Regulatory Competition In Capital Standards with Selection Effects among Banks

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Regulatory competition in capital standards with selection effects among banks*

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Abstract

Several countries have recently introduced national capital standards exceeding the internationally coordinated Basel III rules, which is inconsistent with the 'race to the bottom' in capital standards found in the literature. We study regulatory competition when banks are heterogeneous and give loans to firms that produce output in an integrated market. In this setting capital requirements change the pool quality of banks in each country and inflict negative externalities on neighboring jurisdictions by shifting risks to foreign taxpayers and by reducing total credit supply and output. Non-cooperatively set capital standards are higher than coordinated ones and a 'race to the top' occurs when governments care equally about bank profits, taxpayers, and consumers.

Keywords: regulatory competition, capital requirements, bank heterogeneity

JEL Classification: G28, F36, H73

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1 Introduction

The regulation of banks, and in particular the setting of capital adequacy standards, is arguably one of the most important policy issues in the aftermath of the 2007/08 financial crisis. In many countries large, commercial banks needed to be recapitalized with public funds in recent years. In several countries, such as Ireland or Iceland, the public bailout was so massive that it threatened the entire state of public finances. The new Basel III capital standards, which foresee the ratio of common equity (Tier 1 capital) to risk-weighted assets to rise to 7 percent until 2019, are therefore widely believed to represent a critical step forward in ensuring more resilient banking sectors around the world.

The financial sectors of many countries have grown dramatically in recent decades and represent an important source of value added, highly paid jobs, and - in good times - tax revenue.[1] Therefore, an important concern in policy discussions is that the national setting of higher capital adequacy standards will not distort international competition between the banking sectors of different countries, and maintain a 'level playing field'. Interestingly, however, it is by no means clear whether individual countries, which may be tempted to pursue beggar-thy-neighbor policies, have an incentive to set their national capital standards above or below that of neighboring jurisdictions.[2]

On the one hand is the conventional concern that maintaining low capital adequacy rules reduces the cost of doing business for domestic banks, thus securing an 'unfair' advantage in the international competition for bank customers. This concern is echoed in the entire existing literature on the subject (to be discussed below), which unanimously holds that national capital standards will be set too lax in the process of international policy competition, and a 'race to the bottom' will therefore result.

At the same time, many countries have enacted capital standards that substantially *exceed* the internationally negotiated Basel III rules. Switzerland, for example, introduced a core capital ratio of 10% for its largest banks, well above the Basel III standards, and it did so earlier than implied by the Basel schedule. Similarly, the United States

[1]Auerbach et al. (2010, Figure 9.5) document the increasing fiscal importance of the financial sector in the United States and the United Kingdom. In both countries, corporate tax revenues from financial corporations made up more than 25% of total corporate tax revenues before the financial crisis.

[2]This is very different from the issue of tax harmonization, for example, where the concern is almost exclusively about a downward competition of tax rates. See Keen and Konrad (2013) for a recent survey of this literature.

demands a (non-risk weighted) leverage ratio of 5% from its largest and systemically relevant banks, significantly above the Basel III standard of 3%. In the European Union, British plans to impose national capital standards above the Basel III standards met with stern resistance from most EU partners.[3] The final compromise was that the United Kingdom was allowed to implement national capital standards ahead of the Basel III schedule, but that it would not exceed the capital standards in other EU member states.

One important reason for why countries have enacted tight regulation policies is to protect national taxpayers. The latter effectively pay for bank failures when governments make discretionary decisions to bail out individuals financial institutions, but they are also involved more generally because virtually all developed countries have national deposit insurance schemes.[4] It is therefore no coincidence that many of the countries that have adopted capital standards above the Basel III rules have large banking sectors, relative to the country's GDP. At least in the case of Switzerland, high capital requirement are also seen as a measure to restore faith in the Swiss banking system, after one of Switzerland's largest banks, UBS, had incurred huge losses in the US subprime loan market, and needed to be saved with large public loans.[5]

Interestingly, Swiss banks do not seem to have been hurt by the higher capital requirements imposed by Swiss regulators. Figure 1 plots the market shares of Swiss banks in the European market for bank credits to the private sector for the period 2007-2015, and compares it to those of its main European competitors. The figure shows that the market share of Swiss banks has continuously risen during this period, from less than 4 per cent in 2008 to 6.5 per cent in 2015, whereas the less regulated banking sector in Germany, for example, has lost market shares during the same period.

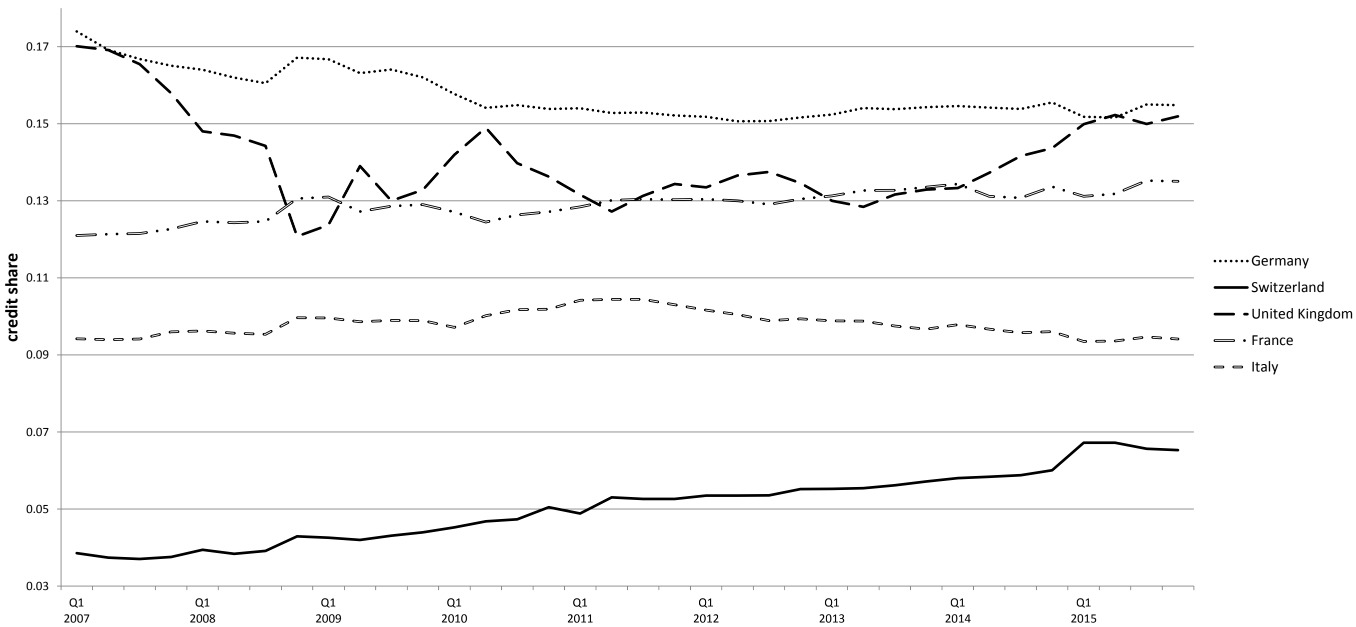
In sum, these developments question the paradigm that tighter capital standards imposed by a country cause a competitive disadvantage for the country's resident banks,

[3]See "European Leaders to weigh new capital requirements for banks", The New York Times, 1 May 2012.

[4]This argument is stressed explicitly in the communication with which the Board of Governors of the U.S. Federal Reserve System (2014) motivated higher leverage ratios for systemically relevant banks: "Higher capital standards for these institutions place additional private capital at risk before the federal deposit insurance and the federal government's resolution mechanism would be called upon, and reduce the likelihood of economic disruptions caused by problems at these institutions."

[5]See "How Switzerland saved its banking industry", Newsweek Magazine, 27 December 2010. http://europe.newsweek.com/how-switzerland-saved-its-banking-industry-68855?rm=eu

Figure 1: Credit shares of banks in five European countries, 2007-2015



Source: Bank for International Settlements, Credit statistics 2016, Table F2.4: Bank credit to the private non-financial sector; http://stats.bis.irg/statx/srs/table/f2.4. Credit shares are fractions of total credits given by banks in 22 European countries.

and that the national setting of capital standards leads to a 'race to the bottom' in capital regulation. And indeed, the European Commission mentions the opposite scenario of a possible 'race to the top' to motivate why capital standards among EU members must be strictly harmonized at the level of the Basel III accord: "It is uncertain what the potential impact in terms of costs and growth would be in case of higher capital requirements in one or more Member States, potentially expanded through a 'race to the top' mechanism across the EU" (European Commission, 2011, p. 10).

Despite its obvious policy relevance, we are not aware of any contribution to the literature that explains why countries have an incentive to set national capital standards above the internationally coordinated levels. The present paper aims to fill this gap. Our model of regulatory competition in capital standards introduces two new features that jointly offer a motivation for how tighter capital standards imposed by a country can benefit the resident banks, and why the non-cooperative setting of capital standards can lead to overly strict levels of regulation.

First, our model allows for banks that are heterogeneous in their monitoring ability, and hence in their probability of failure. When individual banks are unable to signal their quality themselves, higher capital standards act as a signal of average quality in the national banking sector. This is because higher capital standards drive the weakest banks from the market, thus improving the pool quality of the remaining banks. Loan-taking firms anticipate the increase in average bank quality and are willing to pay higher loan rates in exchange for the added security. For low levels of capital requirements, we show that this *selection effect* of capital standards can be sufficiently strong to overcompensate the higher cost of capital, thus increasing the market share of banks in the more strictly regulated economy.

A second distinguishing feature of our model is that we consider governments that incorporate taxpayers and consumers in their welfare function, in addition to the profits of the banking sector. Our model incorporates competitive firms that use bank credit to produce output for an integrated market. Changes in the availability and the price of credit thus have consequences for the real economy, and these spill over to the foreign country through the integrated output market. Moreover, we explicitly incorporate taxpayers that have to come up for the losses of failed banks due to the existence of a deposit insurance scheme.

In the Nash equilibrium, we show that tighter capital controls in one country reduce this country's aggregate loan volume while increasing the average quality of its banks. These changes benefit the foreign banking sector, but they simultaneously exert negative externalities on both foreign consumers and foreign taxpayers. Foreign consumers lose because the reduced loan volume caused by tighter capital standards reduces aggregate output, and accordingly consumer surplus, in *both* countries. Foreign taxpayers lose because the reduced loan supply from the country imposing tighter capital controls will, in equilibrium, draw additional, and lower-quality, banks into the foreign banking sector. This exposes foreign taxpayers to additional default risks, due to both the higher aggregate loan volume and the lower average quality of their banks. Effectively, imposing tighter capital controls can thus serve as an instrument to shift default risks arising from the banking sector from domestic to foreign taxpayers.

The main result of our analysis is that when governments care equally about bank profits, consumers and taxpayers, the negative externalities that tighter capital requirements impose on foreign consumers and taxpayers will dominate the positive externality on the profits of foreign banks. Hence the non-cooperative setting of capital standards will lead to *higher* capital requirements than is optimal from a global welfare perspective, and thus imply a 'race to the top' in capital regulation.

We also consider several extensions of our benchmark model. We show that the regulatory 'race to the top' is even intensified when the banking sector of each country is partly owned by foreign shareholders. In a further extension, we permit individual banks to signal their quality by financing their loans with a share of equity that is (sufficiently) above the minimum capital standard imposed by their country of residence. In this extended model, an increase in minimum capital requirements causes more banks to opt into the high quality pool, thus adding a further positive effect to the stability of the banking sector.

1.1 Related literature

Our analysis is related to several strands in the literature. A first set of papers analyzes the effects of capital regulation in the presence of moral hazard of banks, and shows that it curbs risky behaviour (Rochet, 1992; Hellman et al., 2000; Repullo, 2004). A few papers in this literature also incorporate bank heterogeneity. Morrison and White (2005) set up a model where the regulator uses both screening and capital requirements to address simultaneous moral hazard and adverse selection problems. As in our model, capital requirements improve the quality of the surviving banks in their framework, and hence the average loan quality. Similar results are obtained in Kopecky and VanHoose (2006). These papers do not consider competition between regulators, however.

