{R^D}\varkappa w_t, \tag{1}$$

where $\Lambda \in (0,1)$ is a discount factor and R^D (R^E) the return on deposits (equity). Thus, all else equal, an increase in the return on equity lowers the supply of deposits.

At the end of period t, bankers combine their equity with deposits to lend to entrepreneurs, who invest to produce capital, using either one of two technologies: a risky technology, whose return is stochastic, and a safe (but less productive) technology. Capital becomes available at $t+1$ and is rented to final goods producers, who combine it with labour to produce a homogeneous final good. In $t+1$ banks receive the return on the loans that they made in period t and use it to pay back depositors and cover the return to equity.

At the beginning of period t, entrepreneurs borrow from banks to finance investment and all agents make their optimization decisions. Entrepreneurs using the risky technology are subject to a failure shock, whose probability (which is equal to the fraction of risky entrepreneurs who will eventually fail) is known up-front, but the identity of failing entrepreneurs is only discovered after the realization of the shock. That is, in the model, excessive risk-taking arises from limited liability—the ability to default on loans in the event of failure—and involves the *type* (not necessarily the *amount*) of credit extended by banks. Risk-taking is thus measured in terms of the *composition* of banks' loan portfolios.[6]

As noted earlier, entrepreneurs have access to safe and risky technologies (denoted S and R) to accumulate capital. They have no resource endowment; to produce capital goods, each entrepreneur $j \in (0,1)$ invests the amount borrowed from banks, l_t^j. Thus, capital

[6] See Rochet (1992) for an early analysis of the link between bank capital and risk-taking under limited liability.

produced by an entrepreneur j choosing the safe technology is given by[7]

$$K_{t+1}^{j} = l_{t}^{j}. \tag{2}$$

By contrast, entrepreneurs choosing the risky technology are subject to a failure shock, ζ_{t}^{j}, which is independently and identically distributed. Thus, if the investment is successful, capital is given by

$$K_{t+1}^{j} = \zeta_{t}^{j}(1+\phi)l_{t}^{j}, \tag{3}$$

where $\phi > 0$ is a productivity parameter which ensures that in the absence of failure the risky technology is always more productive than the safe one and, $\forall j$,

$$\zeta_{t}^{j} = \begin{cases} 0 & \text{with prob. } p \\ 1 & \text{with prob. } 1-p \end{cases}, \tag{4}$$

where $p \in (0,1)$ is the probability of failure. Entrepreneur j chooses whether to use technology S or technology R before observing the realization of the idiosyncratic shock ζ_{t}^{j}.

This setup serves to highlight a familiar connection between limited liability and excessive risk-taking: if entrepreneurs (borrowers) are not monitored properly, they may take on more risk than a hypothetical social planner would. Indeed, suppose that (depending on the realization of an idiosyncratic shock) the risky technology yields more capital than the safe technology when it succeeds, but that it yields no capital at all when it fails. Suppose also that using the risky technology to *any* degree is always inefficient, and thus undesirable, from the perspective of the social planner (the regulator in this setting). To ensure that this is the case, the condition $(1-p)(1+\phi) < 1$, $\forall \phi > 0$ is imposed.

Even in such conditions, because of limited liability entrepreneurs still have an incentive to use the risky technology. There is therefore a need to monitor those who claim to use the safe technology, and only banks have the skills needed to do so. At the same time, however, banks themselves have adverse incentives due to limited liability and implicit deposit guarantees, and these adverse incentives create a role for prudential regulation.

As a result of an Arrow-Romer type externality, final output Y_t is linear in the aggregate capital stock, K_t:

$$Y_t = AK_t, \tag{5}$$

[7] Note that there is only one *type* of capital, even though there are two technologies for producing it.

which implies that the competitive wage rate is given by $w_t = (1-\alpha)AK_t$, where $\alpha \in (0,1)$ is the elasticity of output with respect to capital in the individual production function. Thus, the supply of equity, $e_t = \varkappa w_t$, grows at the same rate as physical capital.

Abstracting from monitoring costs, the representative bank's balance-sheet is

$$l_t^S + l_t^R = e_t + d_t, \tag{6}$$

with d_t given in (1).

As in Van den Heuvel (2008) and Collard et al. (2017), Agénor and Pereira da Silva (2017) assume that the regulator observes the total amount of loans made by each bank but cannot detect its risky loans up to a given fraction $\gamma > 0$ of its safe loans. It imposes full capital requirements on risky loans above that fraction, $l_t^R - \gamma l_t^S$. The prudential regime is thus characterized by

$$e_t \geq \mu(l_t^S + l_t^R) + \max(0, l_t^R - \gamma l_t^S), \tag{7}$$

where $\mu \in (0,1)$ is the capital adequacy ratio.[8] In equilibrium, if banks benefit from an implicit government guarantee on their deposits, and if equity is more expensive than deposit finance, banks will hold no more equity than required by regulation. The prudential regime can consequently be equally characterized by the condition

$$e_t = \mu(l_t^S + l_t^R), \tag{8}$$

together with the condition that, if banks take any risk, then they will take the maximum undetectable risk:

$$l_t^R = \gamma l_t^S. \tag{9}$$

The model is closed by requiring that the return on equity, R^E, is solved to equilibrate supply, $\varkappa w_t$, and demand, solved residually from the balance sheet and capital requirement constraints (6) and (8), together with (1) and (9). The solution yields $R^E > R^D$, which ensures that banks will indeed demand equity only up to the point at which the regulatory constraint (8) is binding. From that solution, it can also be shown that a higher capital adequacy ratio raises the rate of return on equity.

[8] Because μ is not risk-sensitive, it is equivalent here to a leverage ratio.

As shown by Agénor and Pereira da Silva (2017), further manipulations imply that the model yields the economy's equilibrium growth rate when risky loans are made as

$$1 + g = [\frac{1 + (1 - p)(1 + \phi)\gamma}{1 + \gamma}]\frac{\varkappa}{\mu}(1 - \alpha)A. \quad (10)$$

Now, to introduce the *skin in the game* argument, Agénor and Pereira da Silva (2017) assume that an increase in the economy-wide (average) capital-loan ratio induces banks to improve monitoring, and that increased monitoring, by mitigating moral hazard stemming from limited liability, reduces the probability of default on risky loans. From (8) and (9) the capital-loan ratio is $(1 + \gamma)\mu$. Thus, this assumption implies that

$$p = p(\mu), \quad (11)$$

with $p' < 0$. It can readily be shown that an increase in the capital adequacy ratio has an ambiguous effect on the steady-state growth rate: on the one hand, it raises the cost of equity and reduces the equilibrium supply of loans, but on the other, by improving monitoring, it reduces the probability of loan default. If the latter effect is sufficiently large, tighter capital requirements will promote long-run growth—despite an adverse effect on the cost of, and supply of, credit.

2.2 Effect on Intermediation Costs

Prudential regulation can affect growth also through its impact on bank intermediation costs. This effect can itself operate through (permanent) monitoring costs, or through (state contingent) verification costs.

2.2.1 Monitoring Costs

To illustrate how prudential regulation can affect growth through monitoring costs, consider an environment in which entrepreneurs, who need external funds (above and beyond their initial wealth) to finance their investment projects, are tempted to choose less productive projects (shirk) with high non-verifiable returns, while banks, who use deposits from households to fund their loans, also have an incentive to shirk because monitoring borrowers is costly.[9] This is thus the double moral hazard problem highlighted by Holmström

[9] Note that the monitoring activities considered here differ from *ex post* monitoring in the costly state verification literature, where lenders monitor when the project outcome is realized and only when the

and Tirole (1997). In that setting, bank monitoring (which can only detect high-shirking projects) helps to mitigate the moral hazard problem associated with the behavior of entrepreneurs; it can induce them to choose between either an efficient project (which succeed with probability π^H) and an inefficient or low-shirking project (which succeeds with probability $\pi^L < \pi^H$). In addition, suppose that (as before) households cannot lend directly to producers, and that, to mitigate the second source of moral hazard and increase incentives for depositors, banks are compelled to hold reserve requirements. Thus, in the context of this model (fully developed in Agénor (2018a)), reserve requirements operate essentially as *partial deposit insurance*: they are used to compensate depositors if the bank fails. This feature provides a rationale for prudential regulation.

