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A cost-benefit analysis of capital requirements for the Danish economy

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Abstract
We analyse the costs and benefits of increasing capital requirements for Danish banks. Costs can be close to 0 if banks suspend dividend payments for a period of time as banks accumulate capital and if investors' required return falls. The latter implies that the Modigliani-Miller effect is close to 1 in the long run. Suspension of dividends mitigates costs in an economically significant way, no matter what is assumed about the Modigliani-Miller effect. The estimates are upper bounds primarily because the model implies an elasticity of 1 for cost of capital for both banks and firms. We show that financial crises have persistent effects on GDP. We find the present value of output losses to be around 84 percent. A reduction in the probability of a financial crisis from a 1 percentage point increase in capital ratios gives an expected benefit of 1 percent of GDP. Based on Danish data and using models for the Danish economy, we thus confirm findings in studies for other economies: The benefits outweigh the social costs of increasing capital ratios. In this sense, there is nothing special about the Danish economy. We argue that it is beneficial to raise capital requirements accompanied by a demand for suspension of dividends and to do so in expansion periods when banks' profits are relatively high. If the required return on equity does not fall in response to higher levels of capital, this outcome could imply, not that equity is more expensive than debt, but a lack of competition. This must be addressed with other instruments.

Resume
Vi analyserer fordele og omkostninger ved at øge kapitalkrav for danske banker. Omkostningerne kan være tæt på 0, hvis bankerne ikke udbetaler dividender i to år, og hvis det krævede afkast for at investere i banker falder i takt med, at ny kapital akkumuleres i bankerne. Den sidste antagelse indebærer, at Modigliani-Miller effekten er tæt på 1 på langt sigt. Hvis bankerne ikke udbetaler dividender, er omkostningerne betydeligt lavere for givne antagelser om Modigliani-Miller effekten. Estimaterne er en øvre grænse, primært fordi den anvendte model indebærer en elasticitet på 1 for højere omkostninger for både banker og virksomheder. Vi viser, at finansielle kriser har persistente effekter på BNP. Hvis vi antager moderate permanente effekter, finder vi, at nutidsværdien af tabene ved finansielle kriser er omkring 84 pct. af BNP. Et fald i sandsynligheden for en finansiel krise ved et højere kapitalkrav på 1 procentpoint giver en forventet fordel på 1 pct. af BNP. Vi bekræfter hermed, ved brug af data for Danmark og modeller udviklet til analyse af dansk økonomi, resultater fra andre studier for andre lande: Fordelene ved at øge kapitalkrav er større end omkostningerne. Vi argumenterer for, at det kan være fordelagtigt at kræve stop for dividendeudbetalinger i takt med højere kapitalkrav, og at øge kapitalkrav i konjunkturopgange. Hvis afkastkravet ikke falder i takt med, at bankerne bliver mere sikre, kan det afspejle svag konkurrence og ikke, at bankkapital er dyrere end gæld.

Key words
Financial Regulation; Models; Financial Markets; Financial Stability

JEL classification
C01; C10; C58; E32; E37; E44; C18

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A cost-benefit analysis of capital requirements for the Danish economy*

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Abstract

We analyse the cost and benefits of increasing capital requirements for Danish banks. Costs can be close to 0 if banks suspend dividend payments for a period of time as banks accumulate capital and if investors required return falls. The latter implies a Modigliani-Miller effect of one in the long run. Suspension of dividends mitigates costs in an economic significant way, no matter how large the Modigliani-Miller offset is. The estimates are upper bounds primarily because the model implies an elasticity of 1 for cost of capital for both banks and firms. We show that financial crisis have long-lasting effects on GDP. We find the present value of output losses to be around 84 per cent. A reduction in the probability of financial crisis from a 1 percentage point increase in capital ratios gives an expected benefit 1 per cent of GDP. Based on Danish data and using models for the Danish economy, we thus confirm findings in studies for other economies: The benefits outweigh the social costs of increasing capital ratios. We argue it is beneficial to raise capital requirements accompanied by a demand for suspension of dividends and to do so in expansion periods when banks' profits are relatively high.

JEL classification: C01, C10, C58, E32, E37, E44, G18

Keywords: Financial Regulation, Models, Financial Markets, Financial Stability

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1. Effects of capital requirements

This paper assesses the macroeconomic costs and benefits of increasing capital requirements for the Danish economy. Our motivation is the financial crisis in which Danish banks lost capital and some came close to the regulatory capital requirements, leading to a downward pressure on credit. This contributed to one of the worst recessions since the Great Depression.

Higher capital ratios could possibly have avoided that some banks got into great trouble; good capitalisation ensures that banks appropriately internalise the costs of their activities and risk taking. Higher bank capital also means better loss absorption. Capital requirements should thus reduce the risk of financial crisis and their costs, should they occur.

If capital is more expensive than debt financing, capital requirements involve a trade-off.[1] While higher levels of capital involve the abovementioned benefits, they may lead to higher funding costs pushing up lending rates, reducing aggregate demand and possibly potential growth.[2] However, the question is not whether higher capital requirements increase borrowing costs from the bank's perspective, which are private costs, but what the effects are for the aggregate economy, meaning the social costs – the costs for society as a whole.

With this in mind, the aim of this paper is to evaluate the costs and benefits of raising capital requirements in Denmark. We look for the net benefits of raising capital requirements by one percentage point permanently. Thus, this is not a study of the effects of a capital buffer, which can be increased in times of elevated systemic risk and released in time of crisis, but a study of the level of capital requirements to form the basis for setting the capital buffer if required. Whether to do so is to a large extent a political decision.

We follow similar studies in many respects, like Bengtsson et al. (2012) for Sweden, Brooke et al. (2015) for the UK, or Financial Stability Board and the Basel Committee on Banking Supervision (2010a), a study by the Basel Committee on Banking Supervision, among many others. The economic benefits are derived from a reduction in the probability of a financial crisis due to a better capitalised financial sector, making it more resilient to losses that can occur in periods of financial distress. By reducing the frequency of crises, some of the substantial output losses associated with financial crises can be avoided. The economic benefits are measured as the expected reduction in output loss due to fewer financial crises. The economic costs are calculated using a structural DSGE model for the Danish economy. The costs are related to possibly higher lending rates in response to higher capital requirements. This can dampen aggregate demand.

[1] See e.g. the discussion in Admati and Hellwig (2014).

[2] Empirical research, Cline (2015) or Martynova (2015), suggests that banks' lending rates do increase if banks are forced to hold more capital, but the effect is modest, around 16 basis points on average for each 1 per cent increase in capital requirements.