The literature on regulatory competition in the banking sector is small. Sinn (1997, 2003) models the competition in regulatory standards as an application of the classical lemons problem, arguing that consumers are unable to discriminate between different levels of regulatory quality. Acharya (2003) introduces competition between bank regulators that choose both the level of capital requirements and the bailout policy when banks become insolvent. Dell'Ariccia and Marquez (2006) model regulators that choose national capital requirements by trading off the aggregate level of bank profits against the benefits of financial stability. All these papers arrive at the conclusion that national capital standards are set inefficiently low from a global welfare perspective. Moreover, none of these papers incorporates firms that use bank loans to produce real output.[6]

[6]Recently, Boyer and Kempf (2016) have analyzed non-cooperative banking regulation in a setting where banks can costlessly choose the jurisdiction in which they operate. In their framework, liquidity regulation to limit risk-taking and taxes on bank profits emerge endogenously as the efficient regulatory instruments. In the non-cooperative equilibrium, a 'race to the bottom' results with respect to profit taxes, which are driven to zero under regulatory arbitrage. In contrast, liquidity standards may be set

A reputation effect that benefits banks is also present in the model of Morrison and White (2009), who focus on the question of whether a common regulatory standard is beneficial for countries that differ with respect to the quality of their national regulator. In their framework the reputation effect arises from the quality of the regulator, however, for which capital requirements act as a substitute. Hence high capital standards are associated with a negative signal, contrary to our framework.

The heterogeneity of banks incorporated in this paper is an important topic in the recent international trade literature. Buch et al. (2011) show a close empirical link between size, productivity and international activity in the banking sector that is similar to the well-established patterns for the manufacturing sector. Niepmann (2015) introduces a framework of cross-border banking based on international trade theory and Niepmann (2016) extends this model to account for heterogeneous monitoring ability of banks. These papers do not consider regulatory policies. Tax policy competition in a trade framework with heterogeneous firms has been analyzed by Davies and Eckel (2010), Krautheim and Schmidt-Eisenlohr (2011) and Haufler and Stähler (2013).

Finally, a small strand in the recent public economics literature has stressed the qualitative similarities between regulation and taxation of the financial sector (Keen, 2011) and it has analyzed the optimal taxation of financial intermediaries (Lockwood, 2014). This literature has also provided empirical evidence that recent bank levies have been effective in increasing the equity ratio of European banks (Devereux et al., 2013).[7]

This paper is set up as follows. Section 2 presents our benchmark model. Section 3 analyzes nationally optimal regulation policies. Section 4 turns to the central issue of whether decentralized capital standards are set higher or lower than is globally optimal. Section 5 analyzes a variety of extensions of our main model. Section 6 concludes.

2 The model

2.1 Banks

Our benchmark model considers a region of two countries $i \in \{1, 2\}$, which are symmetric in all respects. Banks in each country extend loans to firms in an integrated

more stringently by competing national regulators, as compared to supranational regulation.

[7]A selection of papers dealing with the taxation and regulation of the financial sector is collected in de Mooij and Nicodème (2014).

regional market. In each country multiple, heterogeneous banks operate under the authority of a national regulator who imposes capital requirements k_i for all banks within his jurisdiction. The number of active banks in each country and the volume of loans distributed by each bank are endogenous.

Banks differ exogenously in their monitoring skills, which determine the quality q of the individual bank.[8] We assume that the variable q is distributed uniformly in the interval [0,1] and it corresponds to the likelihood that the investment financed by the individual bank's loan is successful. Therefore, in our model the bank's monitoring quality is the critical determinant in the success of firms.

There are several ways in which the quality of a bank can improve the payoff to borrowing firms. First, due to their repeated interaction with different customers, banks acquire a knowledge that is complementary to that of firms (see Boot and Thakor, 2000). In this sense, q can be interpreted as the general and sector-specific expertise of an individual bank, which directly affects the probability of successful production. Second, especially smaller and less mature firms derive substantial benefits from having long and stable relationships to banks, as they can more flexibly draw on existing lines of credit (Ivashina and Scharfstein, 2010), or receive favorable credit terms for new loans (Bolton et al., 2013). With such 'relationship lending', the probability of successful production will again be a function of bank quality, when their monitoring ability q leads banks to flexibly provide its customers with credit.[9] Given these reasons for why a firm's success rate is positively correlated with its bank's monitoring quality, our assumption that this correlation is perfect merely serves to simplify the analysis.

Each bank can fund itself either through equity capital or through external funds, which we take to be saving deposits of individuals. In line with with common practice in virtually all developed countries, we assume that the savings deposits are fully insured by the government of the country in which the bank is located.[10] Hence, and importantly

[8]Thus we do not endogenize a risk-taking (monitoring) decision of banks, as is done in much of the literature on capital regulation. Instead we focus on the direct role of capital standards in increasing the equity requirement of banks. This reduces the implicit exposure of taxpayers to the default risks in the banking sector, which arises from the existence of a deposit insurance scheme.

[9]See Inderst (2013) for a recent analysis where the expected payoff of projects depends on the ability of banks to roll over loans, and for examples of capital losses arising for firms when their bank fails or encounters liquidity problems.

[10]The main argument in favor of deposit insurance schemes is that they prevent bank-runs and thus stabilize the banking system (Diamond and Dybvig, 1983). Barth et al. (2006) give an overview of

for our model, the (expected) costs of bank failures are partly borne by the taxpayers of the bank's residence country. Being fully insured against failure, depositors demand a competitive return on their savings, which we normalize to unity. In contrast, equity holders may demand a risk premium and the per-unit cost of equity is exogenously given by $\rho \geq 1$.[11]

Another critical assumption of our benchmark model is that individual banks are not able to signal their quality to firms.[12] Hence, no bank will choose to hold costly equity capital in excess of the minimum level k_i stipulated by the national regulator. At the same time, the capital adequacy ratio set by the government of country i will, in ways that we specify below, determine the return that firms are willing to pay for a loan from a bank resident in country i. The expected profits of a bank in country i with quality q that chooses to distribute a total number of l loans are then given by

$$\pi_i(q,l) = q[R_i - (1-k_i)]l - \rho k_i l - \frac{1}{2}\, bl^2 \quad \forall\, i \in \{1,2\}\ . \tag{1}$$

Here R_i is the return per unit of the bank's loans, which depends on the capital standards set by the bank's home country i, but not on the individual quality of the bank. From this gross loan rate the bank must deduct the costs of savings deposits $(1-k_i)$, which are paid back by the bank only with its success probability q. The return on the bank loan is zero, if the borrowing firm's risky investment fails. In this case the bank will also go bankrupt. Savers will be compensated by payments from the national deposit insurance fund, whereas equity holders lose all their investment. Total equity capital in the bank is $k_i l$ and equity holders have a fixed opportunity cost of ρ per unit of capital invested (cf. footnote 11 above). Finally, the quadratic cost term $(1/2)bl^2$ represents transaction costs that are rising more than proportionally when the bank's level of operation rises. This term therefore limits the scale of operations of each bank.[13] All net profits, and all uncovered losses, accrue to equity holders as residual claimants.

We assume that all banks are small relative to the overall loan market and hence take R_i as given when choosing l. The optimal loan volume l^* for each bank in country i is

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deposit insurance schemes around the world, and discuss its benefits and costs.

[11] This is a standard assumption in the literature (e.g. Hellman et al., 2000; Dell' Ariccia and Marquez, 2006; Allen et al., 2011). An alternative setting where the cost of equity depends on the bank's quality q is discussed in Section 5.1.

[12] This assumption will be relaxed in Section 5.4, which introduces (imperfect) quality signalling by individual banks.

[13] See Acharya (2003) for a similar assumption.

then given by

$$l^* = \frac{q\phi_i - k_i\rho}{b} \quad \forall\, i\ , \tag{2}$$

where we have defined the short-hand notation

$$\phi_i \equiv R_i - (1 - k_i) \quad \forall\, i \tag{3}$$

to indicate the return per unit of loans for each bank in country i, net of the funding costs for savings deposits. This term therefore represents the expected increase in the cash flow of a bank in country i when the success probability of its loan increases.

From eq. (2), the loan volume of a bank is an increasing function of its quality q. Thus, a better bank is also larger in equilibrium.[14] Moreover, the loan volume is an increasing function of the return R_i and a decreasing function of the capital adequacy ratio k_i, both of which are specific to the country in which the bank is located.

Substituting (2) in (1) gives the optimized profits of a bank of quality q in country i:

$$\pi_i^*(q) = \frac{(q\phi_i - k_i\rho)^2}{2b} \quad \forall\, i\ . \tag{4}$$

The equilibrium number of banks in country i is determined by the condition that the marginal bank, denoted by the cutoff quality level $\hat{q}_i$, receives zero expected profits from its operations:

$$\hat{q}_i\phi_i - k_i\rho = 0 \quad \forall\, i\ . \tag{5}$$

Consequently, only banks with $q \geq \hat{q}_i$ will be active in the market. Equation (5) shows that capital standards in country i directly affect the cutoff quality level $\hat{q}_i$ by increasing the cost of capital for all banks. As low-quality banks benefit most from limited liability and cheap deposit funding, they are hit hardest by an increase in capital standards. Without any capital requirements ($k_i = 0$), all banks will be active in the market ($\hat{q}_i = 0$). In contrast, full equity financing of banks ($k_i = 1$) results in $\hat{q}_i = \rho/R_i$. Hence, a necessary condition for a positive number of banks to stay in the market even with full equity financing is that the cost of equity ρ is lower than the equilibrium return on loans, R_i. We make this assumption in the following.

It remains to determine the aggregate loan volume of all active banks in country i. We normalize the exogenously given number of potentially entering banks to unity. To

[14] This corresponds to the empirical evidence in Buch et al. (2011) that bank productivity and bank size are positively correlated.

arrive at the aggregate loan volume, we integrate over the optimal loan volumes (2) of all active banks. This gives

$$L_i = \int_{\hat{q}_i}^{1} l(q)dq = \frac{(1-\hat{q}_i)(\phi_i - k_i\rho)}{2b} = \frac{(1-\hat{q}_i)^2\phi_i}{2b} \qquad \forall\, i. \tag{6}$$

Here $(1-\hat{q}_i)$ is the measure of active banks in country i, whereas $(\phi_i - k_i\rho)/2b$ gives the average loan volume per active bank.[15] The second step in (6) then uses (5) to simplify the resulting expression.

2.2 Firms and consumers

One of the features of our model is that we explicitly incorporate firms that use bank loans to produce consumer goods. In the following sections this will allow us to study the welfare effects of capital standards on banks, taxpayers and consumers.

We assume that there are a large number of identical, potential producers in an integrated final goods market, which do not have any private sources of funds. The potential producers compete for credit in the international loan market, where each firm can obtain credit from either the domestic or the foreign banking sector.[16] Each firm that enters the market in equilibrium demands one unit of credit to produce one unit of output. Total output in the integrated market therefore depends on the expected number of successful loans from banks in both countries. Denoting the expected output produced with loans from banks located in country i by y_i, total output is[17]

$$y \equiv y_i + y_j = \int_{\hat{q}_i}^{1} ql(q)dq + \int_{\hat{q}_j}^{1} ql(q)dq = L_i\left(\frac{2+\hat{q}_i}{3}\right) + L_j\left(\frac{2+\hat{q}_j}{3}\right) \qquad \forall\, i \neq j\ . \tag{7}$$

Next we determine the loan rate that firms are willing to pay to banks from each country i in the competitive equilibrium. All potential entrants in the final goods

[15]Using eq. (2) shows that this term is the unweighted average of the loan volume chosen by the best bank (with $q = 1$), and the loan volume of the marginal entering bank with $\hat{q}$, which is zero.

[16]The location of firms is irrelevant in our model, because all firms are identical and the output market is integrated.

[17]Note from (7) that at least two thirds of all loans will lead to successful production, even in the absence of any capital requirements (i.e., for $\hat{q} = 0$). This follows from our assumption of a uniform distribution of bank qualities and from the fact that high-quality banks supply more loans [see eq. (2)]. The expected success rate increases further, when capital requirements drive the worst banks from the market and $\hat{q} > 0$.

sector have to incur a uniform fixed cost c for their projects. Further, as firms can not observe the quality of the contracting bank, they have to form expectations about the average quality of loans distributed by all active banks that reside in a specific country. We denote the expected success rate of loans originating from banks in country i by q_i^e. If the investment is successful, the firm sells its product in the integrated market for the homogeneous consumer good. This output market is characterized by the inverse demand function $P = A - y$, where A measures the size of the integrated market. Firms will not repay the loan if their project fails, but the fixed cost c has been incurred nevertheless. Thus, allowing for free entry of firms into the output market, the zero profit condition for entering, risk-neutral firms implies

$$q_i^e(P - R_i) = c \quad \forall\, i. \tag{8}$$

Since producing firms are identical, they also make zero expected profits in the aggregate. Effectively, all expected profits are transferred to banks via the loan rate R_i.