The solution of the model presented in Agénor (2018a) yields the steady-state growth rate as

$$1 + g = \frac{(1-\beta)\upsilon\Phi}{\pi^H - \pi^L}, \tag{12}$$

where $\beta \in (0,1)$ is a consumption preference parameter for entrepreneurs (with $1-\beta$ denoting the preference for bequests), $\upsilon \in (0,1)$ the share of the return to investment that the entrepreneur can appropriate if he chooses an inefficient project, and Φ a composite parameter, which varies negatively with the required reserve ratio and also depends on monitoring intensity, γ. With constant monitoring intensity, it can be established from this equation that an increase in the required reserve ratio (motivated by the desire to make domestic banks safer and induce households to increase deposits at home) unambiguously lowers the steady-state growth rate. On the one hand, it raises incentives for savers, as noted earlier; but on the other, it reduces the bank's loanable funds. The second effect dominates when monitoring is exogenous. However, suppose that the private benefit of the inefficient project is decreasing in monitoring intensity, so that $\upsilon = \upsilon(\gamma)$, with $\upsilon' < 0$, and that monitoring intensity is endogenously determined. In such conditions, an increase in the required reserve ratio has conflicting effects on investment and growth: on the one hand, by requiring banks to put away a larger fraction of the deposits that they receive, it reduces (as noted earlier) the supply of loanable funds; on the other, it also mitigates banks' incentives to monitor, thereby lowering monitoring costs and freeing up resources

borrower defaults. Accordingly, the cost of monitoring in that literature is more akin to a bankruptcy cost. See the subsequent discussion.

to increase lending and promote growth. Thus, here again prudential regulation can have an ambiguous effect on growth—this time as a result of its impact on the net amount of resources that banks can rely on to finance investment.

2.2.2 Contingent State Verification Costs

Another mechanism through which changes in intermediation costs can affect the link between prudential regulation and growth is related to the cost of state verification, in a setting where, as in Townsend (1979) and Gale and Hellwig (1985), entrepreneurs may be tempted to default in bad states of nature. Appendix A presents the details of a new model, which also captures (in line with the objectives of this paper) the impact of the degree of financial development and the degree of financial openness on growth.

The core structure of the model bears several similarities with the framework developed in Agénor and Pereira da Silva (2017) and summarized earlier. For simplicity, however, households are now assumed not to consume at all in the first period of life. Thus, while the supply of equity is again $e_t = \varkappa w_t$, the remainder of first-period wage income is entirely saved. Instead of (1), deposits are now simply given by

$$d_t = (1 - \varkappa)w_t. \tag{13}$$

By implication, household consumption is $R^D d_t + R^E e_t = [R^D(1-\varkappa) + R^E \varkappa]w_t$ in period $t+1$. In addition, although each entrepreneur is once again born with one unit of labor time in adulthood, they vary in their capacity to provide effort, ε, which is uniformly distributed over the interval $(0, \varepsilon_m)$, with $\varepsilon_m > 0$ and a probability density function $h(\varepsilon^j) = 1/\varepsilon_m$. Effort provides disutility. Each entrepreneur's time is used entirely to operate a risky technology, which converts units of the final good into a capital good. When it succeeds, the investment (which equals borrowing, l_t) produces at $t+1$ a verifiable amount of capital K_{t+1} equal now to

$$K_{t+1} = (1 + \zeta_t)l_t, \tag{14}$$

where ζ_t is again a productivity shock that is identically and independently distributed across entrepreneurs. The value of ζ_t is realized *after* a borrower has contracted a loan. For simplicity, suppose that ζ_t is uniformly distributed over the interval $(-\zeta_m, \zeta_m)$ and that $\zeta_m < 1$, to ensure that capital produced (even in the worst state of nature) is positive.

The representative bank's balance sheet is now (assuming a fixed exchange rate normalized to unity), instead of (6),

$$l_t = e_t + d_t + b_t, \tag{15}$$

where b_t is foreign borrowing, which occurs at the same rate of return R^D as deposits and is equal to a fraction $\theta > 0$ of equity:

$$b_t = \theta e_t, \tag{16}$$

Coefficient θ can be viewed as a measure of the severity of world capital market imperfections—or equivalently, as in von Hagen and Zhang (2014), for instance, a measure of the degree of financial openness.

As in (8), the prudential regime imposes a minimum constraint on bank equity:

$$e_t = \mu l_t, \tag{17}$$

where again $\mu \in (0, 1)$ is the capital adequacy ratio. Suppose now that the cost of equity is directly set as a markup over the deposit rate, namely, $R^E > \delta R^D$, where $\delta > 1$; if so, banks again have no incentives to hold more equity than required by the regulator. Combining (15), (16), and (17), and recalling that $e_t = \varkappa w_t$, yields the demand for deposits by banks:[10]

$$d_t = (\mu^{-1} - 1 - \theta)e_t. \tag{18}$$

Substituting $w_t = \varkappa^{-1} e_t$ in (13) and equating the result to (18) yields the equilibrium share of bankers in each household:

$$\varkappa = \frac{1}{\mu^{-1} - \theta}.$$

This result shows that an increase in the capital adequacy ratio raises the equilibrium share of bankers, that is, the supply of loans. Intuitively, with the ratio of the equity rate to the deposit rate fixed at δ, the equilibrium of the equity market is obtained through a quantity adjustment.[11]

Due to asymmetric information and limited liability, an entrepreneur may be tempted to default on his loan repayment by claiming falsely that he is bankrupt due to a bad

[10] The restriction $\mu(1 + \theta) < 1$ is imposed to ensure that the demand for deposits is strictly positive.

[11] Agénor (2018*b*) considers, in a related model, the case where the cost of equity is endogenous.

realization of ζ_t. The solution to this problem, in standard fashion, involves costly state verification.[12] The equilibrium contract maximizes the entrepreneur's expected utility, subject to the bank's participation constraint. As shown in Appendix A, the solution yields the equilibrium loan rate, R^L:

$$R^L = \Lambda R^D + R^K \zeta_m \pi^2 + \chi\pi, \tag{19}$$

where $\Lambda = 1 + \mu(\delta - 1) > 0$, R^K is the return to capital, π the probability of default, and $\chi > 0$ the unit cost of verification, which measures therefore the extent of capital market imperfections (or the degree of financial development). Thus, for a given probability of default, an increase in the capital adequacy ratio raises the loan rate, because of the direct cost effect (alluded to earlier) of higher equity requirements. However, at the same time, an increase in the capital adequacy ratio lowers the bankruptcy threshold, the probability of default, and therefore (contingent) verification costs. The net effect on the equilibrium loan rate is thus ambiguous.

The solution also yields a threshold level of effort, $\tilde{\varepsilon} = \boldsymbol{\varepsilon}(\chi, \mu, \theta)$, above which no entrepreneur will choose to invest, and a growth rate of the economy (assuming again an Arrow-Romer externality as in (5)) given by

$$1 + g = (\frac{1}{1 - \mu\theta})\frac{(1 - \alpha)A}{\varepsilon_m}\boldsymbol{\varepsilon}(\chi, \mu, \theta), \tag{20}$$

It can be established from this equation and the results in Appendix A that an increase in the capital adequacy ratio has once again an ambiguous effect on growth. On the one hand, an increase in the capital adequacy ratio tends to lower the returns from investment and makes bankruptcy more likely. Faced with lower expected returns from borrowing, fewer entrepreneurs find it profitable to take on loans. Thus, $\boldsymbol{\varepsilon}_\mu < 0$; the higher the capital adequacy ratio, the lower the number of entrepreneurs. This has an adverse effect on growth. On the other, however, an increase in that ratio raises the equilibrium share of bankers (or, equivalently in this setting, the supply of loans), which tends to promote growth.

[12] See Townsend (1979) and, for a broader discussion, Freixas and Rochet (2008). As in Agénor and Aizenman (1998), for instance, it could be assumed that lenders—in addition to verification costs—also incur costs of contract enforcement, that is, spend resources (such as legal fees) on seizing assets (or any collateral) of borrowers who choose to default. Assuming that these costs are proportional to the realized output of capital goods would not affect significantly the results.