The results in this paper point to a positive net benefit of increasing capital ratios for Danish banks. Specifically, if investors in Danish banks reduce their required return partly, but not necessarily fully, when capital is accumulated, i.e. if there are only small Modigliani-Miller effects, the benefits of increasing capital requirements for Danish banks will be greater than the costs. Higher capital requirements are therefore considered to be economically beneficial. We thus confirm findings from similar studies for other economies, the difference being that we are using data for Denmark and a model built to study the Danish economy estimated on Danish data. With regard to financial regulation, Denmark does not seem to be different.

We also point to the following insights and findings, which we believe are somewhat new compared with similar studies. Firstly, we use an estimated structural model with a micro founded banking sector. This allows us to study in detail how the banks react to changes in regulation and also how they react under different assumptions regarding, for example, dividend payments. In fact, one important finding is that suspension of dividends is key to mitigating short-run costs. We also address timing. In our empirical study we confirm findings of other studies: The probability of a financial crisis is higher, the higher the growth in credit and real house prices. And, as can be expected, it is easier for banks to increase capital ratios in an expansion, when profits are relatively high, than in a recession, when profits are low. Hence, the benefits of raising capital requirements are higher in expansions than in recessions; timing matters. We finally point to the role of competition, its interaction with shareholders' required return on investment in banks, and the effect of capital requirements. In the model used in this study, higher capital is initially accumulated through higher lending margins, a lower level of lending and higher retained earnings. If the required return on equity is kept constant, lending margins are higher relatively to the situation before. But this means that a bank with a slightly lower required return on capital could lower its lending margins or fees slightly and capture market shares. Hence, we find that a low cost of entry to provide financial services in Denmark and high competition are key to the effect of higher capital requirements.

The question of whether it is in fact costly to raise capital in the long run can be answered theoretically by the Modigliani-Miller theorem, see Modigliani and Miller (1958) and Modigliani and Miller (1963). The theorem states that the value of a firm, including a bank, is independent of its funding structure subject to some important assumptions. Intuitively, if the MM theorem does not hold – if equity is more costly than debt – banks will raise lending rates and/or fees in response to higher capital requirements, and if they are able to pass on higher funding costs to borrowers, the economy will be negatively affected. On the other hand, as bank capital is increased, banks are perceived as safer, implying lower funding costs and hence cost of capital for them. However, in the short run banks are likely to increase retained earnings through higher margins, so even in the case where equity is more costly than debt, there can be short-run effects of raising capital requirements. The aim of this study is to measure these costs in terms of GDP.

Our aim is to assess the costs for the real economy of 1 percentage point permanently higher capital requirements for banks in Denmark. We will quantify both the long-run costs, defined as the effect on GDP after 10 years, the short-run costs, defined as the effect on GDP during the first 1-3 years, and the transition costs, the present value of the difference between GDP with and without higher capital requirements.

We use a structural dynamic macroeconomic model with forward-looking agents presented in Pedersen (2016). This model has both financial frictions and banks with endogenous bank profitability. The model provides a unified framework to analyse how changes in capital affect banking and financial markets, and, through general equilibrium, the rest of the economy. Hence, changes in regulation not only affect the banking sector, but also directly feeds back to the economy and output through interest rate spreads and lending. Importantly, the model includes instruments for the banks to meet the extra capital requirements, such as suspension of dividends, and the structure of the economy.

We only consider non-risk-weighted capital ratios, or leverage ratios. This is due to the lack of good data for risk-weighted capital ratios for the estimation of the econometric models used to analyse benefits of higher capital requirements, and on the modelling side, due to the lack of a meaningful role for risk weights. That is, the model could include weighted assets and we could set these weights as we see fit. But these weights would not in any meaningful way reflect risk as the model does not include defaults. However, it does imply that banks cannot change the composition of their portfolio of assets in response to higher capital requirements, e.g. shifting credit from relatively risky to safer lending. The absence of defaults in the model explains why we do not use the structural model to perform, for example, a full structural welfare analysis of capital requirements; if nobody in the model defaults, the welfare analysis would not capture the benefits of higher capital ratios. As we will explain later, we will instead rely on econometric models to estimate the benefits of higher capital requirements.

Our estimates of the costs of increasing capital requirements, using our structural model, must be considered as being upper bounds for the following reasons. For simplicity, in the model the only way to raise capital for banks is to alter the asset side of the balance sheet by raising lending rates and/or increasing retained earnings; it is not possible to raise capital in the market. While this might seem like a strong assumption at the outset, as shown by Cohen (2013), retained earnings accounted for the bulk of the increase in risk-weighted capital ratios over the period 2009-12. Also, according to the *pecking order theory* for capital structure, a bank uses equity financing last. That is, firms are said to prefer retained earnings as their main sources of funds. Next in order of preference is debt, and external equity financing comes last, see Myers (1984). Further, even though the model is a small-open-economy model, there are no external funding markets for banks. Hence, banks fund themselves through domestic savings only. It follows indirectly from the previously mentioned aspects of the model that any changes in cost of funding for banks can be passed on one-to-one to firms and households. This implies a double failure of the MM-theorem: Firstly, the banks' shareholders do not adjust their required return on equity and the costs of capital increase, and, secondly, firms absorb the extra funding costs. According to the MM theorem, if debt financing has become more expensive, firms should use more equity financing and hence undo the higher costs-of-capital.

However, outside the model banks can raise equity on both foreign and domestic capital markets, while borrowers can bypass higher lending rates and fund projects using their own funds or through capital markets. As a stylised example, if a benevolent foreign investor would provide bank capital to Danish banks and demand the same or a lower return on equity, the effects on the real economy of increasing capital requirements would be zero. Finally, in the model financial entrepreneurs cannot enter the market for financial services and e.g through competition capture market shares and depress interest margins.

We find it important to bear these caveats in mind important when discussing the results of our analysis. They both point to the uncertainty surrounding the estimates and to this uncertainty going one direction only; the estimates for costs are likely to be upper bounds. The analysis shows that the cost of increasing capital requirements for Danish banks can be close to 0 under two conditions. Firstly, banks suspend dividend payments during the 2 years after the announcement of the policy change, and secondly, investors required return falls as capital buffers are built up. The latter implies an MM effect of one meaning that, in the long run, the Modigliani-Miller theorem holds. If we relax the first assumption, the costs increase to around 0.8 per cent of GDP, while if we relax the second assumption, the costs are close to 1 per cent of GDP. Key to the long run effects is thus to which extent the Modigliani-Miller theorem holds.[3]

Our starting point is that in the very long run the MM effect is close to one. One argument for this is that if the MM effect is far from being one, and banks keep lending margins and/or fees elevated after the new level of capital has been reached to sustain a constant ratio of profits above bank capital, a financial entrepreneur could access the market, demand a slightly lower return on equity and lower lending margins, and thus capture a larger share of the market.