To derive the equilibrium loan rate for banks in each country, R_i, we rearrange (8) and substitute the inverse demand function $P = A - y$. This gives:

$$R_i = A - \frac{c}{q_i^e} - y = A - \frac{3c}{2 + \hat{q}_i} - y \quad \forall\, i. \tag{9}$$

In the second step of eq. (9) we have assumed that firms rationally anticipate the average success rate of loans from banks in country i, which is $q_i^e = (2 + \hat{q}_i)/3$ from (7). Thus the loan price is decreasing in total output and in the amount of fixed costs c. Moreover, (9) shows that loan rates are country-specific and depend positively on the expected quality of the banking sector in country i. A higher expected quality of i's banking sector reduces each firm's probability of failure and thus raises its willingness to pay for the loan. Hence, national capital requirements k_i act as a selection mechanism by affecting the pool quality of national banks, which in turn determines the price that borrowers are willing to pay for a bank loan emanating from country i. Consequently the price of bank loans differs systematically between the two countries whenever their capital requirements differ, with bank loans from the country with the higher capital requirement receiving a higher return.

2.3 Market equilibrium and welfare

To derive the market equilibrium, we substitute eq. (9) into (5) and, together with (2), into (7). This yields a system of three simultaneous equations:

$$\hat{q}_1\left[A-\frac{3c}{2+\hat{q}_1}-y-1+k_1\right]=\rho k_1, \tag{10a}$$

$$\hat{q}_2\left[A-\frac{3c}{2+\hat{q}_2}-y-1+k_2\right]=\rho k_2, \tag{10b}$$

$$\begin{aligned} y=y_1+y_2 \;=\; & \frac{1}{b}\int_{\hat{q}_1}^{1}\left[q^2(A-y-1+k_1)-qk_1\rho-q^2\left(\frac{3c}{2+\hat{q}_1}\right)\right]dq \\ +\; & \frac{1}{b}\int_{\hat{q}_2}^{1}\left[q^2(A-y-1+k_2)-qk_2\rho-q^2\left(\frac{3c}{2+\hat{q}_2}\right)\right]dq. \end{aligned} \tag{10c}$$

Equations (10a)–(10c) jointly determine the cutoff qualities of banks, $\hat{q}_1$ and $\hat{q}_2$, and the aggregate output level y, all as functions of the capital requirements k_1 and k_2 imposed by the two countries. These core variables then determine the total level of loans from each country from (6) and the country-specific loan rate from (9).

We consider a national regulator in each country who sets capital requirements so as to maximize national welfare. Welfare in country i is taken to be a weighted sum of bank profits Π_i, tax revenue T_i and consumer surplus S:

$$W_i=\alpha\Pi_i+\beta T_i+\gamma\frac{S}{2}, \quad \alpha,\beta,\gamma\geq 0. \tag{11}$$

Here $\Pi_i \equiv \int_{\hat{q}}^{1}\pi_i^*(q)$ [cf. eq. (4)] denotes the aggregate profits of all banks of country i that are active in the regional market. As we have discussed above, this aggregate corresponds to the sum of all gains and losses accruing to equity holders in the banking sector of country i. In our benchmark analysis we assume that all equity holders are residents of country i.[18] In addition, the regulator considers the expected costs to resident taxpayers when banks fail and depositors must be compensated for their losses through the deposit insurance fund. Hence the expected tax revenue T_i will always be negative. Finally, by affecting the supply of loans, capital standards also affect aggregate output and hence consumer surplus. Since the output market is regionally integrated, and the model is symmetric, we allocate one half of the total consumer surplus S in the integrated market to each of the two countries.

[18] In Section 5.2 we analyze the case where the banking sector of each country is partly owned by foreign residents.

Note that the three components of national welfare included in (11) cover all agents in country i whose income is affected by capital regulation. Depositors can be ignored because they are guaranteed a fixed return (normalized to unity), which equals their opportunity costs of funds. Moreover, recall that all producing firms make zero profits from eq. (8).

The components of national welfare can be directly calculated from the equilibrium in the loan market. Total profits in the banking sector of country i are given by aggregating (4) over all active banks. This yields

$$\Pi_i = \int_{\hat{q}_i}^{1} \frac{(q\phi - k_i\rho)^2}{2b}\, dq = \frac{6by_i^2}{(2+\hat{q}_i)^2(1-\hat{q}_i)} \quad \forall\, i\ , \tag{12}$$

where we have used (6) and (7) to express banking sector profits in country i as a function of output with loans from country i and of the cutoff quality of banks in i.

The expected losses borne by taxpayers in country i arise from the deposit insurance scheme.[19] These losses are determined by the share of deposit financing, the aggregate loan volume, and the average failure probability of country i's banks. Moreover, we abstract from international contagion effects and assume that the losses from failed banks arise only in the country in which the bank is located.[20] Aggregating and using (6) and (7) in the second step gives

$$T_i = \frac{-(1-k_i)}{b} \int_{\hat{q}_i}^{1} (1-q)(q\phi_i - k_i\rho) dq = \frac{-(1-k_i)(1-\hat{q}_i)y_i}{(2+\hat{q}_i)}. \tag{13}$$

Finally, total consumer surplus in the region is

$$S = \frac{1}{2}(A-P)y = \frac{y^2}{2}, \tag{14}$$

which is shared equally in equilibrium between the two symmetric countries.

From (12)-(14) we can determine the effects of capital requirements on national and regional welfare, as well as its components.

[19] Our analysis abstracts from insurance funds paid by the banking sector. From 2016 onwards the member states of the European Union, for example, are building up an EU-wide 'resolution fund', financed by levies on member states' banks. This fund, however, is built up only gradually and with a moderate overall target volume.

[20] See Niepmann and Schmidt-Eisenlohr (2013) and Beck and Wagner (2013) for analyses of international regulatory coordination when bank failures in one country have adverse effects on banks in the other country.

3 Nationally optimal capital standards

In this section we analyze the effects of capital standards that are set in a nationally optimal way. In Section 3.1 we first discuss the effects that capital requirements have on the equilibrium in the loan market. Section 3.2 then analyzes the welfare effects of capital standards. It first analyzes the effects of introducing a small capital requirement and then turns to the conditions under which a symmetric Nash equilibrium in capital standards exists.

3.1 Capital standards and the loan market

In a first step we derive the effects that a unilateral increase in country i's capital requirement k_i has on the equilibrium in the loan market. The changes in the endogenous variables $\hat{q}_i$, $\hat{q}_j$, y_i and y_j (where $i \neq j$) are derived in Appendix A.1 and are given by[21]

$$\frac{\partial \hat{q}_i}{\partial k_i} = \frac{(\rho - \hat{q})\Theta + \rho(\phi + \tilde{c}\hat{q})(2 + \hat{q})(1 - \hat{q})^2}{2(\phi + \tilde{c}\hat{q})\Omega} > 0 \,, \tag{15}$$

$$\frac{\partial \hat{q}_j}{\partial k_i} = \frac{\hat{q}(1 - \hat{q})\kappa}{2(\phi + \tilde{c}\hat{q})\Omega} \,, \tag{16}$$

$$\frac{\partial y_i}{\partial k_i} = \frac{(1 - \hat{q})\Theta\kappa}{12b(\phi + \tilde{c}\hat{q})\Omega} \,, \tag{17}$$

$$\frac{\partial y_j}{\partial k_i} = \frac{-2\phi(1 - \hat{q})(1 - \hat{q}^3)\kappa}{12b(\phi + \tilde{c}\hat{q})\Omega}, \qquad \frac{\partial y}{\partial k_i} = \frac{(1 - \hat{q})\kappa}{2\Omega} \,, \tag{18}$$

where we have introduced the short-hand notations

$$\Theta \equiv 6b(\phi + \tilde{c}\hat{q}) + 2\phi(1 - \hat{q}^3) > 0, \tag{19}$$

$$\Omega \equiv 3b(\phi + \tilde{c}\hat{q}) + 2\phi(1 - \hat{q}^3) > 0, \tag{20}$$

$$\tilde{c} \equiv \frac{3c}{(2 + \hat{q})^2} \,, \tag{21}$$

and

$$\kappa = \underbrace{-\phi\left[3(\rho - 1)(1 + \hat{q}) + (1 + 2\hat{q})(1 - \hat{q})\right]}_{cost\ effect} + \underbrace{\tilde{c}(1 - \hat{q})(2 + \hat{q})\rho}_{selection\ effect} <> 0. \tag{22}$$

Equation (15) shows that an increase in country i's capital requirement unambiguously raises the quality of the cutoff bank in this country, $\hat{q}_i$. This is due to both the higher

[21] To save on notation we omit country subscripts in the following when no confusion is possible, invoking the symmetry of our model.

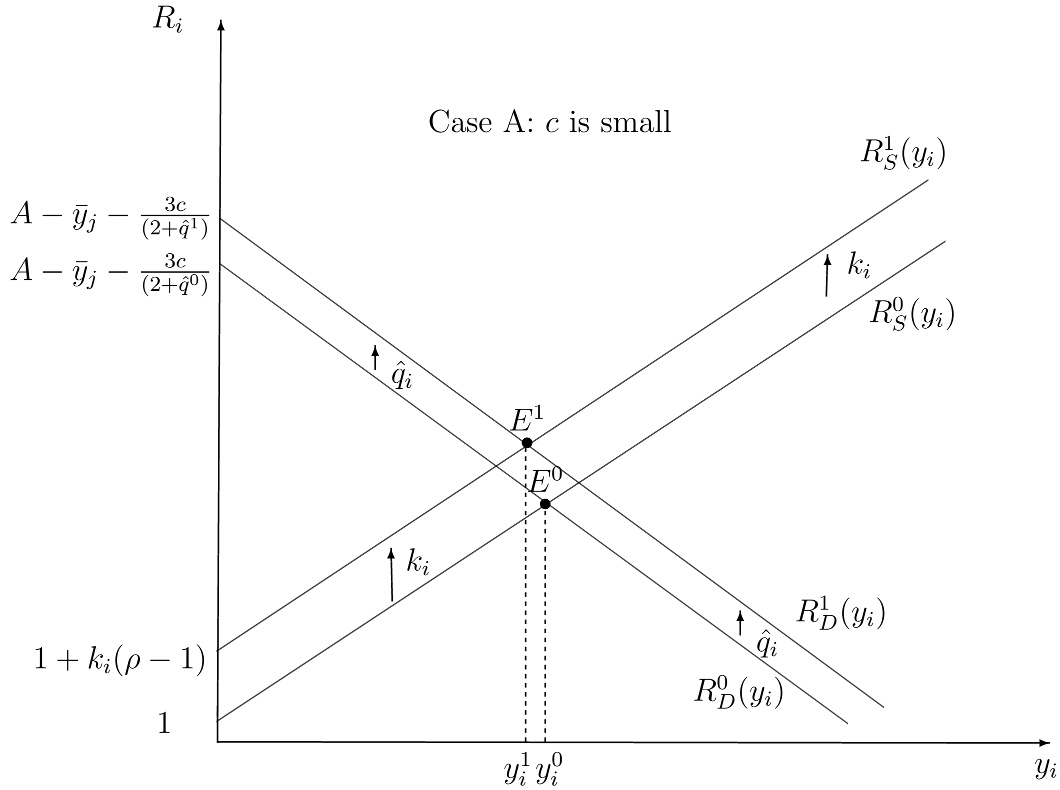
cost of equity in comparison to savings deposits, and to the reduced volume of implicit taxpayer subsidies as a consequence of the higher equity ratio. Hence, by raising the cost of finance for all banks, capital requirements drive the weakest banks in country i from the market.