2.3 Effect on Financial Sector Size

To the extent that it attempts to prevent, or respond to, destabilizing effects associated with financial development, prudential regulation can also affect growth indirectly. The literature on *too much finance* suggests that the relationship between financial development and growth may be nonlinear—being (at the margin) positive at first and negative beyond a certain point.[13] This inverted U-shape relationship can be due to a number of factors. A larger financial system can promote growth initially due to large efficiency and productivity gains that are widely shared across sectors. But beyond a threshold, as it continues to expand, it may induce a slowdown in technological progress due to a reallocation of talent from core innovation activities to the financial sector, as a result of higher compensation there. Alternatively, the non-monotonic relation between growth and financial depth may result from conflicting effects of finance on productivity and the amount of resources that are available to finance investment (Bucci et al. (2018)).

Prudential regulation can affect the shape of this relationship as well. At first, as the financial sector expands, the prudential regime may lose effectiveness in some market segments (thereby contributing to the growth of the shadow financial system), so that the effects on financial risks and financial volatility are uncertain. As the financial sector continues to grow in size, however, the prudential regime is eventually tightened, which could slow down the provision of credit and the level of investment. This could make the slopes of the financial development-growth curve steeper, both before and after the turning point.

2.4 Distributional Effects

Finally, prudential regulation can also affect growth, indirectly, through its impact on income and wealth distribution. Most prudential instruments operate through their impact on credit provision to the economy, either directly through quantity constraints (as is the case for instance with debt-to-income and loan-to-value ratios on mortgages) or indirectly, by raising (as noted earlier) the cost of credit. While this may be important, from a systemic

[13] See contributions by Arcand et al. (2012), Cecchetti and Kharroubi (2012), Gambacorta et al. (2014), Law and Singh (2014), Ductor and Grechyna (2015), Samargandi et al. (2015), Bucci et al. (2018), and Salas (2018).

perspective, to safeguard financial stability, it could also affect durably the ability of some groups to access the credit market—either because of the cost effect or because constraints on the ability to acquire real estate may limit the scope for small entrepreneurs to pledge housing as collateral for business loans—with potentially significant distributional consequences among savers and borrowers.[14] If, following an increase in capital requirements, for instance, banks respond by permanently cutting loans to small and medium-size firms—in effect rationing them out of the credit market—there may be adverse consequences on their ability to generate income and accumulate assets over the long term. Whether this distributional shift has a negative impact on growth cannot be ascertained a priori; the relationship between income or wealth inequality and growth is indeed theoretically ambiguous and depends in particular on the degree of heterogeneity in the propensity to save across agents and the composition of assets among households. Nevertheless, the recent evidence suggests that this relationship tends to be negative (Cingano (2014), Grigoli et al. (2016), and Gründler and Scheuermeyer (2018)). Thus, prudential policies may also have a significant impact on growth if their distributional effects are large and persistent.

The thrust of the foregoing discussion is that the impact of prudential regulation on growth can indeed be positive if its mitigating effect on risk-taking—the conventional argument—dominates. However, there are other channels, operating namely through the cost of equity (which raises the loan rate), intermediation costs, and broader effects on the size of the financial system and income or wealth distribution, which can mitigate and possibly reverse the positive effect of a reduction in risk-taking. This theoretical ambiguity means that an empirical analysis is required. In this paper, our focus is not on identifying any particular channel, or assessing the relative importance of each of these channels, but rather on assessing their *net* effect on growth. We will therefore conduct this analysis using a reduced-form approach, supported by an instrumental variable methodology.

Before we do so, and given that in our empirical analysis we will also consider the effects of financial development and financial openness on growth, it is worth noting the predictions of the costly state verification model presented earlier for these variables. As shown in

[14] See for instance Iacoviello et al. (2016) for a formal analysis of the distributional effects of loan-to-value ratios and taxes on assets in an economy where heterogeneous agents are subject to collateral constraints. Frost and van Stralen (2018) provide some preliminary empirical evidence on the impact of macroprudential policies on income inequality.

Appendix A, it can be established from (20) that a reduction in the (unit) verification cost, χ, or an increase in the degree of financial openness, θ, have a positive effect on the steady-state growth rate. The beneficial effect on growth associated with a reduction in χ is due to its positive impact on the number of entrepreneurs (that is, the demand for credit) who find it profitable to take on loans. The positive effect of an increase in the degree of financial openness is due to a pure resource effect, which increases the supply of loans. However, it is also worth noting that this effect can be ambiguous if an adverse impact on domestic volatility is accounted for. Indeed, given that volatility, as measured by a mean-preserving spread of the distribution of the production shock (that is, an increase in ζ_m) has an adverse effect on growth—a common result in models with costly state verification—the benefits of openness could be significantly mitigated if ζ_m, or the unit verification cost χ itself, increases at the same time as θ.

3 Data and Econometric Model

The foregoing discussion provides a broad framework for exploring empirically the effects of prudential policies, financial development, and financial openness, as well as the possible interactions between them, on economic growth. To conduct this analysis, we formulate an econometric model that takes into account nonlinear effects.

3.1 Data Sources

The econometric analysis is based on data collected from a variety of sources. To a large extent, these sources (including those related to indicators of financial development and financial openness) are fairly standard; in particular, all macroeconomic data (GDP, population, schooling, government consumption, and inflation) are taken from the World Bank's *World Development Indicators* database. But because there is less consensus on data related to prudential regulation, in what follows we explain in more detail how these data were compiled.

Specifically, we merged data on prudential policy actions compiled by Lim et al. (2011, 2013), Kuttner and Shim (2016), and Cerutti et al. (2017*b*).[15] The data classify pru-

[15] These datasets draw on a variety of sources including official documents and reports from central banks and regulatory authorities, financial stability reports and monetary policy bulletins.

dential policy measures under 10 categories: credit growth limits, liquidity requirements, maximum debt-service-to-income ratio and other lending criteria, capital requirement/risk weights, provisioning requirement, limits on banks' exposure to the housing sector, reserve requirements, maximum loan-to-value ratio and loan prohibition, limits on net open position, and foreign currency lending limits. Altogether, these different data sources allow us to build a database of prudential policy measures covering 64 advanced and developing economies over the period 1990-2014. The data indicate a large degree of heterogeneity across countries, which does not appear to be simply explained by country size, degree of openness, regional or other specific factors. For this reason, we decided to adopt a panel analysis that allows us to exploit the cross-sectional variability in the sample.

Macroprudential policy measures can be divided into two broad categories. Some instruments are indeed intended to increase directly the financial sector's resilience (as in the spirit of many theoretical models), while others focus on dampening the cycle as an intermediate target.[16] In our data, the prudential tools that affect financial system resilience are (a) capital-based measures (capital requirement/risk weights and provisioning requirements) and (b) liquidity requirements. Conversely, instruments that would be better suited to smoothing the credit cycle include (c) asset-side instruments (credit growth limits, maximum debt service-to-income-ratios, limits to bank exposures to the housing sector such as maximum loan-to-value ratios); (d) changes in reserve requirements; and (e) currency instruments (limits on foreign currency exchange mismatches and net open positions). In what follows, we will therefore consider three indicators of prudential policy, a first one encompassing all categories of prudential policy, a second one focusing on measures aimed at managing the cycle and a third one focusing on measures aimed at improving resilience. Out of the latter, we will single out policies on "capital requirement/risk weights" as this category accounts for the lion's share of prudential policy decisions aimed at improving resilience.

For each category, the prudential policy index can take on three different values: loosening actions, tightening actions or no change.[17] We hence sum over all prudential policy

[16] Borio (2011) and Claessens et al. (2013), for example, classify commonly used policy tools according to the goals for which they might be best suited. Macro-prudential tools whose main objective is enhancing the resilience of the financial sector include capital-based instruments (countercyclical capital requirements, leverage restrictions, general or dynamic provisioning) and liquidity-based requirements.