We also address front-loading. Experience has shown, that when new regulation is imposed, financial institutions tend to front-load accumulation of bank capital even though they are given a relatively long implementation horizon. We show that front-loading the accumulation of bank capital increases the short-run costs while leaving the transition costs unchanged.

To assess the benefits of higher capital ratios, we follow a widely used approach used by e.g. Brooke et al. (2015), Schanz et al. (2011), and Basel Committee on Banking Supervision

[3]We notice that dividend payments are exogenously given in the model; the decision about dividend payments is not an equilibrium outcome of the model.

(2010). The benefits of higher capital ratios are derived from a lower probability of financial crises and output losses in the event of a crisis. This approach seeks to assess the risks associated with various levels of capital and credit growth in the financial sector, which are absent in the DSGE model. Our approach to measuring benefits has also been set out in a broader conceptual framework by the IMF for assessing the net benefits of macro-prudential policy measures, cf. Arregui et al. (2013). We use a multi-country dataset for the analysis covering a period of over 30 years (1980-2013), as there are too few crisis episodes in Denmark for an empirical analysis. Even though the characteristics of individual economies differ, panel data techniques are still useful to evaluate the impact of capital ratios on the probability of a financial crisis, and the output loss in the event of a crisis. Using empirical evidence from a large number of financial crises is likely to be more indicative of the output loss from any future financial crisis than e.g. a study of a financial crisis in Denmark, as financial crises tend to vary in length, depth and causes.

We use a multi-country logit model to estimate the probability of a financial crisis and the reduction in risk from higher capital ratios. We thus consider the risk of a system-wide crisis in the economy, and not the risk of default of individual banks, as the relevant event for this analysis. As in the analysis of the costs of raising capital ratios, we use non-risk-weighted capital ratios for the probability model. For Denmark, we estimate an average probability of a financial crisis to be 6.3 per cent for the period of 1982-2013. The period comprises large variations in the level of risk. For 2008, we estimate the probability of a financial crisis to be as high as 31 per cent, whereas in the early 1990s it is under 2 per cent. An increase in capital ratios of 1 percentage point leads to an average reduction in the probability of a crisis of 1.2 percentage points. Further increases in capital ratios lead to gradually declining risk reductions, and at some level the benefits from higher capital ratios will be less than the costs of increasing capital requirements. The reduction in the probability of financial crises from raising capital ratios is dependent on the level of capital ratios, and furthermore on the level of other risk factors included in the model, i.e. growth in credit relative to GDP and growth in house prices relative to GDP. Curtailing high growth rates in credit and house prices crises are also found to reduce the risk of future financial crises.

To estimate the output loss associated with a financial crisis, we use the local projection method of Jordà (2005). Using panel data techniques, we measure the loss in output relative to its pre-crisis trend growth path. We find that financial recessions carry large output losses and that the impact on GDP is significant even 6 years after the onset of a crisis. Our results indicate that the impact of a financial crisis is very persistent. Depending on the persistency of the effects of a financial recession, output losses fall by around 84 per cent of GDP. The benefit of a 1 percentage point increase in the capital ratio is thus expected to reduce the output loss from future financial crises by about 1 per cent of GDP.

The rest of this paper is arranged as follows. We start by reviewing the literature in section (2), emphasising previous findings and where we deviate from the existing methodologies. Section (3) analyses the benefits of increasing capital requirements. We estimate probabilities of financial crises in section (3.1), present our data in section (3.2), and discuss our findings from this model in section (3.3). The effect on output of financial crises is analysed in section (3.4)-(3.5). We present our total estimate of the benefits of capital requirements in section (3.6).

Section (4) is devoted to the analysis of the costs of increasing capital requirements. We discuss the Modigliani-Miller theorem in section (4.1), which helps to understand the long run effects of changes in capital requirements. Section (4.2) discusses the choice of model we use with an emphasis on how capital requirements propagate within that model, while section (4.3) presents the scenarios and the quantitative effects. Section (4.4) discusses our findings with regard to costs. We conclude in section (5).

2. Literature review

Since the beginning of the financial crisis there has been an increased interest in the study of output costs of financial crises on one hand and the effects of capital requirements on the other hand. We will in this section review the main findings in the literature. The common finding is that financial crises are costlier and longer-lasting than regular recessions, while there are short run costs of increasing capital requirements for banks; the long run effects are to a large extent determined by what is assumed about the cost of capital in response to higher capital ratios. That is, how large the Modigliani-Miller effect is. That is, if a bank increases the percentage of equity and if equity is a more expensive form of funding than debt, then an increase in the banks cost of capital can be expected. But more equity means a larger buffer against losses, and hence the bank becomes less risky, and therefore the cost of debt and equity decreases for the bank. The latter effect is what we refer to as the Modigliani-Miller effect.

With regards to the benefit of capital requirements, Romer and Romer (2015) estimate the impulse response of GDP of an advanced economy to periods of financial distress using local projection methods of Jordà (2005). They find an immediate response of GDP of 2 per cent and a peak decline of 6 per cent three years after the beginning of a period of financial distress. The decline in GDP remains large: GDP is depressed by 4.3 pct 5 years after the beginning of the financial crisis. Their results are somewhat sensitive to the choice of sample period and the countries included in their study. They consider a continuous measure of financial distress, relying on qualitative as well as quantitative evidence of financial distress.

Brooke et al. (2015) use a similar methodology and estimate a peak loss of over 4 per cent of GDP four years after the onset of a crisis. Assuming moderate permanent effects on output they find the net present costs of a financial crisis to be 43 per cent of GDP. Krishnamurthy and Muir (2016) estimate the output contraction to be 8.2 per cent in 5 years of cumulative GDP growth. Laeven and Valencia (2012) calculate the output costs as the difference between actual GDP and its pre-crisis trend 0-4 years after the beginning of a financial crisis. The median cost for an advanced economy is 33 per cent, and the result for Denmark is 36 per cent of GDP. In a regime-switching model, Hollo et al. (2012) study the reaction of output growth in times of high financial stress versus periods of low financial stress, and find large negative impulse responses in high stress regimes.

Using results from several studies in the literature, the Basel Committee on Banking Supervision (2010) finds a median cost of 19 per cent of GDP in studies assuming no permanent effect on output, and a median cost of 158 per cent assuming permanent effects on output. The associated benefit from a lower probability of crises due to higher capital requirements are 0.20 per cent and 1.56 per cent of GDP per year, respectively.

In a series of papers, Jordà et al. (2013), Jordà et al. (2017) and Taylor (2015) find that financial crisis recessions are far more costly than regular recessions, and tend to be followed by slower recoveries. Furthermore, they find that credit build-up is an early warning signal of rising financial risks, and that recoveries from financial crisis recessions are much quicker in countries with higher pre-crisis capital ratios.