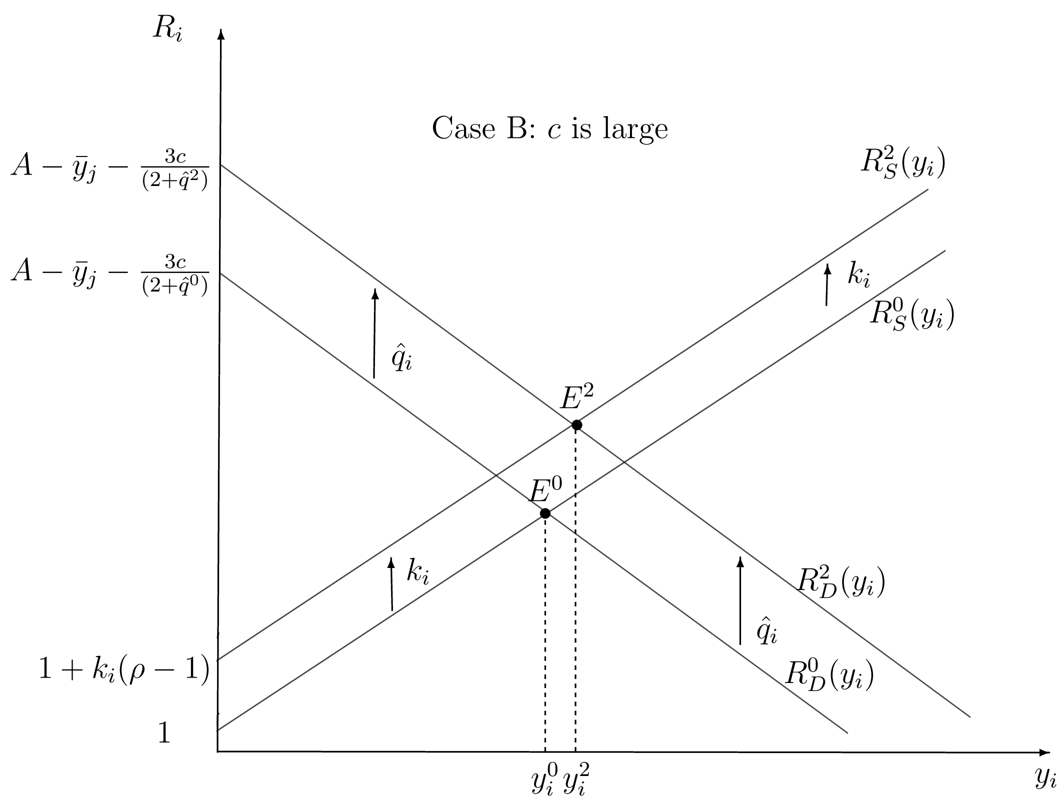
The remaining effects in (16)–(18) all depend on the size of κ, as given in (22). It is thus critical for our analysis to discuss the effects summarized by κ in detail. As shown in (22), the effect of a higher capital requirement on the total level of performing loans can be decomposed into two parts. The first term is unambiguously negative, as capital standards raise the costs of refinancing for all banks. We label this the *cost effect* of higher capital standards. The second term involving $\tilde{c}$ [see eq. (21)] is, however, positive. This captures the positive effect of higher capital requirements on the pool quality of banks in country i. The rise in $\hat{q}_i$ induced by a higher capital requirement [see eq. (15)] results in a higher loan rate that firms are willing to pay for loans from banks based in country i, as they face a lower probability of losing their fixed cost c. In the following we will refer to this effect as the *selection effect* of capital standards. In sum, we can therefore not sign κ, in general.

Figure 2 illustrates the two cases corresponding to $\kappa < 0$ and $\kappa > 0$ for the introduction of a small capital requirement in country i. Eq. (6), together with (7) yields an inverse supply function $R_S(y_i)$ that describes the loan rate in country i as a positive function of y_i when y_j is held constant. At the same time, $P = A - \bar{y}_j - y_i$ gives the price that competitive firms achieve in the output market, as a function of country i's volume of successful loans. From this, the demand for loans from banks in country i, $R_D(y_i)$, can be derived as a parallel shift of the demand function in the output market. The vertical intercept of this shift is determined by the firms' fixed investment cost c and the average success probability $\hat{q}_i$ [see eq. (9)].

In the absence of any capital requirements, the loan supply curve for country i's banks, R_S^0, starts at per-unit refinancing costs of unity. This represents the case of pure deposit finance. A small capital requirement k_i shifts the loan supply curve upward (*cost effect*). The associated increase in the cutoff quality of country i's banks also leads to a parallel upward shift of the initial loan demand demand curve R_D^0, by lowering the firms' probability of losing their fixed costs (*selection effect*). In Case A, given in the upper panel of Figure 2, the fixed cost c is small and the shift in the loan supply curve dominates the shift in the loan demand curve. As a result the equilibrium shifts from E^0 to E^1 and the volume of successful loans given by country i's banks is reduced

Figure 2: The effects of a small capital requirement in country i





from y_i^0 to y_i^1. This case thus corresponds to $\kappa < 0$. In Case B, shown in the lower panel of the figure, the firms fixed costs c are sufficiently large so that the upward shift in the loan demand curve to R_D^2 dominates the shift in the loan supply curve. Hence the equilibrium shifts from E^0 to E^2, resulting in an increase in successful loans by country i's banks from y_i^0 to y_i^2. This corresponds to the case $\kappa > 0$.

The implications for country j then follow from the equilibrium in the loan market. If $\kappa < 0$, banks in country i distribute fewer loans in the aggregate. This raises the loan rate for banks in country j. The higher profitability will draw additional banks in country j into the market, thus lowering $\hat{q}_j$ [eq. (16)]. Moreover, the aggregate loan volume in country j will rise, and with it the output y_j generated from these loans [eq.(18)]. Hence a unilateral increase in country i's capital requirement shifts business from banks in country i to banks in country j. If $\kappa > 0$, all effects are reversed. In this case, a higher capital standard in country i will boost the aggregate loan supply of banks in country i. The expansion of loans from country i will then reduce the loan price for banks in country j, raising $\hat{q}_j$ and reducing y_j.

3.2 Welfare effects of capital standards

In a second step, we use the effects on the loan market equilibrium variables, as given in (15)–(18), to determine the effects of the capital standard k_i on country i's welfare. Differentiating the welfare function (11) and its components (12)–(14) gives

$$\frac{\partial W_i}{\partial k_i} = \alpha \, \frac{\partial \Pi_i}{\partial k_i} + \beta \, \frac{\partial T_i}{\partial k_i} + \frac{\gamma}{2} \frac{\partial S}{\partial k_i} \, ,$$

where

$$\frac{\partial \Pi_i}{\partial k_i} = \frac{18 b y_i^2 \hat{q}_i}{(1-\hat{q}_i)^2 (2+\hat{q}_i)^3} \frac{\partial \hat{q}_i}{\partial k_i} + \frac{12 b y_i}{(1-\hat{q}_i)(2+\hat{q}_i)^2} \frac{\partial y_i}{\partial k_i} \, , \tag{23}$$

$$\frac{\partial T_i}{\partial k_i} = \frac{(1-\hat{q}_i) y_i}{(2+\hat{q}_i)} + \frac{3(1-k_i) y_i}{(2+\hat{q}_i)^2} \frac{\partial \hat{q}_i}{\partial k_i} - \frac{(1-k_i)(1-\hat{q}_i)}{(2+\hat{q}_i)} \frac{\partial y_i}{\partial k_i} \, , \tag{24}$$

$$\frac{1}{2} \frac{\partial S}{\partial k_i} = \frac{y}{2} \frac{\partial y}{\partial k_i} \, . \tag{25}$$

In the following we evaluate the welfare effects in equations (23)–(25) at a minimum capital standard of $k_i = 0$ and at a maximum capital ratio of $k = 1$, respectively. The first implies that the banks' funding needs can be fully met by cheap (and insured) savings deposits, whereas the latter case implies that all lending must be financed by more expensive equity. We derive the conditions under which aggregate welfare is increasing in k_i when evaluated at $k_i = 0$, but falling in k_i when evaluated at $k_i = 1$. Since all arguments of the welfare function (11) are continuous in k_i, an interior optimal capital standard must then exist for each country i when these conditions are met.

We first evaluate equations (23)–(25) at an initial capital standard of $k_i = 0$, that is, we ask how welfare in country i is affected by the introduction of a small capital standard. Note that an initial capital standard of $k_i = 0$ implies $\hat{q}_i = 0$ from (5). Turning first to the effects on the profits of country i's banking sector in (23), the first term in this expression vanishes when $\hat{q}_i = 0$ initially. Hence the effects on bank profits are exclusively determined by the change in the aggregate level of successful loans (i.e., output), as given by the second term. The induced output change also determines the change in consumer surplus in the integrated market, as given in (25).

The effects on tax revenues in (24) are threefold. The first effect gives the direct, positive effect on tax collections (i.e., a reduction in expected subsidy payments) by decreasing the bank's reliance on deposits backed by a tax-financed insurance mechanism. Moreover, increasing the critical bank quality $\hat{q}_i$, and hence raising the average success rate of loans, additionally reduces the expected burden on taxpayers by the second effect. The sign of the third effect is ambiguous, however, as it depends on the change in the aggregate volume of loans offered by banks in country i, and hence on the sign of κ.

In Appendix A.2 we derive the conditions under which (23)–(25) are all positive when evaluated at $k_i = 0$ initially, and the introduction of a small capital standard strictly increases welfare in country i. These conditions are given by

$$\frac{3(2\rho - 1)c}{3\rho - 2} > (A - 1), \tag{26a}$$

$$\left[\frac{15}{8} + \frac{1}{4b}\right] c < (A - 1). \tag{26b}$$

The inequality in (26a) is just the condition for κ to be positive at $k = 0$. Effectively, this requires that the firms' fixed investment costs c must be sufficiently large, relative to the market size parameter A, which determines the profit margin of banks. If condition (26a) is fulfilled, the *selection effect* of capital standards dominates the *cost effect* when both are evaluated at an initial capital adequacy ratio of zero. Inequality (26b) states, in contrast, that the firms' fixed cost, and hence the induced expansion of bank loans is not so large as to overcompensate the positive first two effects of a small capital standard in the tax revenue expression (24).[22] We summarize these results in:

[22]Note that conditions (26a) and (26b) are not mutually exclusive. For example, if $\rho = 1$ and $b = 2$,

Proposition 1 *(i) When firms' fixed production costs are sufficiently high, relative to the size of the output market [condition* (26a) *holds], then introducing a small capital standard* $k_i > 0$ *raises the aggregate profits of country i's banking sector.*
(ii) If, in addition, the firms' fixed costs c are not overly high, relative to market size [condition (26b) *holds], then introducing a small capital standard* $k_i > 0$ *benefits banks, consumers and taxpayers in country i simultaneously and country i's welfare is improved for any combination of* $\alpha, \beta, \gamma \geq 0$.

Our model thus shows that in the presence of selection effects, introducing capital standards may be unanimously approved by all agents in a country, even if the regulation is imposed unilaterally. In particular, introducing a small capital standard may be in the overall interest of the country's banking sector when the latter is heterogeneous. By raising the costs of doing business, the capital standard drives the least productive (most risky) banks from the market. High-quality banks will then benefit from the market exit of low-quality banks via a higher loan rate. When firms value the increase in the pool quality of banks sufficiently, as measured in our model by their fixed costs of production c, then the higher profits of infra-marginal banks dominate the profit losses of marginal, low-quality banks. These redistributive effects between heterogeneous banks may thus explain why large and productive banks do not generally oppose new capital regulations, and in some cases even actively advocate them.[23]

We now turn to the other extreme case and evaluate (23)–(25) for an initial capital ratio of $k_i = 1$ (full equity financing of loans). For $k_i = 1$, the first term in the tax revenue expression (24) is positive, whereas the other two terms are zero. Since the first term in the profit expression (23) is also positive and the remaining terms in (23) and the consumer surplus term (25) are positive multiples of κ, it follows directly that $\kappa < 0$ must hold at $k_i = 1$, if an interior optimum for national capital standards is to exist. Moreover, since the negative terms involving κ must exceed the positive terms in (23) and (24), we now have to specify relative weights for the three components

both conditions are simultaneously fulfilled when $3c > A - 1 > 2c$.

[23]Vig et al. (2016) show, for example, that the introduction of the Basel II capital regulations significantly increased the loan market share of the largest banks in Germany, at the expense of their smaller competitors. One mechanism by which this occurred was that the Basel II rules gave banks the option to calculate the risk weights of their loans on the basis of an internal rating algorithm. This option was used only by the larger banks and loan default rates were systematically underestimated in these internal ratings. For a theoretical study of competition between banks of different size under the Basel II rules, see Hakenes and Schnabel (2011).

of national welfare. A natural choice is to assume that the social planner places equal welfare weights on bank shareholders, taxpayers and consumers so that $\alpha = \beta = \gamma = 1$.