[17] A similar metric is used in other contributions, such as Fendoglu (2017), Akinci and Olmstead-Rumsey

actions of the 10 aforementioned categories and count for each year s and each country i the number of tightening decisions, $\tau_{i,s}$, and the number of easing decisions, $e_{i,s}$. We then consider a five-year horizon and construct an aggregated prudential index, which depends positively on tightening decisions, and negatively on easing decisions, as follows:

$$PP_{i,t} = \frac{1}{5}\sum_{s=t}^{t+5}\frac{1+\tau_{i,s}}{1+e_{i,s}}.$$

The index therefore measures the extent to which prudential policy is tightening or looosening over the period under consideration. Linking this index to growth, we therefore implicitly assume that only *changes* in prudentual policy can affect real growth, i.e. changes in output, while the *level* of prudential policy only affects the *level* of output. Note also that this indicator assigns the same weights to the ten different categories. This allows us to investigate the overall effectiveness of prudential tools. Considering the log of this prudential index, it takes a positive value if there are more categories for which policy is being tightened while it takes negative values if there are more categories for which policy is being eased. It is equal to zero if there are as many categories in which policy is being tightened as categories for which policy is being eased.

While this measure, for any given set of prudential policy decisions, captures both tightening and easing decisions, in order to study possible asymmetric effects we also consider separately the number of easing decisions and the number of tightening decisions:

$$PP^{\tau}_{i,t} = \frac{1}{5}\sum_{s=t}^{t+5}(1+\tau_{i,s}), \qquad PP^{e}_{i,t} = \frac{1}{5}\sum_{s=t}^{t+5}(1+e_{i,s}).$$

Once again we will consider log values for both these indices. Table 1 provides descriptive statistics for the prudential actions in our sample, as well as other key variables used in our analysis.

3.2 Econometric Model

As noted earlier, we use panel data analysis to study the links between financial development, financial openness, and prudential policies and growth. In doing so care is needed

(2018), and Altunbas et al. (2018). Unfortunately, we do not have information on the intensity of tightening or loosening actions.

in controlling for unobserved factors, whether across countries or time-varying, that might have an influence on macroeconomic performance not captured by our set of observable variables. Correction for possible reverse causality, that is, the fact that a country may choose to implement certain prudential policies in response to output growth conditions, is also needed. To account for possible unobserved factors we use country and time fixed effects, while we deal with the reverse causality problem by using the approach of Andersen and Hsiao (1982).[18]

Our baseline empirical specification is given by

$$\Delta y_{i,t} = \alpha_i + \alpha_t + \beta_0 y_{i,t-1} + \beta' X_{i,t} + \gamma \ln PP_{i,t} \tag{21}$$

$$+\delta FD_{i,t} + \eta OPEN_{i,t} + \varepsilon_{i,t},$$

where the dependent variable $\Delta y_{i,t}$ is the five-year (non-overlapping) average real per capita GDP growth, and i and t represent as before country and time period indexes, respectively.[19]

The key variables in the model's specification are as follows. The first is the prudential policy index defined earlier, $\ln PP$, which is a positive (negative) function of the number of prudential policy tightening (easing) decisions taken in a given country over a five-year period.[20] The second is the indicator of financial development, FD, taken from Sahay et al. (2015), which is a composite indicator of different measures of developments for financial institutions and financial markets.[21] The third is the indicator of financial openness, $OPEN$, for which we use the Chinn and Ito (2006) index. The Chinn-Ito index is broader, of course, than the one typically defined in theoretical models, which refers solely to bank access to world capital markets; however, in practice these measures tend to be highly

[18] We also used GMM as an alternative estimation technique. While results tend to be qualitatively similar, those obtained using the Andersen-Hsiao approach tend to be more stable and less subject to the specific choice of instruments.

[19] Non-overlapping periods are considered when computing averages.

[20] The logarithm helps to reduce the effect of tail observations. Our results are robust to alternative specifications, including a specification in levels and a specification that reduces tail observations by winsorising the prudential policy index at the 1 percent level.

[21] Specifically, the financial development index is constructed by aggregating six sub-indexes for the "depth", "access" and "efficiency" of financial institutions and financial markets. The weights are obtained from principal component analysis, reflecting the contribution of each underlying series to the variation in the specific sub-index. The total index is normalized between 0 and 1.

correlated over a sufficiently long period of time.[22]

In addition, in (21), $y_{i,t-1}$ is the one-period lagged log of GDP per capita, the vector $X_{i,t}$ includes a set of control variables, whereas α_i and α_t are country and time fixed effects, which take care of the unobserved cross-country heterogeneity as well as unobserved time-varying factors common across countries. Control variables include the average number of years of schooling (in logs), the average population growth, the average government consumption to GDP (in logs), the average inflation rate and an index for independence of the supervisory authority (Barth et al. (2004)), which indicates the degree to which regulators are able to make decisions independently of political considerations. This index, which ranges from 0 to 1 (with higher values indicating greater independence), could be interpreted as a proxy for policy constraints, akin to that used by Fatás and Mihov (2012).

In addition to the baseline specification (21), we also consider a set of extended regressions where (in line with our earlier discussion) we allow the effect of prudential regulation to depend on the degree of financial development and financial openness:

$$\Delta y_{i,t} = \alpha_i + \alpha_t + \beta_0 y_{i,t-1} + \beta' X_{i,t} + \gamma \ln PP_{i,t} + \delta FD_{i,t} + \eta OPEN_{i,t} \tag{22}$$

$$+\gamma_1 FD_{i,t} \ln PP_{i,t} + \gamma_2 OPEN_{i,t} \ln PP_{i,t} + \varepsilon_{i,t}.$$

Later on, we also separate "tightening" episodes from "easing" ones, the former counting the number of prudential policy decisions taken which end up tightening credit conditions, while the latter is the equivalent for prudential policy leading to an easing of credit conditions. This allows us to assess the extent to which the effect of prudential policy on growth are symmetric or not.

Given that our specification is a dynamic fixed effect model, we need to use instrumental variable techniques to ensure consistent estimates. To do so, we rely on the standard Andersen-Hsiao approach where the specification is first written in levels and then rearranged in first differences. For specification (21) for instance, we rewrite the model in first differences and estimate it with instrumental variables in the following form:

$$\Delta y_{i,t} = \Delta\alpha_t + (1 + \beta_0)\Delta y_{i,t-1} + \beta' \Delta X_{i,t} + \gamma \Delta \ln PP_{i,t} \tag{23}$$

[22] In practice, trade and financial openness tend to be highly correlated. For instance, Baltagi et al. (2009, Table 1b) documented a high degree of correlation (about 0.52) between their *de facto* measure of financial openness and their measure of trade openness for developing countries.

$$+\delta \Delta FD_{i,t} + \eta \Delta OPEN_{i,t} + \Delta \varepsilon_{i,t}.$$

In this regression (as well as the corresponding form for (22), we consider the lagged dependent variable $\Delta y_{i,t-1}$ and the prudential policy indicator $\Delta \ln PP_{i,t}$ to be endogenous to the dependent variable and instrument them with 2-period lagged levels of the log of GDP per capita and 2-period lagged levels of the prudential policy index and the log of that variable.

4 Regression Results

Our econometric results are presented in Tables 2 and 3. Three main conclusions can be drawn from these results. First, prudential policy measures aimed at dampening (promoting) credit growth have a positive (negative) effect on economic growth. Financial development and financial openness also appear to have a direct positive impact on growth, although the effect seems stronger for the latter than the former. These results are consistent with the formal model presented earlier.[23]

Second, there is some evidence that prudential policy measures aimed at improving the resilience of the financial sector tend to be less effective in raising growth when the economy is more financially opened or when the economy is more financially developed. One possible reason for these findings could be that the effectiveness of prudential policies (typically designed for banks) is reduced when less regulated financial intermediaries have increased market share (that is, when countries experience further financial development), and when openness allows firms and households to obtain funds from foreign financial sources. These results are in line with some other contributions, such as Cerutti et al. (2017*a*).[24]

[23] Regarding the impact of financial efficiency or development on growth, other researchers have also found a similar result, operating through the various channels identified in the Introduction. However, the literature is not unanimous on the positive impact of openness on growth (Rodriguez and Rodrick (2000); Baldwin (2004)). The possibility that higher growth induces openness (reverse causality) calls for caution in the interpretation of these findings. Attempts to deal with this issue appear to confirm the influence of openness, albeit not a particularly strong one (see for instance Lee et al. (2004)).