Capital ratios have been found to be a predictor of rising financial risks. Most studies use data from a large range of countries and crisis periods, and also differ with respect to additional predictors included to estimate the probability of financial crises. Barrell et al. (2009) use a multi-country logit model and find that a 1 percentage point higher capital ratio could significantly have reduced the probability of a crisis in 2007/2008. For the UK they find a 6 percentage point reduction in the crisis probability in 2007. Other significant predictors include house price growth and the liquidity ratio. They note that a 1 percentage point increase in capital ratios is twice as effective as an equivalent increase in liquidity ratios. Barrell et al. (2010) find similar results in a model that additionally includes current-account balances as a predictor. Brooke et al. (2015) also find that higher capital ratios reduce the risk of a financial crisis, and additionally use growth in credit to GDP and deposits to total liabilities as predictors. Costa Navajas and Thegeya (2013) also find that the capital ratio is a significant predictor among a large number of financial and macroeconomic variables.

With regards to the costs of increasing capital requirements for banks, the Financial Stability Board and the Basel Committee on Banking Supervision (2010b) find that the maximum decline in the level of GDP to be 0.19 per cent from the baseline path occurring four and a half years after the start of implementation. This is equivalent to a reduction in the annual growth rate of 0.04 percentage points of the period. The costs stem from higher lending margins depressing demand. Slovik and Cournède (Slovik and Cournède) find a very similar result. Here the authors use a bank balance sheet identity and assume a constant return on equity (ROE) and derive how much lending spreads must increase in response to the new regulation. This lending spread is next run through a traditional macroeconometric model at the OECD. The same methodology is used by Jensen (2015) for Denmark, who finds a short run negative impact on GDP of around 0.15 per cent and a long run impact of 0.005 per cent.[4]

The Financial Stability Board and the Basel Committee on Banking Supervision (2010a) consider the impact on GDP of a 1 percentage point increase in capital ratios implemented over a 32 quarter period using 89 different models. They find that the median path of GDP falls steadily relative to its baseline path reaching 0.15 per cent below baseline before recovering. This maximum is reached at quarter 35 and thus after the new capital ratio has been hit. GDP recovers to 0.10 per cent below baseline after 12 years. The results point to a 3 basis point lower growth in GDP during the period of implementation on an annual basis. They also find that the effect on GDP depends on the implementation horizon. The mechanisms at play are wider spreads and reductions in lending.

Angelini et al. (2015) find that each percentage point increase in the capital ratio translates into a 0.09 per cent loss in the level of steady state output relative to the baseline. This is the median across the point estimates of the available models.

Schanz et al. (2011) assume that higher capital requirements increase banks' funding costs, which lead to a fall in investment and the stock of capital thereby reducing the long-run level of GDP. Likewise, Copenhagen Economics (2016) analyse a model in which the higher capital ratio is reached through increases in lending spread and where the return on equity and debt are unchanged when the capital requirements increase.

Within the models used in the studies mentioned above, some models do not have bank capital and/or endogenous bank profitability. In these models it is assumed that capital regulation affects economic activity through an increase in the cost of bank intermediation, and this outcome is *assumed* to be an increase in lending spreads. This implicitly assumes that the banks' ROE remains constant in the long term. But if bank profitability is allowed to fall, the estimated increase in the spread must be lower, and so is the impact on economic activity. The studies in Jensen (2015), Slovik and Cournède (Slovik and Cournède), and Copenhagen Economics (2016) make an adjustment for these MM-effects. That is, if the model at hand, or the methodology used, does not allow an endogenous response within the banking sector to the increase in the capital requirement, then the modelers make that adjustment.

Roger and Vlček (2011) are the ones that come closest to our study as they are applying a model, in which bank profitability is endogenous. As discussed above, the models used in the majority of the studies neither have a banking sector nor do they have an endogenous

[4]The author finds a combined impact of respectively 0.29 per cent for the short run and 0.09 per cent for the long run, in which around half can be attributed to higher capital requirements and half to liquidity requirements.

response to the capital requirement. It is implicitly assumed that funding costs rise, which is then passed on to firms and households. While the authors find estimates comparable to i.e. the Financial Stability Board and the Basel Committee on Banking Supervision (2010b), they are also able to show how the effects vary with the banks' choice of instrument to achieve the higher capital ratio. As an example, if the banks lower their required ROE and their dividend payments, the effects on real activity are markedly lower. Cohen (2013) in fact finds that banks met the bulk of the changes in capital requirements through retained earnings and not only through higher lending spreads. We will have more to add to this in the sections to come.

3. The economic benefits of higher capital requirements

In this section, we estimate the economic benefits of higher capital requirements. Our strategy for calculating the economic benefits is structured as follows. The benefits are derived from a lower risk of future financial crises: A better capitalized banking sector makes it more resilient to losses that can materialize in periods of financial distress and reduces the risk that distress in the financial sector results in a recession. This reduction in expected output loss constitutes the economic benefits of higher capital requirements.

We thus need to estimate the probability of a systemic financial crisis and the output loss when a financial crisis has hit the economy. We estimate the probability of a systemic financial crisis in section (3.1)-(3.3). Here we also analyse the effects of higher capital ratios on the risk of a financial crisis. In section (3.4) we estimate the output loss of a financial crisis. The estimated benefit of higher capital requirements is calculated in section (3.6). Afterwards, we analyse the costs, also in terms of output, of increasing capital requirements for banks.

Our main findings can be summarized as follows. Under the assumption that financial crisis have persistent effects on output, we find substantial benefits from a 1 percentage point higher capital ratio equivalent of close to 1 per cent of GDP. The effect is larger in periods of high credit and house price growth.

3.1. Probability model for systemic financial crises

The first step in measuring the economic benefits of higher capital requirements is to estimate the impact of higher capital ratios on the risk of a systemic financial crisis. We use a cross-country panel logit model to estimate the relationship between the average capital ratio in a country and financial crises, while also controlling for additional variables that can affect systemic risk. Similar approaches have been used by e.g. Barrell et al. (2009), Barrell et al. (2010), Brooke et al. (2015), and Costa Navajas and Thegeya (2013).

Financial crises are rare events. While recessions happen on average every 5-10 years, financial crises occur much less frequently. Taylor (2015) finds that the unconditional probability of financial crises from 1870 until now is approximately 6 per cent for high-income countries, corresponding to a crisis every 15-20 years. For an empirical analysis, a large sample of countries and time periods is therefore needed. We have chosen to base our estimates of both the probability and the output costs associated with a financial crisis on a range of countries and crisis periods. As an example, the next financial crisis is likely to be different from the global financial crisis in 2008/2009. It therefore seems reasonable to consider a broader range of crisis periods when estimating financial risks and output costs of any future crises.