For this benchmark case, Appendix A.3 derives the following sufficient conditions for $\partial W_i / \partial k_i < 0$ to hold at $k_i = 1$:

$$A > \left[\frac{(3b+2)\rho}{2b[6(\rho-1)-1]} + \frac{3}{2} \right] c \qquad \text{and} \qquad A > \left[\frac{8(3b+2)}{15b} + \frac{3}{2} \right] c. \tag{27}$$

The two conditions summarized in (27) imply that market size is sufficiently large, relative to the firms' fixed production costs c, so that the *cost effect* of capital standards dominates the *selection effect* at the maximum capital ratio of unity. In addition, the first part of condition (27) will hold only when ρ is sufficiently above unity, implying that increasing the capital requirements is sufficiently costly for banks. When both conditions in (27) hold, this furthermore ensures that the negative effects of a rise in k_i on bank shareholders and consumers dominates the remaining, positive effect on taxpayers when all welfare components are weighed equally in the government's objective function. Invoking the symmetry of our model, we can then prove the existence of a symmetric, interior Nash equilibrium:[24]

Proposition 2 *When governments weigh bank profits, tax revenues and consumer surplus equally* ($\alpha = \beta = \gamma$)*, conditions* (27) *are sufficient to ensure that* $\partial W / \partial k_i|_{k=1} < 0$. *If, in addition, conditions* (26a) *and* (26b) *hold, then a symmetric Nash equilibrium exists in which both countries choose identical, interior capital requirements* $0 < k_i^* < 1$.

Proof: From Appendix A.2 and A.3, conditions (26a)–(26b) imply $\partial W / \partial k_i|_{k=0} > 0$, whereas it follows from (27) that $\partial W / \partial k_i|_{k=1} < 0$. Since all components of W_i are continuous functions of k_i, the welfare function $W_i(k_i)$ must also be continuous in k_i. Hence, for each country i there must exist at least one interior level $0 < k^* < 1$ where $\partial W_i / \partial k_i = 0$ holds. Since both countries are identical, this interior optimum must be reached at the same level of k_i, and hence the Nash equilibrium is symmetric. □

Two elements in our model are responsible for the concavity of the welfare function W_i in the capital ratio k_i. Firstly, taxpayers benefit less from a further tightening of capital requirements, the less they are exposed to the default risks in the national

[24]Note that Proposition 2 does not prove uniqueness, and therefore does not exclude the existence of additional, asymmetric equilibria. Even if such additional equilibria did exist, it seems natural to focus on the symmetric Nash equilibrium, given the symmetry of the two countries.

banking sector. This is seen in the last two terms of eq. (24), which are positive but are approaching zero for $k_i \to 1$. Secondly, the critical term κ falls continuously when the capital requirement k_i is continuously increased. To see this, we differentiate κ in (22) with respect to k_i and use $\phi = 6by_i/[(1-\hat{q})^2(2+\hat{q})]$ from (6) and (7). This gives:

$$\frac{d\kappa}{dk_i} = \varepsilon\,\frac{\partial \hat{q}_i}{\partial k_i} - \frac{6b[3(\rho-1)(1+\hat{q})+(1+2\hat{q})(1-\hat{q})]}{(1-\hat{q})^2(2+\hat{q})}\frac{\partial y_i}{\partial k_i}, \tag{28}$$

where

$$\varepsilon = \frac{-9\rho c}{(2+\hat{q}^2)} - \frac{6by}{(1-\hat{q})^2(2+\hat{q})^2}\left\{3(\rho-1)[5(1+\hat{q})+2\hat{q}^2]+(1-\hat{q})(5+2\hat{q}+2\hat{q}^2)\right\} < 0.$$

From the positive effect of k_i on $\hat{q}_i$ in (15) we see that the first term in (28) is unambiguously negative. Moreover, the second term in (28) is also negative when $\kappa > 0$ initially and hence $dy_i/dk_i > 0$ [see eq. (17)]. Therefore, as long as the value of κ is non-negative, κ must be unambiguously falling in k_i. When conditions (27) both hold, this process will continue until the sign of κ switches from positive to negative.

Intuitively, the *selection effect* of capital standards becomes less important when k_i is increased and the critical quality level of banks in country i rises [eq. (15)]. Since a higher level of $\hat{q}$ reduces the heterogeneity of active banks, the producing firms' marginal willingness to pay for a higher expected loan quality accordingly falls.[25]

Finally, we determine the sign of κ in the symmetric, interior Nash equilibrium. The argument starts by setting $\kappa = 0$. From (25) and (18) the effect on consumer surplus is then zero, whereas bank profits and tax revenues will unambiguously rise from (23) and (24), together with (15) and (17). But this implies, from the concavity of $W_i(k_i)$, that k_i must be further raised towards its optimal level. From (28) it thus follows that κ has to fall from its initial level of zero. Hence in a non-cooperative, interior optimum in capital standards, the value of κ must be negative and the *cost effect* of higher capital standards dominates the *selection effect*. Using (15)–(18) we can then state:

Proposition 3 *In a symmetric Nash equilibrium where capital standards are at an interior optimum, $0 < k_i^* < 1 \;\forall\; i \in \{1,2\}$, the sign of κ in (22) is negative. In the Nash equilibrium, a marginal increase in the capital standard of country i then reduces the aggregate loan supply and raises the average quality of active banks in country i, and it has the opposite effects in the foreign country j.*

[25] This is seen by differentiating the loan rate (9) with respect to the expected loan quality q_i^e.

There is some empirical evidence for the result in Proposition 3 that tighter capital regulation in one country shifts aggregate loan supply to the other country. Houston et al. (2012) and Ongena et al. (2013) find that multinational banks operating in several countries shift their activities from countries that impose more, or tighter, regulation to countries with laxer regulation. In our setting this transfer of lending activity between countries does not occur through the regulatory arbitrage of multinational banks, but through the shrinking and expansion of aggregate banking sectors.

Importantly, however, in the presence of bank heterogeneity, the shifting of aggregate loan supply to the less regulated country need not imply that aggregate banking sector profits fall in the country that raises its capital requirement. This is because the average quality of the banking sector improves in the more tightly regulated country [the positive first term in (23)], and this increase in the average profitability of banks may dominate the fall in the total lending volume [the negative second term in (23)]. Moreover, even if total banking sector profits were to fall in the more tightly regulated country, this need not lead to a 'race to the bottom' in capital standards when governments simultaneously care about consumers and taxpayers. Using the results in Proposition 3, we can infer from (24) that an increase in country i's capital standards unambiguously increases tax revenues (i.e., reduces taxpayer losses) in country i. Moreover, from (25), the increase in k_i will reduce consumer surplus in both countries. In the following, we will analyze how the sum of these effects shapes governments' incentives under regulatory competition.

4 Are decentralized capital standards set too low?

In the last section we have established under which conditions a symmetric Nash equilibrium in regulation policies exists in our model. We now turn to analyzing the efficiency properties of this decentralized policy equilibrium. Since countries are symmetric in our benchmark model, we can simply define regional welfare as the sum of national welfare levels

$$W_W = W_i + W_j \quad \forall\, i,j \in \{1,2\}, i \neq j, \tag{29}$$

where W_i is given in eq. (11). Choosing k_i so as to maximize aggregate welfare, eq. (29) would imply $\partial W_W/\partial k_i = 0$. The nationally optimal capital standards derived in the previous section are instead chosen so that $\partial W_i/\partial k_i = 0$. Hence, any divergence between nationally and globally optimal capital requirements is shown by the effect of country i's policy variable k_i on the welfare of country j. If $\partial W_j/\partial k_i > 0$, then the capital requirements chosen at the national level are 'too lax' from an aggregate welfare perspective, as an increase in k_i would generate a positive externality on the welfare of country i. The reverse holds if $\partial W_j/\partial k_i < 0$. In this case the externality on the foreign country is negative and nationally chosen capital requirements are 'too strict' from an overall welfare perspective.

Differentiating W_j with respect to k_i gives (see Appendix A.4):

$$\begin{aligned}\frac{\partial W_j}{\partial k_i} &= \alpha\frac{\partial \Pi_j}{\partial k_i} + \beta\frac{\partial T_j}{\partial k_i} + \frac{\gamma}{2}\frac{\partial S}{\partial k_i} \\ &= \frac{-\kappa y_j(1-\hat{q})}{2\Omega(\phi+\hat{q}\tilde{c})}\left[\alpha\phi - \gamma(\phi+\hat{q}\tilde{c}) - \frac{\beta(1-k_j)(2+5\hat{q}+2\hat{q}^2)}{(2+\hat{q})^2}\right]. \qquad (30)\end{aligned}$$

There are three terms in the squared bracket of (30). Note that the common multiplier for all these terms is positive because the effects must be evaluated at a negative value of κ in the non-cooperative Nash equilibrium (Proposition 3).

The first term in the squared bracket gives the effect on the profits of country j's banking sector. This effect is unambiguously positive. The reason is that the higher capital standard in country i reduces aggregate loan supply of country i's banks. This raises the loan rate for banks in country j and thus raises their aggregate profits. The second effect in the squared bracket gives the effect on country j's consumers. This effect is negative as the fall in country i's aggregate loan supply reduces aggregate output in equilibrium [eq. (18)]. This loss of consumer surplus is transmitted to country j through the integrated output market. Moreover, the multiplier associated with the loss in country j's consumer surplus $(\phi + \hat{q}\tilde{c})$ is larger than the multiplier associated with the rise in country j's bank profits (ϕ), whenever there is a positive *selection effect* (i.e., when $\tilde{c}$ and hence c is positive).

To explain the higher weight of the negative consumer surplus term, it is again helpful to decompose the reduction in the aggregate loan supply in country i into a *cost effect* (associated with the multiplier ϕ) and a *selection effect* (with multiplier $\tilde{c}$). Banks in country j benefit only from the *cost effect* of country i's reduction in loan supply, as only this part gives banks in country j a competitive advantage. Recall, however, that banks take R_i as given in our model and changes in R_i are directly tied to changes in the consumer price level P by the zero profit condition of competitive firms [eq. (8)]. This, together, with the symmetry of our model, implies that the loss in consumer surplus for j's residents arising from this effect is just equal to the rise in the profits of country j's banking sector. In contrast, banks in country j do not benefit from the reduction in country i's output associated with the *selection effect*, as this effect raises the loan rate in country i, but not in country j. Consumers in j, however, also suffer from the reduction in country i's loan supply resulting from a higher threshold level $\hat{q}_i$. Together, these effects imply that the sum of the first two effects in the squared bracket of (30) is negative, if banking sector profits and consumer surplus are weighed equally in the national welfare function ($\alpha = \gamma$).

Finally, the third effect in (30) is also unambiguously negative. This effect gives the change in expected tax subsidies that taxpayers in country j have to pay for their failing banks. These tax subsidies will unambiguously increase, because the aggregate level of bank loans rises in country j [see eq. (18)], and the average failure probability also rises, due to the lower cutoff quality of country j's banking sector [eq. (16)].

Summing up this discussion, we see that tighter capital regulation in country i will, on net, cause a *negative* externality on country j's welfare whenever consumer surplus is weighed at least as high as bank profits. Capital standards will then be 'too strict' in the non-cooperative regulatory equilibrium. This is stated in our main result:

Proposition 4 *When governments weigh the surplus of banks and consumers equally* ($\alpha = \gamma$)*, then non-cooperatively set capital standards exceed those that maximize aggregate welfare in the union and a 'race to the top' in capital standards occurs. This 'race to the top' is more pronounced, if* (i) *the valuation of taxpayers' losses in the government objective function is large* (β *is high), and* (ii) *if the 'selection effect' of capital standards is strong* (c *is large).*

Proposition 4 is in direct contrast to the results in the existing literature, which have found that the non-cooperative setting of capital standards leads to a 'race to the bottom', or to a 'competition of laxity' (see Sinn, 2003; Acharya, 2003; Dell' Ariccia and Marquez, 2006). Effectively, these contributions have focused on the effect that capital requirements have on the profits of national banking sectors. The same effect is also present in our analysis, and it corresponds to the positive first effect in the squared bracket of (30). However, our model adds two new effects to this analysis that reverse the direction of the net externality in equilibrium.

First, bank loans produce real output in our model, and the output markets of the two countries are integrated. Changes in the overall availability of credit in country i thus affect consumer surplus in both countries. Therefore, while banks in country j benefit from a tighter capital regulation in country i, consumers in country j simultaneously lose. Moreover, as we have discussed above, the loss in consumer surplus will be larger than the gain in bank profits when banks are heterogeneous and a loan premium exists for a better pool quality of banks (*selection effect*).