[24] We do not investigate the effect of the triple interaction, between the macro-prudential policy index, financial development and financial openness. First there is clear analytical argument for why this term should enter positively or negatively in the growth equation. And second, we typically see this triple interaction, to the extent it is significant, as a second order effect compared with the dampening effect of financial development and financial openness on the relationship between macroprudential policy and growth.

From an economic viewpoint these effects are sizable. The last row of Table 2 computes the effects of a one standard deviation shock in the prudential policy index on the growth rate of GDP per capita. The effects are not only statistically significant but also relevant from an economic point of view. One standard deviation increase in the prudential index brings an average increase of GDP per capita of 0.7 percentage points (12.17*0.3/5), that is, roughly one third of the yearly average growth in the sample (see Table 1). These effects are qualitatively very similar when one distinguishes cyclical and resilience prudential measures, including capital requirements.

Third, as shown in Table 3, the result that prudential policies are positively correlated with growth is essentially driven by tightening, not by easing (see columns (I) to (IV)). Put differently, prudential policies that limit systemic risk and/or prevent the occurrence of a boom are good for growth, while prudential policies that ease conditions in a downturn have a more limited effect.

In addition, columns (V) and (VII) show that the growth effect of tightening prudential policy is weaker when the economy is more financially open. This result holds both when the prudential policy index encompasses all measures (column (V)) and more specifically for prudential measures targeting bank capital (column (VII)). By contrast, columns (VI) and (VIII) show that there is no such a similar statistically significant dampening effect with financial deepening, neither for prudential policy encompassing all measures (column (VI)) nor for prudential measures targeting bank capital (column (VIII)). Estimates in columns (V) and (VII) suggest that, in a financially open economy (when the openness index takes the value 1), the growth effect of prudential policy tightening tends to be half of the effect that can be expected in a financially closed economy (when the openness index takes the value 0).

Overall, these results suggest that economies where prudential policy is used to tighten credit conditions—presumably to curb excessive credit growth and mitigate financial risks—tend to benefit from higher growth. This is thus consistent with a net effect of these policies being positive, as discussed in our analytical review. Yet, financial openness tends to weaken this positive effect, possibly because of increased opportunities for financial institutions to bypass domestic regulations (and therefore insulate themselves from domestic financial conditions) and for non-financial firms and households to borrow abroad. Alternatively, it is also possible that greater financial openness provides more scope for leakages in prudential regulation across countries (as discussed by Buch and Goldberg (2017) for instance), thereby allowing banks to circumvent changes in national policy measures.

5 Concluding Remarks

The purpose of this paper was to study the effects of prudential policies, financial development, and financial openness, both individually and jointly, on economic growth. The first part presented an analytical review of the different channels through which prudential policies can affect growth. Cross-effects were also established using an overlapping generations model with banking and prudential regulation in the form of capital requirements. The key conclusion is that prudential regulation can affect growth through a variety of channels, beyond the risk-taking effects typically emphasized in the literature. Moreover, these channels can impact growth in conflicting ways, implying that theoretically the net effect of prudential regulation is ambiguous.

The second part provided a reduced-form empirical analysis, based on panel regressions for a sample of 64 countries. The main results are that prudential policies that limit systemic risk and prevent the occurrence of a credit boom help to promote growth. At the same time, financial openness tends to reduce the growth benefit of prudential policy tightening, either by allowing domestic agents to borrow more directly on world capital markets or by creating more scope for domestic financial institutions to circumvent changes in regulation. These results illustrate the importance, from a growth perspective, of formulating prudential regulation in the broader context of structural policies aimed at promoting financial development and financial integration. They also suggest that greater coordination across countries in setting structural prudential rules may help to promote growth.

There are also some important caveats associated with our empirical analysis. First, prudential policy was measured in terms of the *direction* of changes in the use of these instruments. However, we did not account for the *intensity* of these changes. This is due to the inherent limitations of the data that we used.[25] Second, although instrumental

[25] Some progress on that front has been achieved recently. Richter et al (2018) for instance have attempted to capture the intensity of policy actions by considering the size of changes in regulatory ratios. However, their data are not comprehensive enough for the type of cross-country analysis that we performed in this paper.

variables were used to correct for reverse causality, it is possible that such correction was not complete. In that case, our findings would not be as strong as stated. Indeed, if faster economic growth were to lead to a greater use of prudential policies, the true regression coefficients could be smaller than we reported. One way of dealing with this problem would be to use longer periods to compute average growth, as the five-year growth rates used here—and common in the literature, see Bekaert and Popov (2012) for instance—could capture periods of excessive or unsustainable growth. Unfortunately, the limited time dimension of our sample prevents us from examining the behaviour of growth rates over longer horizons. These issues should be addressed in future research, using more comprehensive databases on the use of prudential instruments. Finally, from a policy perspective, it may be important to assess the relative importance of each of the channels identified earlier, including how prudential regulation can affect growth through its impact on income and wealth distribution.

Appendix A
Complete Model with Verification Costs

Consider a small open economy producing a single final tradable good, whose price is set on world markets. There is a continuum of risk-neutral individuals who live for two periods, adulthood and old age. These individuals are of two types, *households* and *entrepreneurs*. These groups are of equal size of mass 1 and total population is constant and normalized to 2. Each household consist of a fixed number of individuals, which is also normalized to unity. Individuals of either type derive utility from old age consumption only and have no bequest motive. A unit mass of firms produces the final output, using labour (provided by workers) and capital (rented from entrepreneurs). There are also a continuum of competitive banks and a financial regulator. Capital production entails the operation of a risky investment when an entrepreneur is young. Entrepreneurs cannot self-finance and cannot borrow directly on world capital markets; to be able to to invest they must do so from a domestic bank, who has access to foreign funding but subject to an upper limit. Banks set the loan rate in non-renegotiable financial contracts, subject to limited liability and prior to the realization of shocks.

A1 Households

Individual members of each household are born with one unit of time in adulthood, which they supply inelastically to the labor market. That all consume only in the second period of life. Thus, the entire wage income earned in adulthood, w_t, is saved. Households do not have access to a monitoring technology and therefore do not lend directly to entrepreneurs.

As in Agénor and Pereira da Silva (2017), at the end of period t a fraction $\varkappa \in (0, 1)$ of household members are randomly selected to become *bankers*, and join together to form a bank, while the remaining fraction $1 - \varkappa$ becomes *depositors*. Thus, given that the number of households is normalized to unity, $\varkappa$ is also the share of bankers in the economy. Specifically, each household uses $e_t = \varkappa w_t$ as equity to start the bank and allocates the remaining fraction of first-period wage income, $(1 - \varkappa)w_t$, to saving via deposits in a bank (other than the one they own, for clarity), d_t. Deposits can be held either at home or abroad; in the absence of restrictions on capital flows on depositors and no transactions costs, arbitrage implies that both investments yield the same (gross) return, $R^D > 1$, which is set on world markets. Given that there are no bequests, household consumption in period $t + 1$ is thus $R^D d_t + R^E e_t$, where R^E is the return on equity.[26] For simplicity, banking involves no direct time cost and there is full consumption insurance among members of each household.

A2 Entrepreneurs

Each entrepreneur j, with $j \in (0, 1)$, is also born with one unit of labor time in adulthood. Entrepreneurs vary in their capacity to provide effort, and effort provides disutility. Each entrepreneur's time is used entirely to operate a risky technology, which converts

[26] As discussed later, banks make zero profits.

units of the final good into a marketable capital good. Moreover, operating this technology generates no income in the first period. Entrepreneurs therefore do not consume in that period either. They derive utility from their old age consumption, which itself depends on their realized income.

Managing an investment of size l_t^j requires an initial, proportional level of effort $\varepsilon^j > 0$, which is public information. For simplicity, ε^j is taken to be uniformly distributed over the interval $(0, \varepsilon_m)$, with $\varepsilon_m > 0$ and probability density function $h(\varepsilon^j) = 1/\varepsilon_m$. Depending on the value of ε^j, and the return to investment, each entrepreneur must decide whether or not to produce capital by taking on a loan; the decision rule is established later.

A3 Production Sectors

Production in the economy occurs in a *final good sector*, which produces a homogeneous good used for either consumption or investment, and a *capital good sector*, which supplies (as noted earlier) inputs to firms producing the final good.