The probability model is of the form:

$$Pr(crisis_{it}) \equiv Pr[y_{it} = 1|x_{it}] = \Lambda(x'_{it}\beta), \tag{1}$$

where $\Lambda(x'_{it}\beta) = \frac{exp(x'_{it}\beta)}{1+exp(x'_{it}\beta)}$ is the logit function. y_{it} is a dummy variable equal to 1 the first year a financial crisis occurs in country i in year t. In addition to using the average capital ratio in country i in year t as a predictor of a financial crisis, we also include the annual growth in loans relative to GDP and the annual growth in house prices relative to GDP. Loan growth is measured relative to GDP, as credit usually expands to support economic growth. High credit growth in excess of GDP growth is expected to be informative of rising financial risks. Davis and Karim (2008) document that rapid credit growth is a typical early warning indicator for banking crises, and Taylor (2015) and Laeven and Valencia (2010) also find that credit build-up is an early warning signal of rising financial risks. High credit and house price growth can increase the risk of a sharp correction in collateral and asset values, e.g. due to underpricing of risks and overvaluation of housing collateral, which can lead to losses for the financial sector.

Denmark experienced a house price boom and strong credit growth in the years leading up to the global financial crisis. House price to GDP growth peaked at 15 per cent in 2006, while loan to GDP growth was around 7-9 per cent in the years leading up the global financial crisis, see Figure (1). The financial crisis starting in 1987 was also preceded by a strong growth in credit and housing prices, with loan to GDP growth over 9 per cent in 1985 and 1986, and house price to GDP growth in excess of 5 per cent in 1983-1985. In the case of Denmark, Grinderslev et al. (2017) have shown that cycles in real house prices tend to peak around 8 quarters before a peak in the credit cycle. Other studies have shown that periods of financial distress are often preceded by house price booms. Barrell et al. (2009) and Barrell et al. (2010) find that house price booms increase the probability of financial crises. Finally, we include country-fixed effects in x_{it} to control for unobservable country-specific characteristics which can affect the average probability of a financial crisis in a given country.

Model (1) is estimated by maximum likelihood, and standard errors are clustered at the country level. To avoid endogenous effects of financial crises, all explanatory variables enter in lags. As an economy enters into a recession, house price and lending growth are likely to decrease, and capital ratios can fall as a result of losses incurred in the financial system due to e.g. unsound lending prior to the onset of a crisis. Lagging the explanatory variables ensures that we measure the effect of the predictors on financial risks and not the other way around. The model has been estimated using different lag lengths of the explanatory variables, and the final model specification is chosen based on significance of the included predictors and the ability of the model to correctly predict a financial crisis. The final model uses the capital ratio one year prior to the onset of a crisis, while house price and loan growth relative to GDP are lagged two years.[5] We use the *AUC* statistic to measure the predictive content of the included variables. As a null model, we estimate Equation (1) with only country-fixed effects and test against the full model with all predictors included.

3.2. Data

Our dataset is comprised from several sources. We use the Macrohistory Database of Jordà et al. (2017) for GDP, total loans to the non-financial sector, and the financial crisis indicator.[6] We refer to their paper for a complete description of data sources. We have updated the data for Danish GDP to the most recent data from Statistics Denmark. House price indices are from Knoll et al. (2017).[7] The data on capital ratios are comprised from two sources. For the majority of the sample, we use the OECD Bank Income and Balance Sheet statistics.[8] Capital ratios are computed as capital and reserves divided by end-year total non-risk-weighted assets. We use non-risk-weighted assets to compute the capital measure as it is the only measure that is available for a longer period of time. Also, unweighted capital ratios make a more meaningful comparison to the results from the structural dynamic macroeconomic model for the costs of raising capital ratios, as this model considers unweighted assets as well. The use of unweighted assets does come with the caveat that the explanatory variables for the crisis probability model do not explicitly take into account changes in risks that are caused by changes in the riskiness of banks' portfolio.

The OECD database covers 1979-2009, and does not include the UK and Portugal. Furthermore, for some countries, data on capital ratios are not available for the full sample period. To extend the estimation period further, we use the capital ratio data from the World Bank's Global Financial Development Database (GFD), measured as the ratio of bank capital and reserves to total assets. We use the GFD database whenever the OECD statistics are missing. In the cases where data on capital ratios are not available from either source, we

[5] Including one-year lags of house price and loan growth relative to GDP as well leads to similar results.

[6] The data was retrieved in April 2017.

[7] The data is from the OECD housing prices database. The house price index for Denmark is from Statistic Denmark.

[8] The data for Denmark in the OECD statistic is from the Danish Financial Supervisory Authority, (Finanstilsynet).

exclude the corresponding observations in the estimation of the probability model (1). For the UK and Portugal, the GFD Database is used for the full sample. Note that the capital measures from the two databases are not strictly comparable. As a robustness check, we have also estimated the probability model using only observations from the OECD database. This has only a very minor impact on the results.

The dataset includes 22 systemic financial crises in 17 OECD countries from 1980-2013. Financial crises are defined as periods where a country's banking sector experiences bank runs, large increases in default rates, leading to large losses of capital and possibly resulting in public intervention, bankruptcy, or forced merges of major financial institutions. A description of the methodology of crisis classification can be found in Schularick and Taylor (2012). Table (1) summarises these events through time and economies. The unconditional frequency of financial crises is about 4 per cent corresponding to a crisis every 25 years. Just over half of the financial crises are dated during the global financial crisis. For the UK and the US, the onset of the crisis is dated to 2007, and for the remaining countries in which the crisis became systemic in nature, the start of the crisis is dated to 2008. The remaining ten crises occur in 1987-1991, with the exception of the US crisis in 1984 and the Japanese financial crisis in 1997.

3.3. Results for crisis probabilities

The results from the estimation of Equation (1) is reported in Table (2). The coefficients have the expected signs. A higher capital ratio is associated with a lower risk of financial crises. The coefficient is statistically significant at the 1 per cent level with a p value which is zero to three decimal places. The coefficients on loan and house price growth are similar, with house price to GDP growth being significant at the 1 per cent level, and loan to GDP growth being significant at the 5 per cent level. Loan and house price growth in excess of growth in GDP thus contribute to increasing the systemic risks in the financial system two years later. Both the house price and the loan predictors are lagged two years. Potentially unsound lending can take some time to materialize in losses for the financial system, and the best fit is obtained by including the growth rates two years prior to the onset of a crisis.[9]

The third and fourth row report the AUC statistics of the model with all predictors included and with only country-fixed effects included, respectively. A value of 0.5 is equivalent to no information in the predictors (i.e. the model fares no better than a coin toss in predicting crises). A value of 1 is equivalent to a perfect fit. When testing the AUC statistic against the model with only country-fixed effects included, we find the full model significantly better at predicting financial crises at the 1 per cent level. The AUC statistic is comparable to the results of Taylor (2015) who finds a fit of 0.75.