Secondly, we incorporate taxpayers in our model, which eventually pay for the deposit insurance that banks draw on when their loans default. Capital regulation in one country increases taxpayer risks in the foreign country because foreign banks will increase their aggregate loan volume in equilibrium. Bank heterogeneity adds a further effect because lower-quality banks are drawn into the foreign banking sector, thus increasing the average default risk of banks there. In sum, our model shows that higher capital standards can be used to shift risks from domestic to foreign banks and thus, via the national deposit insurance funds, from domestic to foreign taxpayers.[26]

This last effect also explains the difference in results to the tax competition literature, which almost universally finds a 'race to the bottom', at least with respect to capital taxation (see Keen and Konrad, 2013, for a synthesis). In this literature, productive firms typically make deterministic profits and thus represent a source of positive tax revenue for national governments. Therefore, when higher taxes in one country cause firms to move abroad, the resulting increase in its tax base represents a positive externality for the foreign country. With capital regulation of banks and a tax-backed deposit insurance scheme, this externality is reversed in sign: since the tax on banks is negative in expected value, a stricter capital regulation in country i that increases the tax base in country j imposes a negative externality on this country's taxpayers.[27]

The shifting of taxpayer risks is also explicitly mentioned in the European Commission's explanatory memorandum motivating why EU member states are not permitted to set national capital standards above the internationally coordinated Basel III stan-

[26] Note the important difference to the 'financial stability' argument that Dell' Ariccia and Marquez (2006) introduce in the government's objective function to derive positive equilibrium levels of capital regulation. In their model, tighter capital requirements in country i increase financial stability in this country, but have no adverse effects on financial stability in country j. In contrast, in our model the reduced risks for taxpayers in country i are associated with higher risks for taxpayers in country j, due to the changed equilibrium in the international loan market.

[27] Of course this result would be modified, if we allowed for a positive tax on bank profits in case of success. It is questionable, however, whether bank profit taxes paid in 'good times' overcompensate the implicit and explicit bailout costs for banks arising in times of crisis. See Admati and Hellwig (2013) for a pronounced argument that banks represent a net liability for national taxpayers.

dards: "Inappropriate and uncoordinated stricter requirements in individual Member States might result in shifting the underlying exposures and risks (...) from one EU Member State to another" (European Commission, 2011, p. 10). By showing that capital regulation may impose *negative* externalities on foreign countries, on net, the results of our model lend support to the policy of the European Union to harmonize the *upper bound* for national capital standards at the level of the Basel III agreement.

5 Discussion and extensions

In Section 5.1 we first discuss the robustness of our results with respect to introducing quality-dependent cost of equity and imperfect competition to our benchmark model. We then introduce three distinct extensions. In Section 5.2 we ask which additional effects arise when banks in each country are partly owned by residents of the other country. Section 5.3 considers asymmetries between countries and numerically derives the resulting non-cooperative equilibria. Finally, in Section 5.4. we allow banks to (imperfectly) signal their loan quality to borrowing firms.

5.1 Discussion

Quality-dependent cost of equity: In our benchmark model we have assumed that the cost of equity for all banks is exogenously given by $\rho \geq 1$, irrespective of the bank's quality q. Implicitly, therefore, equity investors have no information about the quality of each individual bank. The alternative benchmark case is to assume that equity investors precisely know the quality of each bank. In this case, risk-neutral investors demand a return to equity equal to

$$\rho(q) = \frac{1}{q},$$

where 1 is the risk-free interest rate. Substituting this quality-dependent risk premium into the bank's profit function (1) and solving for the optimal bank size gives:

$$l^*(q) = \frac{q\phi_i - k_i/q}{b} \; . \tag{31}$$

Comparing this with (2) shows that high quality banks have two advantages in this changed setting: not only will they receive the gross return ϕ [see eq. (3)] with a higher probability, but they also face the lower cost of capital. Both of these factors increase the loan volume of a high quality bank, relative to its lower quality competitors. As a result, loan volumes will be more concentrated among the high quality banks under this alternative assumption about the cost of equity.[28]

Substituting (31) back into the profit function and setting profits equal to zero yields the cutoff quality of banks in this alternative setting:

$$\hat{q}^2\phi - k_i = 0. \tag{32}$$

In contrast to the benchmark case [eq. (5)], the cutoff condition is now quadratic in $\hat{q}$. This is the main reason why the algebra in this variant of our model becomes far more tedious and involved. However, the qualitative effects of our benchmark model should remain unchanged. In particular, it can be inferred from (32) that a higher capital requirement k_i will still raise the cutoff quality of banks in country i, thus giving rise to a *selection effect*. The *cost effect* of higher capital standards also remains, as a higher level of k_i reduces the implicit subsidies to the banking sector resulting from deposit insurance. Therefore, the two effects determining the sign of κ [eq. (22)] remain intact.

Moreover, the welfare effects of capital standards do not fundamentally change in this alternative setup. Since an increase in k_i improves the average quality of banks, its overall effect on tax revenue in (24) is very likely positive. But then, an interior optimum for k_i can only exist when the effect of k_i on country i's aggregate loan volume is negative (i.e., $\kappa < 0$, cf. Proposition 3). If this were not the case, all components of national welfare in (23)–(25) would be strictly positive, which is inconsistent with an interior optimum. Moreover, if $\kappa < 0$ holds in the Nash equilibrium, then the externalities arising from regulatory competition should remain qualitatively the same as in eq. (30), i.e. an increase in k_i increases bank profits in country j, but hurts both consumers in country j (through the reduction in total output), and taxpayers in country j (through the reduced average bank quality and the higher aggregate loan volume of country j's banks). Thus the latter two externalities can again dominate the positive externality on bank profits, leading to a 'race to the top' in capital regulation (Proposition 4). The precise conditions under which this holds will, of course, generally differ from our benchmark model.

Imperfect competition: Our model assumes that all banks behave as price takers in the international loan market. Introducing imperfect competition in a framework

[28]In this respect, the effects are similar to changing the distribution of q in the direction of a higher density of high-q banks.

with continuous bank heterogeneity and the explicit modelling of an output market is conceptually difficult. The closest formal analogy is with models of monopolistic competition, which are used extensively in a heterogeneous firms framework in the new trade theory (Melitz, 2003). In our setting this would require that both the output sector and the banking sector are monopolistically competitive, and that the producer of each output variety requires a specific loan product (an assumption that is not trivial to defend). Clearly, such a model will be highly complex.

We can nevertheless discuss which additional effects could be expected in such a model. The most direct implication is that the effects of capital standards on profits would gain more prominence. This is because aggregate banking sector profits would be higher in such a model, and because profits would also be earned by firms in the output market.[29] Our above argument that $\kappa < 0$ must hold in an interior Nash equilibrium can again be made here, implying that, in the Nash equilibrium, a higher capital requirement in country i shifts business from banks in country i to banks in country j.

Would our main result concerning the 'race to the top' in capital regulation (Proposition 4) be upheld in such a setting? We believe that it would, even though the conditions under which it holds are likely to be more restrictive than in our benchmark model. The main reason is that the negative externalities on foreign consumers and on foreign taxpayers will continue to exist in this extended model. Therefore, when the valuation of taxpayer and consumer losses is sufficiently high, relative to the valuation of profits, the net externality will remain negative. One reason for why the welfare weight of bank profits could be relatively low, even in imperfectly competitive markets, is given below.

5.2 Foreign ownership of banks

It is straightforward to extend our analysis to the case where residents in each country own a fraction of the banks in the neighboring country and hence participate in the profits of the foreign banking sector. International cross-ownership of banks is an empirically important phenomenon.[30] To maintain symmetry, let residents of each country

[29] Given their profit-making activities, the location of producing firms would have to be specified in this setting, and the welfare function would have to incorporate firm profits as an additional argument.

[30] To give two examples, foreigners held 43% of the largest German commercial bank, the Deutsche Bank, in 2014 (www.db.com/ir/de/content/673.htm). The share ownership of the French BNP Paribas included 25.8% non-European institutional investors in 2015, and an additional 11% were held by state funds from Belgium and Luxembourg (https://invest.bnpparibas.com/en/share-ownership).

own a share σ of their own resident banks, and a share $(1-\sigma)$ of the foreign banks. The welfare function of country j then changes to $W_j = \alpha\,[\sigma\Pi_j + (1-\sigma)\Pi_i] + \beta T_j + \gamma S/2$. Differentiation with respect to k_i yields

$$\frac{\partial W_j}{\partial k_i} = \alpha\sigma\,\frac{\partial \Pi_j}{\partial k_i} + \alpha(1-\sigma)\,\frac{\partial \Pi_i}{\partial k_i} + \beta\,\frac{\partial T_j}{\partial k_i} + \frac{\gamma}{2}\frac{\partial S}{\partial k_i}\,. \tag{33}$$

In comparison to the previous section [eq. (30)], two changes occur in the analysis of dW_j/dk_i. First, the positive effect of k_i on the profits of the banking sector in country j, Π_j, is now weighed with a factor $\sigma < 1$ and is thus diminished. Secondly, through their partial ownership of banks in country i, residents of country j are now also affected by changes in the banking sector profits of country i. The effect of an increase in k_i on aggregate profits in the banking sector of country i is ambiguous, in general, due to counteracting effects of the reduction in the aggregate loan volume and the concentration of loans among the more profitable banks [see eq. (23)]. When the equilibrium capital standard is not too strict, however, so that $\hat{q}_i$ is moderate, then the positive first term in (23) is small and aggregate profits will fall due to the reduced overall loan volume (since $\kappa < 0$ holds in the Nash equilibrium). In this case an increase in k_i leads to an additional negative externality for the residents of country j and the externalities on the foreign country added by foreign ownership of banks are then unambiguously negative.[31] Under the conditions of Proposition 4, which imply that non-cooperatively set capital standards are above their globally efficient levels even in the absence of foreign ownership, we can then summarize:

Proposition 5 *When governments weigh the surplus of banks and consumers equally ($\alpha = \gamma$) and aggregate bank profits in country i fall after an increase in k_i [$\partial\Pi_i/\partial k_i < 0$ in (23)] then foreign bank ownership magnifies the negative net externality of capital standards on the foreign country and intensifies the 'race to the top'.*

5.3 Asymmetries between countries

As a second extension of our model, we introduce two different types of asymmetries between the two countries. We first assume that country 1 places a higher welfare weight (β) on tax revenues than does country 2. This could arise, for example, because

[31]This negative externality caused by foreign ownership of firms is well known from the tax competition literature as a 'tax-the-foreigner effect'. See Huizinga and Nielsen (1997) for a theoretical derivation of this effect and Huizinga and Nicodème (2006) for an empirical quantification.

Table 1: Numerical results for asymmetric countries

	k_1	k_2	$\hat{q}_1$	$\hat{q}_2$	L_1	L_2	Π_1	Π_2	T_1	T_2
A. Different welfare weights of tax revenue (β_i)										
$\beta_1 = 1.0$	0.335	0.335	0.306	0.306	2.110	2.110	1.068	1.068	–0.325	–0.325
$\beta_1 = 1.5$	0.437	0.336	0.362	0.303	1.971	2.158	1.014	1.113	–0.236	–0.333
$\beta_1 = 2.0$	0.531	0.337	0.406	0.300	1.847	2.207	0.957	1.159	–0.172	–0.342
B. Different costs of equity (ρ_i)										
$\rho_1 = 2.00$	0.335	0.335	0.306	0.306	2.110	2.110	1.068	1.068	–0.325	–0.325
$\rho_1 = 1.75$	0.439	0.334	0.330	0.306	2.094	2.106	1.090	1.065	–0.262	–0.324
$\rho_1 = 1.50$	0.627	0.334	0.365	0.306	2.072	2.101	1.128	1.061	–0.164	–0.324

Note: Parameter values held constant: $A = 10$, $\alpha = \gamma = 1.0$, $\beta_2 = 1.0$, $\rho_2 = 2.0$.

country 1 has a larger size of its banking sector, relative to GDP, and is therefore more concerned about the risks to its public finances as a result of failing banks. Our model is too complicated to be solved analytically, however, when there are asymmetries between countries. We therefore use numerical solution methods and summarize our results in part A of Table 1.

Table 1A. shows the intuitive result that country 1, which has the higher valuation of tax revenues, will have the higher capital standard in the non-cooperative equilibrium. As a consequence, the cutoff quality level of banks, $\hat{q}$, is higher in country 1 than in country 2 [cf. eq. (5)]. The aggregate loan volume and aggregate profits fall in country 1, as the higher cost of capital dominates the increase in the loan rate. However, expected losses to taxpayers fall sharply due to both the lower loan supply and the lower risk exposure of taxpayers in country 1. The reduction in the aggregate loan supply of banks in country 1 raises the loan rate in country 2 and draws some additional banks in this country into the market ($\hat{q}_2$ falls). Accordingly, the total loan volume and aggregate bank profits rise in country 2. Finally, the higher loan volume and the lower average quality of resident banks imply higher expected losses to taxpayers in country 2.