A3.1 Final Good Sector

Competitive firms produce the final good by combining labor and capital, using the technology:

$$y_t = A_t n_t^{1-\alpha} k_t^{\alpha}, \tag{A1}$$

where $\alpha \in (0,1)$, n_t is the number of workers employed by the firm, k_t the firm's capital stock, and A_t an economy-wide productivity parameter.

There is an Arrow-Romer type externality associated with the aggregate capital-labor ratio K_t/N_t, so that

$$A_t = A(\frac{K_t}{N_t})^{1-\alpha}, \tag{A2}$$

where $A > 0$.

Final good producers operate in competitive output and input markets, which implies that equilibrium capital rental and wage rates, R_t^K and w_t, are determined by their marginal product. In equilibrium, where $k_t = K_t$ and $n_t = N_t$,[27]

$$R^K = \alpha A, \qquad w_t = (1-\alpha) A K_t, \tag{A3}$$

and (A1) and (A2) imply a linear relationship between aggregate production, Y_t, and aggregate capital:

$$Y_t = AK_t. \tag{A4}$$

A3.2 *Capital Good Sector*

At period t an entrepreneur j who decides to produce capital invests an indivisible amount l_t^j, which corresponds to the loan obtained from bank j. For simplicity, each bank is assumed to be associated with a single entrepreneur. When it succeeds, the investment produces at $t+1$ a verifiable amount of capital k_{t+1}^j equal to

$$k_{t+1}^j = (1+\zeta_t) l_t^j, \tag{A5}$$

[27] To ensure that the gross return $R^K > 1$, the restriction $A > 1/\alpha$ is imposed.

where ζ_t is a productivity shock that is identically and independently distributed across entrepreneurs. The value of ζ_t is realized *after* a borrower has contracted a loan. For simplicity, ζ_t is assumed to be uniformly distributed over the interval $(-\zeta_m, \zeta_m)$, therefore with a zero mean and probability density function $f(\zeta_t) = 1/2\zeta_m$, and $\zeta_m < 1$.[28] In addition, there is no aggregate uncertainty and capital goods fully depreciate upon use.

All entrepreneurs produce the same type of capital good and are price takers. The common return they earn from renting out their capital is $R^K > 1$, the (constant) marginal product of capital in a competitive equilibrium, given by (A3). Thus, entrepreneur j earns an income of $R^K k^j_{t+1}$ by renting his capital to final good producers. Out of that income, he must repay his loan. Let R^L_{t+1} denote the gross rate of interest on loans; the amount that must be repaid is thus $R^L_{t+1} l^j_t$.[29] An entrepreneur who makes this repayment is left, *ex post*, with a realized net income of $R^K(1 + \zeta_t)q^j_t - R^L_{t+1} l^j_t$. However, there is limited liability; borrowers do not necessarily comply with their debt obligations. This implies that, as discussed next, actual income may differ from that expression.

Assuming that consumption is linear in income and that effort yields linear disutility, an entrepreneur j has utility

$$U^j_t = R^K(1 + \zeta_t)l^j_t - R^L_{t+1} l^j_t - \varepsilon^j l^j_t, \tag{A6}$$

if he chooses to repay his loan, and utility

$$U^j_t = -\varepsilon^j l^j_t, \tag{A7}$$

if he chooses to default.

A4 Banks and Prudential Regulation

As noted earlier, part of each household's wage income in adulthood is used to capitalize a bank, $e^j_t = \varkappa w_t$. Using (A3), a bank's equity is thus given by, $\forall j$,

$$e^j_t = \varkappa(1 - \alpha)Ak_t. \tag{A8}$$

The rate of return on equity is, in line with the evidence, taken to exceed the deposit rate, so that $R^E > R^D$. For tractability, we also set $R^E = \delta R^D$, where $\delta > 1$.

The bank takes deposits from (other) households and combines them with its own resources, as well as foreign borrowing, b^j_t, to lend l^j_t to a matched entrepreneur. The bank's balance sheet is thus

$$l^j_t = e^j_t + d^j_t + b^j_t. \tag{A9}$$

The prudential regime imposes a minimum constraint on bank equity:

$$e^j_t \geq \mu l^j_t, \tag{A10}$$

where $\mu \in (0, 1)$ is the capital adequacy ratio. Because the cost of issuing equity is higher than the cost of alternative sources of funding; banks have no incentives to hold more equity

[28] Because ζ_m is strictly less than unity, there is always *some* output of the capital good, even in the worst case of nature. By implication, as discussed later, in equilibrium growth is always nonnegative.

[29] The loan rate is agreed upon at time t but is dated $t + 1$, to reflect when loans are repaid.

than required by the regulator; accordingly, constraint (A10) is assumed to be continuously binding.

In addition, banks face a borrowing constraint on world capital markets; they can borrow only up to a fraction of their equity, also at the rate R^D.[30] Thus,

$$b_t^j \leq \theta e_t^j, \tag{A11}$$

where $\theta > 0$ can be viewed as a measure of the severity of world capital market imperfections—or equivalently, as in von Hagen and Zhang (2014) for instance, a measure of the degree of financial openness. We assume in what follows that constraint (A11) is continuously binding.

Combining (A9), (A10), and (A11), holding with equality, yields a proportional relationship between loans and deposits:

$$l_t^j = \frac{d_t^j}{\Phi}, \tag{A12}$$

where $\Phi = 1 - \mu(1+\theta) < 1$. We assume that $\mu(1+\theta) < 1$, to ensure that Φ is positive.

A5 Equilibrium Loan Contract and Entrepreneurs

Due to asymmetric information and limited liability, an entrepreneur may be tempted to default on his loan repayment by claiming falsely that he is bankrupt due to a bad realization of ζ_t. The solution to this problem, in standard fashion, involves costly state verification.[31] The equilibrium, non-renegotiable loan contract in this setting maximizes the entrepreneur's expected utility, subject to the bank's participation constraint, which holds with equality in equilibrium.

Specifically, the equilibrium loan contract is one in which, prior to the realization of ζ_t, a bank's expected return from lending is equal to its deposit and foreign borrowing repayment obligations, and the cost of issuing equity:

$$R^D(d_t^j + b_t^j) + R^E e_t^j = \int_{-\zeta_m}^{\hat{\zeta}_t} [R^K(1+\zeta_t) - \chi] l_t^j f(\zeta_t) d\zeta_t + \int_{\hat{\zeta}_t}^{\zeta_m} R_{t+1}^L l_t^j f(\zeta_t) d\zeta_t, \tag{A13}$$

where the cost of verification is for simplicity taken to be proportional to the size of the loan, so that χl_t^j, with $\chi > 0$ measuring therefore the extent of capital market imperfections (or the degree of financial development), and $\hat{\zeta}_t$ the threshold value of ζ_t below which default occurs, given by

$$\hat{\zeta}_t = (\frac{R_{t+1}^L}{R^K}) - 1. \tag{A14}$$

As shown in Appendix B, the equilibrium loan rate can be derived as

$$R_{t+1}^L = \Lambda R^D + R^K \zeta_m \pi_t^2 + \chi \pi_t, \tag{A15}$$

[30] For simplicity, foreign lenders do not explicitly internalize the risk of domestic bank default (which would affect the rate at which the country can borrow) and instead impose constraint (A11) directly. Alternatively, the two-level structure proposed by Agénor and Aizenman (1998) could be adopted.