We show the estimated crisis probabilities for Denmark in Figure (2). The risk of a

[9] We have also estimated a version of the model where credit and house prices are measured not relative to GDP, but as the growth in the series themselves. This model does not lead to different conclusions.

financial crisis in 2008 is estimated at 30 per cent, corresponding to a crisis every third year, substantially higher than for the other years during the sample period. The probability in 2007 is also high with at value of 26 per cent. The substantially increased risks can be attributed to a low capital ratio and high growth rates in loans and house prices relative to GDP in the years leading up to the global financial crisis.

The estimated probabilities are also elevated in the years around the 1987 crisis although at a lower level than for the global financial crisis. The lower level of risks relative to the period before the financial crisis can be explained by a higher capital ratio in the 1980s. Also, this crisis had smaller effects on the real economy than the 2007/2008 crisis. The growth in loan and house prices relative to GDP is of a similar magnitude as in the years leading up to the 2008 crisis. The results show risks of a similar magnitude in 2000-2004, as a result of lending and house price growth. Barrell et al. (2010) also find elevated risks for Denmark for some of the years between 1996-2007, reflecting strong growth in house prices, increasing the levels of risks.

Grinderslev et al. (2017) estimate the financial cycle for Denmark. This concept captures long run swings in financial variables. Large deviations from zero in the financial cycle imply that credit and/or house prices are growing faster than their trend or natural level, and these gaps can thus be interpreted in a similar way as output gaps. We compare the financial cycle for Denmark with the estimated crisis probabilities in Figure (6). As can be seen from this Figure the two series are highly correlated. This makes sense, as the financial cycle is also estimated using data for credit and house prices, but the econometric techniques vary significantly from the techniques used in the current study. We conclude that the model is successful in capturing the period of financial risks, i.e. that credit and/or housing price growth rates in excess of their trend or natural level in increase the risks of financial distress.

The average probability of a financial crisis over the sample period is 6.2 per cent. To estimate the reduction in the probability of a crisis from a higher capital ratio, we evaluate the model at a 1 percentage point higher capital ratio for each year. The result is shown in Figure (3). Increasing the capital ratio reduces the average probability of a crisis by 1.2 percentage points to 5 per cent. We use this as our estimate of the expected reduction in the probability of future crises. This estimate can be considered a proxy for the steady-state effect of increasing the capital ratio.[10]

The probability model does not incorporate spillover effects. A financial crisis might not be triggered by domestic events, but rather by foreign developments that spread to other countries due to the interconnectedness of financial markets. However, since capital ratios have been increased not just in Denmark, but on an international level due to the reform measures developed by the Basel Committee on Banking Supervision, a more realistic scenario is that capital levels for all countries in the sample are increased. This would reduce the risk of financial crises in foreign countries as well, thereby lowering the risks of

[10]Using the average marginal effect from Figure 4 as a measure of the reduction in probability leads to an 1.3 percentage points reduction.

spillover effects from foreign countries to the Danish financial sector. One interpretation of the reduction in risk in Figure (2) is therefore, that it is the effect of increasing capital ratios on an international level, even though spillovers are not explicitly modelled.

We further point to the following observations. *Increasing the capital ratios prior to 2008 would have substantially reduced the risks of a crisis in Denmark.* This can be seen in Figure (4), in which we show the marginal effect of a 1 percentage point change in the predictors for the full sample period. A 1 percentage point higher capital ratio in 2007 would have reduced the probability of a crisis by over 5 percentage points in 2008, and a increase in 2006 leads to a reduction of over 4.7 percentage points. The results are of a similar magnitude to those of Barrell et al. (2009) who find a 6 percentage point reduction for the UK. The reduction in probability is statistically significant for all years with elevated risks. The marginal effect is naturally larger at the upswing of a credit cycle.

A lower growth in credit and house prices relative to GDP also leads to a reduction in the probability of a financial crisis. A percentage point decrease in either variable in the years leading up to the global financial crisis is associated with approximately a 2 percentage point decrease in risks. The effect of reduced credit is, however, only borderline significant, while the effect of reduced house price growth shows somewhat stronger significance. Curtailing excessive growth in credit and housing crises can thus also be expected to reduce future risks of financial crises.

The effects of a higher capital ratio is not linear. Figure (5) shows the probability of a financial crisis at a 0-8 percentage point higher capital ratio for all years. The benefit of a higher capital ratio is lower the higher is the level of capital. Increasing it by a 1 percentage point gives an average reduction of 1.21 percentage point in the risk of a crisis, while the gain of an increase from e.g. 4 to 5 leads to a 0.53 percentage point reduction in the risks of a crisis. A combination of higher capital ratios and lower lending and house price growth would also contribute to a further reduction in the risks of financial distress, as seen in Figure (4).

3.4. Output loss from financial crises

Financial crises vary in terms of length and depth of the following recessions, and also in terms of causes. In this section, we therefore consider the average or typical output behaviour during a financial recession for a generic advanced economy. The same dataset as in the previous section is used for the analysis. We follow the methodology of Jordà (2005) to estimate the output costs of financial crises by local projections. Specifically, we are interested in the impact of a financial crisis on GDP $0 - h$ years after the onset of a crisis. We can define the impulse response of GDP to a financial crisis as the difference between two forecasts (see e.g. Hamilton (1994)):

$$IR(t, h, s_i) = E(y_{i,t+h}|s_{i,t} = 1, X_t) - E(y_{i,t+h}|s_{i,t} = 0, X_t), \qquad h = 0, 1, 2, ... \tag{2}$$

where $E(\cdot|\cdot)$ denotes the best mean-squared error prediction, $y_{i,t}$ is the variable of interest (real GDP), $s_{i,t}$ is the relevant shock (a financial crisis), and X_t is conditioning variables observed at time t. Local projections measure the impulse responses at each forecast horizon h by running a regression for each horizon of the right-hand side of Equation (2). The local projections methodology thus delivers impulse responses with analogous interpretations as impulse responses from a Vector Autoregressive (VAR) specification. Compared to VAR models, local projections have the advantage of being more robust to misspecification of the underlying data-generating process, and, additionally, valid inference is easier to obtain. For a discussion of the relation between VARs and local projections, see Jordà (2005). This methodology has also been used by Taylor (2015), Jordà et al. (2013), Romer and Romer (2015), Krishnamurthy and Muir (2016), and Brooke et al. (2015)

We consider the following specification for measuring the output response of GDP to a financial crises, 0 to h years after the onset of the crises:

$$y_{i,t+h} = \alpha_i^h + \gamma_t^h + \beta^h F_{i,t} + \sum_{k=1}^{4} \phi_k^h F_{i,t-k} + \sum_{k=1}^{4} \theta_k^h y_{i,t-k} + e_{i,t}^h, \tag{3}$$

where i is the country index, t is time index, and h denotes the number of years after the onset of a crisis. The variable $y_{i,t}$ is the logarithm of real GDP for country i at time t, and $F_{i,t}$ is a dummy variable for a systemic financial crisis for country i in year t. We include lags of real GDP to control for business cycle fluctuations in GDP. Country-fixed effects α_i^h are included to control for differences in average growth rates between countries and other unobservables that can affect the behaviour of GDP across countries.