A second asymmetry is to introduce different costs of equity, ρ_i, in the two countries. This can arise, for example, when the quality of the regulatory framework differs across countries and investors in better regulated countries demand lower risk premia. Another possible reason for different costs of equity are country-specific dividend taxes. Investors in the country with the higher dividend tax would then demand a higher (gross) return on their equity, ρ_i. The results for the case where country 1 has the lower cost of equity are shown in part B of Table 1. A lower cost of equity makes it less costly for the government of country 1 to raise its capital standard, and k_1 will accordingly rise in the non-cooperative policy equilibrium. Hence, in our setting the better regulated country – as measured by a lower level of ρ_i – will also have the higher capital standard, contrary to the result of Morrison and White (2009).

The higher capital requirement drives some banks in country 1 to exit the market, despite the reduction in their cost of equity. With respect to the aggregate loan supply and aggregate profits in country 1, the effects of higher capital standards and lower costs of equity are mutually offsetting. As a result, the equilibrium changes in these variables are small. Taxpayer losses are clearly reduced in equilibrium, however, due to the higher equity ratio and the resulting reduction in the risk exposure of taxpayers. Finally, the repercussions of changes in country 1's cost of equity on country 2 are seen to be small, due to the small changes in the aggregate loan volume of country 1.

5.4 Quality signalling by banks

Finally, we extend our basic model by assuming that banks are able to (imperfectly) signal their quality.[32] In particular, high-quality banks are willing to hold costly equity above the minimum standard, in order to signal their high quality to borrowers. This signal will lead entrepreneurs to pay a higher loan rate to banks that hold a higher amount of equity than is mandated by the capital requirement of the bank's country of residence. Given the complexity of bank balance sheets and the potential costs of screening, it seems hard to imagine, however, that even the smallest differences in the capital holding of banks can be observed and understood by the producing firms. Therefore, and to keep the model tractable, we confine our analysis in this section to the case where banks can choose one specific, 'high' level of equity $k_i^h \equiv k_i + \tilde{k}_i$, which exceeds the minimum capital requirement k_i by the amount $\tilde{k}_i$.[33]

[32] We thank Alan Morrison and Klaus Schmidt for their helpful suggestions on the modelling strategy in this extension.

[33] Bank capital holdings in excess of regulated standards are also analyzed by Allen et al. (2011). In their setting, voluntary capital holdings of banks signal their commitment to monitor loans, rather than signalling a high quality type as in our analysis. Moreover, in Allen et al. (2011) capital requirements are chosen either by the regulator or by the bank itself, and the resulting capital holdings are then compared. In our model, the regulator sets instead a minimum capital requirement, and banks choose whether to voluntarily exceed this standard, or not.

The isolated effect of changing the funding structure towards more equity is obtained by differentiating the banks' optimized profits in eq. (4) with respect to $\tilde{k}_i$. This gives

$$\frac{\partial \pi_i^*(q)}{\partial \tilde{k}_i} = \frac{q\phi - \tilde{k}_i \rho}{b} (q - \rho) < 0 \; . \tag{34}$$

Holding more equity unambiguously reduces the profits of all banks, because equity is (weakly) more expensive for banks than savings deposits are, and because the share of bank funds that is covered by deposit insurance declines. Importantly, however, eq. (34) shows that the cost of raising equity above the minimum standard is higher for low quality banks, because these banks benefit most from the existence of the deposit insurance system. This implies that holding equity above the required level is indeed a signal of quality, as such a signal can only be profitable for high quality banks.

Indexing the banks' quality pools by $p \in \{h, l\}$, all banks that choose to hold the high equity level k_i^h will then be identified (by producing firms) as being in the high quality pool ($p = h$), whereas all banks that hold only the minimum amount of equity k_i are classified as belonging to the low quality pool ($p = l$). The quality of the bank that is indifferent between belonging to the high quality pool and the low quality pool is denoted by $\tilde{q}$. From eqs. (3)–(4), this critical quality level is determined by the condition that the additional loan revenue from opting into the high quality pool must equal the additional financing costs:

$$\tilde{q}_i \left(R_i^h - R_i^l \right) = (k_i^h - k_i)(\rho - \tilde{q}_i) \; , \tag{35}$$

where

$$R_i^h - R_i^l = c \left[\frac{1}{q^{el}} - \frac{1}{q^{eh}} \right] \tag{36}$$

gives the difference in loan rates paid by entrepreneurs to banks of the different quality pools h and l in the same country i. The expected probabilities of a successful loan in the high quality and in the low quality banking pool, q^{eh} and q^{el}, can be calculated as the weighted average of the number of loans issued by the lowest quality bank and the highest quality bank within each pool:[34]

$$q_i^{eh} = \frac{(2 + \tilde{q})l_1 + (2\tilde{q} + 1)l_{\tilde{q}}}{3(l_1 + l_{\tilde{q}})} \; , \qquad q_i^{el} = \frac{2\tilde{q} + \hat{q}}{3}. \tag{37}$$

Again, the mechanisms of this extended model are best described by means of numerical analyses. An important property of the extended model is that the switching of banks

[34]To arrive at eq. (37), we substitute eq. (2) in $q^{ep} = \frac{Y^p}{L^p} = \int_{\underline{q}^p}^{\bar{q}^p} q l(q) dq / \int_{\underline{q}^p}^{\bar{q}^p} l(q) dq$, solve the integrals, and set the pool-specific lower bounds at $\underline{q}^l = \hat{q}$, $\underline{q}^h = \tilde{q}$ and upper bounds at $\bar{q}^l = \tilde{q}$, $\bar{q}^h = 1$.

Table 2: Numerical results for quality signalling by banks

	$\hat{q}_i$	$\tilde{q}_i$	$R_i^h - R_i^l$	y_i^l	y_i^h	y_i	Π_i	T_i	W_i
				A. low fixed cost of firms ($c = 0.50$)					
$k_i = 0.00$	0.000	0.961	0.270	1.814	0.230	2.044	6.270	-1.018	9.330
$k_i = 0.10$	0.020	0.922	0.285	1.578	0.446	2.023	6.144	-0.868	9.283
$k_i = 0.14$	0.028	0.901	0.294	1.464	0.551	2.015	6.092	-0.807	9.262
				B. high fixed cost of firms ($c = 0.75$)					
$k_i = 0.00$	0.000	0.633	0.879	0.456	1.451	1.908	5.467	-0.655	8.386
$k_i = 0.10$	0.033	0.299	2.544	0.029	1.818	1.847	5.180	-0.163	8.411
$k_i = 0.14$	0.052	0.248	3.063	0.012	1.830	1.841	5.165	-0.115	8.430

Note: Parameter values held constant: A=10, $\rho = 1.25$, $\alpha = \gamma$ =1.0, β =1.1, k_i^h =0.9.

from one quality pool to the other causes discontinuities in the welfare function when k_i is gradually increased. This makes the analysis of Nash equilibria difficult even for a numerical analysis. We therefore analyze exogenous and coordinated changes in k_i that will maintain symmetry between the two countries. Our simulation results highlight how the fixed cost parameter of firms, c, which gives rise to a *selection effect*, interacts with the bank's self-selection into a certain pool quality $p \in \{h, l\}$. We differentiate case A, where the fixed cost parameter is relatively low ($c = 0.50$), and case B, where it is relatively high ($c = 0.75$). The results of the numerical analyses are summarized in Table 2. The analytical expressions for output levels, aggregate bank profits and (negative) tax revenues in this two-tier model are given in Appendix A.5.

In case A, the fixed cost of firms is low, implying from (36) that the difference in loan rates $R_i^h - R_i^l$ is small in equilibrium. Eq. (35) then implies a relatively large value of $\tilde{q}_i$ for any given extra cost of signalling $(k_i^h - k_i)(\rho - \tilde{q})$. Hence in this case a relatively large share of banks remains in the low quality pool. Coordinated increases in the minimum capital ratio k_i raise $\hat{q}_i$ above zero, implying that the weakest banks in each country exit the market. A coordinated increase in k_i also reduces the *extra* cost of signalling the high quality level k_i^h [the right-hand side of (35)], and thus tends to reduce the quality level of the cutoff bank $\tilde{q}_i$ [on the left-hand side of (35)]. With a low cost parameter c, this effect is moderate, however, and the equilibrium change in $\tilde{q}_i$ is therefore also moderate. As a result, bank profits, total output and expected losses to taxpayers will all be moderately reduced by a coordinated increase in k_i. When losses to taxpayers are valued only slightly more than bank profits and consumer surplus ($\alpha = \gamma = 1.0$;

$\beta = 1.1$), the net effect on welfare will be negative in both countries. Hence in this case the optimal coordinated capital requirement would be zero.

In case B, the fixed cost of firms c is high and so is the added loan revenue in the high quality pool, $R_i^h - R_i^l$. Since the extra financing costs of being in the high quality pool are the same as in case A, eq. (35) implies that the quality of the cutoff bank $\tilde{q}_i$ is now lower. Hence most loans are now provided by banks in the high quality pool. A higher minimum capital requirement k_i again reduces the extra costs of signalling to enter the high quality pool. Since the benefits of being in the high quality pool ($R_i^h - R_i^l$) are larger, the cutoff quality $\tilde{q}_i$ falls more strongly in equilibrium than in case A, implying that capital requirements reduce the expected losses to taxpayers more effectively. A welfare function giving a slightly higher weight to taxpayers ($\beta = 1.1$) than to bank profits and consumer surplus ($\alpha = \gamma = 1.0$) is then sufficient for a positive overall welfare effect of capital requirements. Hence, in this case the optimal coordinated capital requirement eliminates all lending by banks in the low quality pool ($k_i \approx 0.14$).

To summarize, introducing quality signalling by banks implies that changes in capital requirements k_i affect the selection of heterogeneous banks in two different ways. First, as in the benchmark model, an increase in the minimum capital ratio raises the critical quality for market entry, $\hat{q}_i$, leading the weakest banks to exit the market. A second and new effect is that a higher minimum capital requirement also changes the cutoff quality $\tilde{q}_i$ above which banks self-select into the high quality pool. By increasing the financing costs in the low quality pool, a higher capital requirement makes it attractive for a larger set of banks to opt into the high quality pool. Therefore, the imposition of minimum capital requirements has an additional, positive effect on banking sector stability, and hence taxpayers, when quality signalling by individual banks occurs. This effect is the stronger, in equilibrium, the higher is the valuation of quality by producing firms, as measured by their fixed production cost c.

6 Conclusions

This paper has studied international competition in capital standards in a symmetric two-country model where banks differ exogenously in the quality of their monitoring, and hence in the likelihood that their loans will succeed. In this setting national capital standards act as a positive signal for the pool quality of banks in the regulating country, and imply higher financing costs but also higher loan rates for the resident banks in equilibrium. In the Nash equilibrium, the higher cost of capital must dominate, implying that each country's capital standards impose a positive externality on the foreign country's banking sector. At the same time, however, capital standards shift taxpayer risks from the more regulated to the less regulated country and they also reduce consumer surplus in the integrated market by lowering the overall availability of credit. These negative externalities on the foreign country will dominate when national governments weigh all components of national welfare equally, implying that the non-cooperative setting of capital standards leads to a 'race to the top'. This result is in direct contrast to the 'race to the bottom' on which the existing literature has focused.

Our model can thus explain why countries such as Switzerland or the United States, which are characterized by large banking sectors and accordingly a high risk exposure of national taxpayers, introduce capital adequacy rules that exceed internationally coordinated standards. At the same time, our model offers a motivation for why the European Union has insisted on a strict harmonization of capital standards among its member states at the levels agreed upon in the Basel III accord (which therefore act simultaneously as lower and upper bounds for national capital standards). The consumer surplus externality that arises from capital standards in our model provides an argument for why the setting of an upper bound on national capital standards is especially relevant in an integrated market like the European Union.

Our model can be extended in several ways. A first relevant extension is to introduce an endogenous monitoring decision of banks while maintaining heterogeneity in monitoring costs. In this setting capital standards would play a further role in reducing moral hazard in the banking sector, in addition to their roles of signalling the quality of the national banking sector and of protecting national taxpayers, on which the present analysis has focused. Another relevant extension would be to endogenize the degree to which governments provide insurance for savings deposits. Such a setting would also permit an analysis of how the introduction of a supranational deposit insurance scheme – as is currently being debated as the final pillar of the European banking union – interacts with the harmonization of capital adequacy standards. Finally, a testable implication of our model is the existence of a *selection effect* in real-world loan contracts. That is, do higher capital standards in the home country of a bank have a positive and significant effect on the lending rate that this bank can charge? We leave these and other issues for future work.