[31] See Townsend (1979) and Gale and Hellwig (1985).

where $\Lambda = 1 + \mu(\delta - 1) > 0$, and π_t is the probability of default, defined as

$$\pi_t = \int_{-\zeta_m}^{\hat{\zeta}_t} f(\zeta_t) d\zeta_t = \frac{\hat{\zeta}_t + \zeta_m}{2\zeta_m}. \tag{A16}$$

The expressions in (A14) and (A15) define a simultaneous system in R^L_{t+1} and $\hat{\zeta}_t$. Its solution, as also established in Appendix B, is given by[32]

$$\tilde{\zeta} = \boldsymbol{\zeta}(\chi, \mu, \theta), \tag{A17}$$

$$\tilde{R}^L = \mathbf{R}(\chi, \mu, \theta), \tag{A18}$$

where $\boldsymbol{\zeta}_\chi > 0$, $\boldsymbol{\zeta}_\mu < 0$, $\boldsymbol{\zeta}_\theta = 0$, and $\mathbf{R}_\chi > 0$, $\mathbf{R}_\mu \lesseqgtr 0$, $\mathbf{R}_\theta = 0$. We therefore get the following results:

Proposition A1. *A reduction in the verification cost, χ, lowers the bankruptcy threshold and the equilibrium loan rate. An increase in the capital adequacy ratio, μ, lowers the bankruptcy threshold but has an ambiguous effect on the equilibrium loan rate. An increase in the degree of financial openness, θ, has no effect on the bankruptcy threshold or the equilibrium loan rate.*

The result regarding a reduction in the degree of capital market imperfections (or a higher degree of financial development) is fairly standard—by reducing the expected verification cost it lowers a borrower's chances of going bankrupt; in turn, this translates into a lower loan rate. The novel results here relate to changes in μ and θ. An increase in the capital adequacy ratio lowers the bankruptcy threshold—and, through (A16), the probability of default, and consequently verification costs—but has an ambiguous effect on the equilibrium loan rate because the direct effect is positive. An increase in the degree of openness has no effect on either variable because the assumption that the cost of deposits and foreign borrowing is the same implies that these two sources of funding are effectively perfect substitutes. However, as shown in (A12), for a given level of deposits the degree of financial openness does affect the supply of loans.

As noted earlier, the *ex post* utility of a borrower (entrepreneur) is given by (A6) if the realization of $\zeta_t \in (\hat{\zeta}_t, \zeta_m)$, or (A7) if $\zeta_t \in (-\zeta_m, \hat{\zeta}_t)$. Thus, prior to observing ζ_t, an entrepreneur's expected utility from investing is

$$E(U_t^j) = \int_{\hat{\zeta}_t}^{\zeta_m} [R^K(1 + \zeta_t) l_t^j - R^L_{t+1} l_t^j] f(\zeta_t) d\zeta_t - \varepsilon^j l_t^j, \tag{A19}$$

where E is the expectations operator.

Entrepreneur j will invest if the above expression is positive, that is, $E(U_t^j) > 0$. As shown in Appendix B, this condition defines a critical value of ε^j, denoted $\tilde{\varepsilon}$, above which no entrepreneur will choose to invest:

$$\tilde{\varepsilon} = R^K - [\frac{\boldsymbol{\zeta}(\chi, \mu, \theta) + \zeta_m}{2\zeta_m}]\chi - \Lambda R^D = \boldsymbol{\varepsilon}(\chi, \mu, \theta), \tag{A20}$$

[32] To ensure that the solution is feasible, that, is $\tilde{\zeta} \in (-\zeta_m, \zeta_m)$, and unique, the restriction $\Lambda R^D + \chi < R^K < \Lambda R^D(1 - \zeta_m)$ must be imposed.

where $\boldsymbol{\zeta}()$ is defined in (A17). Thus, given that entrepreneurs for whom $\varepsilon^j \in (\tilde{\varepsilon}, \varepsilon_m)$ do not invest, the population of capital producers is $\int_0^{\tilde{\varepsilon}} h(\varepsilon^j)d\varepsilon^j = \tilde{\varepsilon}/\varepsilon_m$. As shown in Appendix B, $\boldsymbol{\varepsilon}_\chi < 0$, $\boldsymbol{\varepsilon}_\mu < 0$, and $\boldsymbol{\varepsilon}_\theta = 0$. We get therefore the following results:

Proposition A2. *A reduction in the verification cost, χ, or the capital adequacy ratio, μ, raises the equilibrium number of entrepreneurs. An increase in the degree of financial openness, θ, has no effect on the equilibrium number of entrepreneurs.*

Thus, the greater the degree of financial development, the higher is the number of entrepreneurs who take on loans; by contrast, the higher the capital adequacy ratio, the lower the number of entrepreneurs. In particular, as noted earlier, a reduction in the verification cost reduces the contractual interest rate and makes bankruptcy less likely. Faced with higher expected returns from borrowing, more entrepreneurs find it profitable to take on loans.[33] By raising the cost of loans, an increase in the capital adequacy ratio tends to lower the returns from investment.

Deposit Market Equilibrium

Substituting (A10) for l_t^j and (A11) for b_t^j, both holding with equality, in (A9) yields the bank's demand for deposits as

$$d_t^j = (\mu^{-1} - 1 - \theta)e_t^j,$$

which must be equated to the supply of deposits by households, $(1 - \varkappa)w_t$. Thus, given that $e_t^j = \varkappa w_t$, the equilibrium of the deposit market requires $1 - \varkappa = (\mu^{-1} - 1 - \theta)\varkappa$, which can be solved for the equilibrium share of bankers:

$$\varkappa = \frac{1}{\mu^{-1} - \theta}, \tag{A21}$$

where $\varkappa \in (0, 1)$ given the restriction $\mu(1+\theta) < 1$ imposed earlier with respect to equation (A12). This result shows that $\varkappa$ varies positively with the capital adequacy ratio, μ, and the degree of financial openness, θ.

Equilibrium Growth

The expected amount of capital produced by each entrepreneur who chooses to take a loan and invest, that is, those for whom $\varepsilon^j \in (0, \tilde{\varepsilon})$, is given from (A5) as $E(k_{t+1}^j) = \int_{-\zeta_m}^{\zeta_m} (1 + \zeta_t) l_t^j f(\zeta_t) d\zeta_t = (2\zeta_m)^{-1}\ \zeta_t + 0.5\zeta_t^2 \Big|_{-\zeta_m}^{\zeta_m} l_t^j = l_t^j$. Because ζ_t is independently and identically distributed across investments, appealing to the law of large numbers allows us to deduce an expression for the aggregate capital stock:

$$K_{t+1} = \int_0^{\tilde{\varepsilon}} h(\varepsilon^j) l_t^j d\varepsilon^j = (\frac{\tilde{\varepsilon}}{\varepsilon_m}) l_t. \tag{A22}$$

[33] In the limit case where $\chi = 0$, meaning that lenders are able to costlessly verify the bankruptcy claims of borrowers, an increase in uncertainty (as measured by a a mean-preserving spread of ζ_t) has no effect on interest rates and the proportion of entrepreneurs.

Now, from (A12), $l_t = \Phi^{-1}d_t$. At the same time, $d_t = (1 - \varkappa)w_t$, with w_t determined by (A3). Substituting these results in (A22) and using (A4) yields the equilibrium growth rate of aggregate output as

$$1 + g = (1 - \varkappa)\frac{(1 - \alpha)A}{\Phi\varepsilon_m}\tilde{\varepsilon},$$

that is, using the definitions in (A20) and (A21) for $\tilde{\varepsilon}$ and $\varkappa$,[34]

$$1 + g = (\frac{1}{1 - \mu\theta})\frac{(1 - \alpha)A}{\varepsilon_m}\boldsymbol{\varepsilon}(\chi, \mu, \theta). \tag{A23}$$

As also shown in Appendix B, using (A20) it can be established from (A23) that $\partial(1 + g)/\partial\chi < 0$, $\partial(1 + g)/\partial\mu \lesseqgtr 0$, and $\partial(1 + g)/\partial\theta > 0$. These results can be summarized in the following proposition:

Proposition A3. *A reduction in the verification cost, χ, or an increase in the degree of financial openness, θ, have a positive effect on the steady-state growth rate. An increase in the capital adequacy ratio, μ, has an ambiguous effect on the steady-state growth rate.*

The positive effect on growth from a reduction in χ is, as discussed earlier, due to its positive impact on the number of entrepreneurs who find it profitable to take on loans. The conflicting effects of the capital adequacy ratio stem from two separate effects of prudential regulation on growth: a positive effect on the equilibrium share of bankers, $\varkappa$, and a negative effect on the equilibrium proportion of entrepreneurs, ε, as discussed earlier.