The γ_t^h are year-fixed effects. We include these to control for common economic developments that affect all countries in a given year. Countries that do not experience a financial crisis in a given year are likely to be hit by a recession due to e.g. global shocks and spillovers from countries that experience a financial crisis.[11] By controlling for business cycles, average growth rates, and common global developments, Equation (3) thus measures the impact on GDP of a financial crisis relative to its trend or structural level.

From Equation (2) it is clear that the impulse response of GDP to a financial crisis is $IR(t, h, s_{i,t}) = \beta^h F_{i,t}$, and the effect on economic activity h years ahead to a systemic financial crisis in year t is obtained by estimating Equation (3) separately for each horizon h. It should be noted that we do not discriminate between the causes of financial distress in Equation (3). That is, we do not separate financial crises that are triggered by relatively exogenous factors in a given country from crises where cyclical developments are the main cause.

[11] As an alternative specification, we have also estimated a version of Equation (3) where we include a country-specific linear trend instead of time fixed effects. This leads to similar impulse responses as reported later.

The model is estimated by pooled OLS, and standard errors are clustered at the country level. In the baseline model, we include four lags for both real GDP and the crisis indicator. We do the same for the specification that includes house price indices and lending to the non-financial private sector.[12] We consider impulse horizons from 0 to 6 years.

We consider a number of alternative specifications of Equation (3) as a robustness check of the results. First, we extend the estimation period to 1960-2013 to get more information about the average dynamics of GDP. Around half of the financial crisis periods in our sample occur during the global financial crisis. We therefore exclude the 2007-08 crisis from the sample to investigate whether this period is the main driver of the results. We also consider a specification where we include real house prices and real loans to the non-financial private sector as additional predictor variables for GDP. Finally, we estimate Equation (3) using generalized least squares (GLS). Specifically, we compute the variance of the residuals for each country from the OLS estimation of Equation (3) and use these as weights for the GLS estimation.

3.5. Estimation results for output losses

In Figure (7) we show the impulse responses for the five specifications of Equation (3) together with 95% confidence bands. In Figure (8) the results are shown together in the same graph to facilitate comparison of the different specifications. The corresponding table of results is reported in Table (3).

We point to the following: The onset of a financial crisis is associated with a contemporaneous decline in GDP. The baseline specification (OLS, upper left-hand graph) shows that GDP falls about 2 percentage points on impact. The decline in GDP grows substantially over the following years with a peak loss of 6.1 per cent four years after the onset of a crisis. The negative impact then starts to lessen, but remains at 4.6 per cent six years after the start of a crisis.

Expanding the estimation period to 1960-2013 from 1980-2013 has hardly any effect on the results (OLS 1960-2013, top figure to the right). The impulse response of GDP is almost identical to the results from the baseline specification. The period from 1960-1980 includes only two additional financial crises, and these crisis periods do not show substantially different output behaviour. Excluding the global financial crisis from the sample leads to a different impulse response of GDP (OLS 1980-2006, middle figure to the left). The effect on GDP on impact increases by 0.5 percentage points to 2.6 per cent. The decline in GDP increases to 6.3 per cent after only two years, after which the negative impact on GDP begins to lessen. A possible explanation for less step decline in GDP when including the recent crisis in the sample could be the various measures undertaken by governments and central banks in the attempt to lessen the impact of the crisis. The impact on GDP after 6 years is,

[12]The results are not sensitive to the choice of lag length: Different choices of lag length give similar results for the β^h coefficients.

however, very similar to whether or not the recent crisis is included in the sample. The accumulated output costs are about the same as when using the full sample period. The global financial crisis is therefore not the main driver of the estimated output costs.

Including house prices and credit as additional control variables have only a minor impact on the impulse responses (OLS Housing and loans, middle figure to the right). The impulse response is shifted upwards compared to the baseline specification with a reduction of about 0.3-0.9 percentage points at all horizons.

Controlling for country-specific heteroskedasticity in the residuals has a somewhat larger effect on the results (GLS, bottom figure). The pattern of the impulse response is largely unchanged, but the magnitude is smaller. The peak loss is reduced to 4.7 per cent after four years and after six years the decline in GDP is 2.6 per cent. This points to a large variation of financial recessions, as GLS estimation tends to down-weigh large outliers.

The results are comparable to previous ones in the literature. Jordà et al. (2013) find a peak loss after 3 years of 3.9 per cent of real GDP per capita using longer time series running back to 1870. Brooke et al. (2015) estimate a peak loss of around 5 per cent and a loss after 6 years of 4 per cent. Romer and Romer (2015) finds a peak loss of 6 per cent and a decline of 4 per cent after 5 years, very similar to our findings. They also show that using GLS estimation reduces the estimated output costs somewhat.

The overall conclusion is that financial crises have a substantial negative effect on GDP. The output loss remains large and significant even 6 years after the onset of a crisis. In comparison, Taylor (2015) finds that the negative impact of a normal recession on GDP is about 1.3 per cent and tends to last for two years. The output losses associated with financial recessions are thus substantially larger than for regular recessions.

3.6. Estimated benefits of higher capital requirements

In this section, we will combine the results of the previous sections to estimate the benefits of a 1 percentage point higher capital requirement in terms of a reduction in expected output loss due to a lower frequency of financial crises. We thus need an estimate of the reduction in the probability of a financial crisis, which we analysed in section (3.1)-(3.5), and an estimate of the output loss from a financial crisis, analysed in section (3.4).

3.6.1 Our estimate of the output loss of financial crises in terms of GDP

A main issue for assessing the long-run benefits of higher capital requirements is whether the loss in GDP associated with financial recessions is assumed to be permanent or temporary, that is, do financial crises affect the level of potential output? This is illustrated in Figure (9). The loss in GDP is the area between the trend path and GDP growth, the shaded area in the figure. In the left-hand panel, GDP growth falls below its trend following the crisis, but eventually returns to its pre-crisis growth path. GDP growth is for some years larger than the trend growth until the economy is back on its long run growth path. The loss in terms of GDP is thus temporary, and a financial crisis has no permanent impact on the level of potential GDP.