Appendix

A.1 Derivation of eqs. (15)–(18)

To analyze the effects of an increase in k_i on aggregate output and the cutoff qualities $\hat{q}_i$ in the two countries, we totally differentiate the equation system (10a)-(10c) to get

$$[A - y - 1 + k_i - 2\tilde{c}]\, d\hat{q}_i = \hat{q}_i dy + (\rho - \hat{q}_i) dk_i, \tag{A.1}$$

$$[A - y - 1 + k_j - 2\tilde{c}]\, d\hat{q}_j = \hat{q}_j dy, \tag{A.2}$$

$$dy = \frac{3(1-\hat{q}^3)c}{[3b + 2(1-\hat{q}^3)](2+\hat{q})^2}\,(d\hat{q}_i + d\hat{q}_j) - \frac{[3\rho(1-\hat{q}^2) - 2(1-\hat{q}^3)]}{6b + 4(1-\hat{q}^3)}\,(dk_i + dk_j), \tag{A.3}$$

where we have used the short-hand notations (3) and (21) from the main text, eq. (5) has been used to simplify terms, and (A.3) has used symmetry after differentiation.

This equation system can be simplified by substituting (A.3) into (A.1) and (A.2). This yields the two-equation system

$$\begin{aligned}\left\{(\hat{q}\tilde{c} + \phi)[6b + 4(1-\hat{q}^3)] - 2\hat{q}(1-\hat{q}^3)\tilde{c}\right\} dq_i &= 2\hat{q}\tilde{c}(1-\hat{q}^3)dq_j \\ + \left\{(\rho - \hat{q})[6b + 4(1-\hat{q}^3)] - [3\rho\hat{q}(1-\hat{q}^2) - 2\hat{q}(1-\hat{q}^3)]\right\} dk_i &\end{aligned} \tag{A.4}$$

$$\begin{aligned}&\left\{(\hat{q}\tilde{c} + \phi)[6b + 4(1-\hat{q}^3)] - 2\hat{q}(1-\hat{q}^3)\tilde{c}\right\} dq_j \\ &= 2\hat{q}\tilde{c}(1-\hat{q}^3)dq_i - \hat{q}[3\rho\hat{q}(1-\hat{q}^2) - 2\hat{q}(1-\hat{q}^3)]dk_i\end{aligned} \tag{A.5}$$

Solving the system (A.4) and (A.5) gives equations (15) and (16) in the main text. Substituting these results back into (A.3) yields

$$\frac{\partial y}{\partial k_i} = \frac{(1-\hat{q})\kappa}{2\phi\Omega}, \tag{A.6}$$

where κ and Ω are given in (22) and (20). Finally, differentiating (7) gives

$$dy_i = \frac{1}{6b}\left\{-2(1-\hat{q}_i^3)dy + 2(1-\hat{q}_i^3)\tilde{c}d\hat{q}_i - [3\rho(1-\hat{q}_i^2) - 2(1-\hat{q}_i^3)]dk_i\right\} \tag{A.7}$$

Substituting (15) and (16) along with (A.6) into (A.7) gives (17) and (18) in the main text.

A.2 Derivation of conditions (26a)–(26b)

From (23) and (25) and using (17), a positive effect of capital standards on bank profits and consumer surplus, evaluated at $k = 0$ initially, requires that $\kappa > 0$ in (22). Evaluating κ at $k = 0$ and noting that $\hat{q} = 0$ for $k = 0$ from (5), this condition is

$$\kappa|_{k=0} = \frac{3\rho c}{2} - (R_i - 1)(3\rho - 2) > 0. \tag{A.8}$$

The endogenous variable $(R_i - 1)$ can be substituted using (9) together with (6) and (7). This yields

$$R_i - 1|_{k=0} = \frac{3b}{(3b+2)} \left(A - \frac{3c}{2} - 1\right). \tag{A.9}$$

Substituting (A.9) in (A.8), a sufficient condition for $\kappa|_{k=0} > 0$ is

$$\frac{3}{2}\rho c - (3\rho - 2)\left[A - \frac{3c}{2} - 1\right] > 0.$$

Collecting the terms for c gives condition (26a) in the main text.

A positive effect on taxpayers will result when the positive first two effects in (24) dominate the third effect, which is negative for $\kappa > 0$. Substituting in from (15) and (17), evaluating at $k = \hat{q} = 0$ and using $y|_{k=0} = (R_i - 1)/3b$ from (6) and (7) gives

$$\left.\frac{\partial T_i}{\partial k_i}\right|_{k=0} = \frac{(R_i - 1)}{6b} + \frac{3\rho}{12b} - \frac{\kappa}{12b\phi} > 0.$$

Ignoring the positive first term and noting that $\phi|_{k=0} = (R_i - 1)|_{k=0}$ gives, as a sufficient condition

$$\left.\frac{\partial T_i}{\partial k_i}\right|_{k=0} > 0 \quad \Leftrightarrow \quad 3\rho(R_i - 1) - \kappa > 0. \tag{A.10}$$

Using (A.8) and (A.9) yields

$$\left.\frac{\partial T_i}{\partial k_i}\right|_{k=0} > 0 \quad \Leftrightarrow \quad \frac{12b(2A - 3c - 2)(3\rho - 1)}{(3b+2)} > \frac{3\rho c}{2}. \tag{A.11}$$

Noting that $(3\rho - 1) \geq 2\rho$ and collecting the terms involving c gives (26b) as a sufficient condition.

A.3 Derivation of equation (27)

Setting $\alpha = \beta = \gamma = 1$ in (11), evaluating the welfare components (23)–(25) at $k_i = 1$ and using (15)–(18) shows that $\partial W_i/\partial k_i|_{k=1} < 0$ iff $\Delta < 0$, where

$$\begin{aligned}\Delta \;\equiv\;& \frac{\theta\kappa}{(2+\hat{q})^2} + \frac{18by_i\hat{q}}{(1-\hat{q})^2(2+\hat{q})^3}\left[(\rho - \hat{q})\Theta + \rho(\phi + \tilde{c}\hat{q})(2+\hat{q})(1-\hat{q})^2\right] \\ +\;& \frac{(1-\hat{q})}{(2+\hat{q})}(\phi + \tilde{c}\hat{q})\Omega + \frac{(1-\hat{q})(\phi + \tilde{c}\hat{q})\kappa}{2},\end{aligned} \tag{A.12}$$

and Θ, Ω, $\tilde{c}$ and κ are given in (19)–(22).

We decompose $\rho-\hat{q} = (\rho-1)+(1-\hat{q})$, substitute $y_i = (2+\hat{q})(1-\hat{q})^2\phi/6b$ from (6) and (7) and replace Ω in the third term by $\Theta > \Omega$. Since this term is positive, negativity of the changed condition, labelled Δ^+, is sufficient for $\partial W_i/\partial k_i|_{k=1} < 0$. Collecting terms gives:

$$\begin{aligned}\Delta^+ &= \Theta\left\{\frac{(\rho-1)}{(2+\hat{q})}[\tilde{c}(1-\hat{q})-3\phi] + \frac{(1-\hat{q})}{(2+\hat{q})}\left[\tilde{c} - \frac{(1-\hat{q})\phi}{(2+\hat{q})} + \phi + \tilde{c}\hat{q}\right]\right\} \\ &+ (\phi+\tilde{c}\hat{q})(1-\hat{q})^2\left[\frac{\tilde{c}(2+\hat{q})}{2} - \frac{(2-\hat{q}+2\hat{q}^2)\phi}{2(2+\hat{q})}\right]\rho. \end{aligned} \tag{A.13}$$

We determine the conditions for negativity of the two terms in (A.13) separately. Substituting c for $\tilde{c}$ using (21), the condition for the first term (in the first line) to be negative is

$$\Delta^1 = 3c(1-\hat{q})(\rho+\hat{q}) - \phi(2+\hat{q})[3(\rho-1)(2+\hat{q}) - (1-\hat{q})(1+2\hat{q})] < 0.$$

Since this term is unambiguously falling in $\hat{q}$, we evaluate it at $\hat{q} = 0$. This ensures that negativity holds for all levels of $\hat{q}$. This leads to the condition

$$\phi > \frac{3\rho c}{2[6(\rho-1)-1]}. \tag{14a}$$

The condition for the second term in (A.13) to be negative is

$$\Delta^2 = 3c - (2-\hat{q}+2\hat{q}^2)\phi < 0.$$

This expression has an interior maximum at $\hat{q} = 0.25$. Evaluating at $\hat{q} = 0.25$ guarantees that the condition for negativity is sufficient for all levels of $\hat{q}$. This gives

$$\phi > \frac{3\rho c}{2[6(\rho-1)-1]}. \tag{14b}$$

In the final step, we note that $\phi_i = R_i$ holds at $k_i = 1$ from (3). Using (9) together with (6) and (7) gives an expression for R_i that is minimized for $\hat{q} = 0$. Evaluating at this level gives:

$$R_i^+ = \frac{3b}{3b+2}\left(A - \frac{3c}{2}\right). \tag{15}$$

This corresponds to R_i in (A.9), except that the term (-1) is missing on both sides of the equation, because ϕ is now evaluated at $k = 1$. Equating ϕ in (14a) and (14b) with R_i^+ in (15) gives the two conditions summarized in (27) in the main text. If both of these conditions hold, this is sufficient (but not necessary) for $\partial W_i/\partial k_i|_{k=1} < 0$.

A.4 Derivation of equation (30)

Using (12)–(14), we can write welfare in country j as

$$W_j = \frac{6\alpha b y_j^2}{(1-\hat{q}_j)(2+\hat{q}_j)^2} - \frac{\beta(1-k_j)(1-\hat{q}_j)y_j}{(2+\hat{q}_j)} + \frac{\gamma(y_i+y_j)^2}{4} \quad i \neq j.$$

Differentiating with respect to k_i gives, in a first step

$$\begin{aligned} \frac{\partial W_j}{\partial k_i} &= \frac{12\alpha b y_j}{(1-\hat{q})(2+\hat{q})^2}\frac{\partial y_i}{\partial k_i} + \frac{18\alpha b y_j^2 \hat{q}}{(1-\hat{q})^2(2+\hat{q})^3}\frac{\partial \hat{q}_j}{\partial k_i} \\ &- \frac{\beta(1-k_j)(1-\hat{q})}{(2+\hat{q})}\frac{\partial y_j}{\partial k_i} + \frac{3\beta(1-k_j)y_j}{(2+\hat{q})^2}\frac{\partial \hat{q}_j}{\partial k_i} + \frac{\gamma(y_i+y_j)}{2}\frac{\partial y}{\partial k_i}. \end{aligned} \tag{16}$$

Substituting in from (16)–(18), using $\phi_j = 6by_j/[(1-\hat{q})^2(2+\hat{q})]$ and collecting terms gives eq. (30) in the main text.

A.5 The extended model with signalling by banks

Total output with loans from banks in country i is composed of the output produced with bank loans from the low and the high quality pool, $y_i = y_i^l + y_i^h$. These are

$$\begin{aligned} y_i^l &= \int_{\hat{q}_i}^{\tilde{q}_i} \frac{q\phi_i^l - k_i\rho}{b} dq = \frac{\tilde{q}_i^3 - \hat{q}_i^3}{3b}\phi_i^l - \frac{\tilde{q}_i^2 - \hat{q}_i^2}{2b} k_i\rho, \\ y_i^h &= \int_{\tilde{q}_i}^{1} \frac{q\phi_i^h - k_i^h\rho}{b} dq = \frac{1-\tilde{q}_i^3}{3b}\phi_i^h - \frac{1-\tilde{q}_i^2}{2b} k_i^h\rho. \end{aligned} \tag{17}$$

Analogously, total bank profits in country i are composed of bank profits in the low and the high quality pool

$$\begin{aligned} \Pi_i = \Pi_i^l + \Pi_i^h &= \int_{\hat{q}_i}^{\tilde{q}_i} \frac{(q\phi_i^l - k_i\rho)}{2b} dq + \int_{\tilde{q}_i}^{1} \frac{(q\phi_i^h - k_i^h\rho)}{2b} dq \\ &= \frac{(\phi_i^h - k_i^h\rho)^3}{6b\phi_i^h} + \frac{(\tilde{q}_i\phi_i^h - k_i^h\rho)^3}{6b}\left(\frac{1}{\phi_i^l} - \frac{1}{\phi_i^h}\right), \end{aligned} \tag{18}$$

where, following integration, the second step has used (5) and (35).

Finally, expected losses to taxpayers can be calculated as

$$T_i = -\left[(1-k_i)(1-q_i^{el})\frac{y_i^l}{q_i^{el}} + (1-k_i^h)(1-q_i^{eh})\frac{y_i^h}{q_i^{eh}}\right], \tag{19}$$

where y_i^l and y_i^h are given in (17), q_i^{el} and q_i^{eh} are in (37), and loan levels in each quality pool $p \in \{h, l\}$ follow from output levels by $L_i^p = y_i^p/q_i^{ep}$.

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