Finally, the positive effect of an increase in the degree of financial openness is due to a pure resource effect, which increases the supply of loans. However, this effect is unambiguous because a possible adverse impact on domestic volatility is not accounted for. Indeed, given that volatility, as measured by a mean-preserving spread of the distribution of the production shock, that is, an increase in ζ_m, has an adverse effect on growth (a common prediction of the CSV model), the benefits of openness could be significantly mitigated if ζ_m, or the unit verification cost χ itself, increases at the same time as θ.[35]

[34] Note that the same result obtains by using (A10), holding with equality, to write $l_t = \mu^{-1}e_t$, noting that $e_t = \varkappa w_t$, and using (A3), so that $l_t = \mu^{-1}\varkappa(1 - \alpha)AK_t$. Substituting this result in (A22), and substituting for $\varkappa$ from (A21), gives (A23).

[35] The higher the degree of volatility, the greater the likelihood of a borrower going bankrupt, and the higher verification costs are. As a result, the higher is the interest rate on loans and the lower is the number of entrepreneurs who take on loans.

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Activism in the use of prudential policies and output growth[1]

Table 1

Variables	average	median	st. dev	skewness	kurtosis
GDP per capita growth	2.18%	2.43%	4.50%	-1.78	20.67
PP net tightening	1.78%	1.61%	0.30%	1.21%	4.67%
of which: **cyclical**	1.72%	1.61%	0.27%	1.49%	6.19%
of which: **resilience**	1.71%	1.61%	0.16%	1.47%	5.86%
of which: **capital based**	1.70%	1.61%	0.15%	1.81%	5.92%
PP activism tightening	0.78%	0.69%	0.88%	0.81%	2.57%
of which: **cyclical**	0.56%	0.00%	0.79%	1.20%	3.42%
of which: **resilience**	0.38%	0.00%	0.57%	1.25%	3.44%
of which: **capital based**	0.34%	0.00%	0.53%	1.31%	3.57%
PP activism easing	0.59%	0.00%	0.72%	1.00%	3.07%
of which: **cyclical**	0.53%	0.00%	0.67%	0.98%	2.84%
of which: **resilience**	0.13%	0.00%	0.38%	3.23%	13.47%
of which: **capital based**	0.07%	0.00%	0.25%	3.64%	15.49%

Source: Authors' calculations.

Prudential policies and output growth: Symmetric effects

Table 2

	All Prudential			Cyclical			Resilience			Capital		
	(I)	(II)	(III)	(I)	(II)	(III)	(I)	(II)	(III)	(I)	(II)	(III)
Lagged dependent variable	1.001***	0.750***	0.882***	0.970***	0.856***	0.844***	1.011***	0.733***	0.867***	1.016***	0.709***	0.859***
	(0.154)	(0.195)	(0.146)	(0.151)	(0.198)	(0.136)	(0.157)	(0.167)	(0.136)	(0.157)	(0.223)	(0.133)
$\log(PP_{i,t})$	12.17***	23.59***	41.51**	16.67**	17.85**	43.41**	18.94**	36.27**	33.38	24.72**	84.87**	58.99
	(4.695)	(8.976)	(19.14)	(8.050)	(7.793)	(21.68)	(9.021)	(17.31)	(24.34)	(11.40)	(39.28)	(40.42)
$\log(PP_{i,t})$ x OPEN		-13.83**			-6.552			-15.83**			-33.44**	
		(6.72)			(7.894)			(7.705)			(16.21)	
$\log(PP_{i,t})$ x FD			-52.58*			-56.90*			-40.67			-73.02
			(-31.39)			(33.99)			(44.89)			(62.85)
OPEN	0.0238*	0.284**	0.0220*	0.0257**	0.146	0.0225*	0.0193	0.308**	0.0162	0.0177	0.625**	0.0151
	(-0.0134)	(0.128)	(0.0129)	(0.0131)	(0.147)	(0.0127)	(0.0136)	(0.141)	(0.0120)	(0.0138)	(0.293)	(0.0123)
FD	0.0445	-0.0287	1.057*	0.00396	-0.00615	1.097*	0.0864	0.0965	0.889	0.0691	0.00465	1.462
	(0.136)	(0.140)	(0.566)	(0.140)	(0.134)	(0.592)	(0.134)	(0.118)	(0.819)	(0.133)	(0.131)	(1.139)
Other controls (1)	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	270	270	268	270	270	268	270	270	268	270	270	268
Hansen Stat	9.076	8.647	6.025	10.72	14.29	15.27	7.081	14.01	12.98	13.61	4.32	14.79
p.value	0.43	0.118	0.128	0.0981	0.16	0.291	0.215	0.299	0.294	0.0516	0.932	0.337
Effects of a one s.d. tightening in PP (per year, in pp) (2)	0.74	0.39	0.79	0.91	0.53	0.69	0.61	0.53	0.37	0.73	1.26	0.58
Effect of a one s.d. tightening in PP (in % of average growth) (2)	31.78%	16.59%	34.04%	39.03%	22.68%	29.50%	26.00%	22.71%	15.59%	31.41%	54.89%	24.71%
R squared	0.284	0.293	0.274	0.29	0.368	0.356	0.273	0.416	0.385	0.286	0.14	0.401

Note: The dependent variables is real growth rate of GDP per capita. The financial development (FD) index is described in Sahay et al (2015). The index is normalised between 0 and 1. The openness measure (OPEN) is the Chinn-Ito index. Robust standard errors in parentheses; */**/*** denotes statistical significance at the 10/5/1% level in the first-stage regression, respectively. (1) All specifications include as additional controls: average years of schooling, population growth, inflation rate, government consumption to GDP, supervision independence index. A complete set of time and country fixed effects are also included. (2) In the regressions that include interaction terms, we have computed the effect considering the average sample value of OPEN and FD.

Prudential policies and output growth: Asymmetric effects

Table 3

Explanatory variables	All MaP	Cyclical	Resilience	Capital	All Macro-Prudential		Capital	
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)
Lagged GDP per capita growth	0.813***	0.807***	0.793***	0.804***	0.690***	0.812***	0.717***	0.797***
	(0.143)	(0.146)	(0.137)	(0.137)	(0.154)	(0.125)	(0.150)	(0.122)
$\log(PP_{i,t})$ tightening	4.741**	6.663**	5.801**	6.276**	10.78***	17.77**	11.79***	17.00*
	(2.115)	(3.026)	(2.496)	(2.443)	(4.089)	(8.611)	(3.477)	(9.641)
$\log(PP_{i,t})$ easing	-1.775	-4.975	2.704	1.098	-7.027	-12.32*	-1.739	3.904
	(2.599)	(4.084)	(4.094)	(5.282)	(4.421)	(7.482)	(3.947)	(17.32)
$\log(PP_{i,t})$ tightening*OPEN					-4.665**		-4.423**	
					(1.828)		(1.963)	
$\log(PP_{i,t})$ easing*OPEN					3.705**		0.392	
					(1.826)		(2.866)	
$\log(PP_{i,t})$ tightening*FD						-22.04		-22.26
						(14.24)		(15.89)
$\log(PP_{i,t})$ easing*FD						14.72		-5.904
						(13.03)		(33.69)
OPEN	0.0241**	0.0263**	0.0161	0.0170	0.0342**	0.0262*	0.0244**	0.0152
	(0.0115)	(0.0122)	(0.0120)	(0.0120)	(0.0170)	(0.0135)	(0.0120)	(0.0121)
FD	0.0732	0.0156	0.111	0.0778	-0.0694	0.136	0.0369	0.155
	(0.124)	(0.133)	(0.121)	(0.121)	(0.150)	(0.147)	(0.117)	(0.116)
Other controls (1)	yes	yes	yes	yes	yes	yes	yes	yes
Observations	270	270	270	270	270	267	270	267
Hansen Stat	17.26	14.06	15.99	17.54	15.29	13.85	18.04	15.71
p. value	(0.188)	(0.463)	(0.250)	(0.975)	(0.728)	(0.389)	(0.530)	(0.402)
R-squared	0.442	0.392	0.434	0.440	0.291	0.302	0.450	0.423

Note: The dependent variables is real growth rate of GDP per capita. The financial development (FD) index is described in Sahay et al (2015). The index is normalised between 0 and 1. The openness measure (OPEN) is the Chinn-Ito index. Robust standard errors in parentheses; */**/*** denotes statistical significance at the 10/5/1% level in the first-stage regression, respectively. (1) We also include as additional controls: average years of schooling, population, inflation rate, government consumption, supervision independence index.

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