The right-hand panel illustrates a situation where the effect on output is permanent. Following a crisis, GDP growth falls as in the left-hand panel. However, the economy never fully recovers. GDP instead returns to its pre-crisis growth rate, but at a lower path for potential output. The economy therefore suffers a loss every year after the crisis, as it never reverts to its pre-crisis growth path.

We take both approaches for calculating the costs of financial crisis to remain agnostic about the long-run costs of financial crises.[13] We base our results on the median of the impulse responses reported in Table (3), reflecting the variability from the different specifications. Assuming permanent costs of a crisis, we take the peak median loss as the permanent effect on potential GDP and calculate the present value of future output loss using a discount rate of 4 per cent. The result is shown in Table (4). The present value of a financial crisis amounts to 142 per cent of GDP. As a comparison, Ollivaud and Turner (2015) estimate the effect of the global financial crisis on potential output in a range of OECD countries. They find a median loss in potential output of about 5.5 per cent, which is very similar to the 4-year median peak loss from Table (3), which is 5.46 per cent. Assuming temporary costs for the economy, we calculate the present value cost of a crisis as the discounted output loss 0-6 years after a crisis, again using a 4 per cent discount rate. This gives a cost of 27 pct of GDP. The mean costs between the two estimates are 84 pct of GDP.

As a robustness check, we have computed the output loss of the recession in Denmark starting in 2008 using the methodology of Laeven and Valencia (2012). This results in an output loss 31 per cent of GDP relative to its pre-crisis trend.

3.6.2 Our estimate of the benefits of higher capital requirements

As shown in section (3.3), the risk of a financial crisis and the associated reduction in probability from a higher capital ratio vary substantially over time. The historical average reduction in the probability shown in Figure (3) is 1.21 percentage points. We use this as a proxy for the steady-state benefit of a higher capital ratio. As of 2016, the average leverage ratio for Danish banks is around 5.6. Hence, the historical average of 7 is actually larger than the current level indicating that the reduction in the probability of a financial crisis would be higher than our estimate.

[13] We have also estimated the output losses for up to 10 years after the onset of a crisis using Equation (3). The results tend to vary substantially between the different specifications of the model and do not give any clear evidence on the persistency of the output loss.

Table (4) shows the estimated reduction in output loss of a 1 percentage point higher capital ratio. The average effect over the sample period amounts to 0.32 per cent of GDP, assuming transitory effects of financial crises. With permanent effects on output, the gain is 1.7 per cent of GDP.

Taking the mean result as a proxy for persistent effects on output from a financial crisis, gives rise to substantial benefits from a one percentage point higher capital ratio. The effect is larger in periods of high credit and house price growth. In 2008, following years of strong house price and credit growth, the reduction in probability from a 1 percentage point higher capital ratio is over 5 percentage points, giving rise to a substantially greater benefit in terms of a reduction in expected output loss, 4 to 5 times greater than reported in Table (6). Having analysed the benefits of increasing capital requirements for Danish financial institutions, we next proceed to analyse the costs.

4. Analysing the costs of higher capital requirements

Our aim in what follows is to assess the costs on the real economy of higher capital requirements for banks in Denmark. We consider the case in which the capital requirement is increased by 1 percentage point permanently. Our aim is to quantify both the long run costs, defined as the effect on GDP in the new state of the economy with the higher capital ratio, the short run costs, defined as the effect on GDP during the first 1-3 years, and the transition costs, the present value of the difference between GDP with and without higher capital requirements. For the latter we will use, as is the case for the calculation of the benefits of higher capital ratios, a discount factor of 4 per cent, which is approximately equal to the steady state long run interest rate in the model at hand. We discount until the economy has reached steady state. The difference between the transition costs and the long run costs is that the former also includes the short run costs during the built-up of capital, while the latter only consider the effects on GDP when the capital has been accumulated. Other studies, for example Almenberg et al. (2017), measures costs only in terms of the long run costs, which are smaller than the transition costs. However, we believe that this way of measuring costs is biased as the short run costs can be large. One motivation for using the long run costs only is the way benefits are measured, which is not capturing the transition to a new steady state.

We use the structural dynamic generel equilibrium macroeconomic model with forward-looking agents presented in Pedersen (2016). This model has both financial frictions and banks with endogenous bank profitability. The model provides a unified framework to analyse how changes in capital affect banking and financial markets and, through general equilibrium, the rest of the economy. Hence, changes in regulation not only affect the banking sector, but also directly feeds back to the real economy and output through interest rate spreads and lending. Additionally, the model includes instruments for the banks to meet the extra capital requirements, such as suspension of dividends, which we will analyse in what follows. We have calculated the benefits of higher capital requirements using the techniques explained in section (3), and within the macroeconomic model, as the model does not include defaults, as explained in what follows.

Our main findings are summarized in Figure (10(a)), (10(b)), and Table (5). We point to the following: The estimates are likely to be upper bounds for the effects of capital requirements in terms of costs. The reasons for this are many, but primary due to a one-to-one relationship between increases in cost-of-capital for banks and for cost-of-capital for firms and households. In short, this implies a double break-down of the MM-theorem, as will be explained in what follows.

Our results show that the cost of increasing capital requirements for Danish banks can be close to 0 under two conditions. Firstly, banks suspend dividend payments during the 2 years after the announcements of the policy change, and secondly, investors required return falls as new capital is accumulated. The latter implies an MM effect of one in the long run. If we relax the first assumption, costs increase to around 0.8 per cent of GDP, while if we relax the second assumption, the costs are close to 1 per cent of GDP. Key to the long run effects is thus how large the Modigliani-Miller offset is. Key for the short run effects is to which degree dividend payments are kept constant: The short run effects are between 1/2 and 2/3 lower, if banks meet higher capital requirements through suspension of dividends during the buildup of the capital ratio. Frontloading of the accumulation of bank capital increases the short run costs while leaving the transition costs unchanged.

4.1. Modigliani-Miller theorem: Capital requirements do not matter for the value of the banks

Key to the effect of higher capital ratios is the extent to which the Modigliani-Miller theorem, MM, holds. According to Modigliani and Miller (1958) and Modigliani and Miller (1963) the value of a firm, including a bank, is independent of its funding structure subject to some important assumptions. The capital structure is within this framework only important for the distribution of returns on a firm's assets.

The proposition suggests that a bank's value and its average cost of funding are independent of the capital ratio: A higher capital ratio will lower the risk facing shareholders, and the required risk premium demanded will decrease to a level where the average cost of funding is the same as before the change to capital ratio. Hence, the total required return on debt and equity should be unaffected by the composition of these two. When forcing a bank to fund a higher share of the assets, it will be less risky for both equity and debt owners. The loss capacity of the banks increases and the risk of bankruptcy falls. This will in turn reduce the required rate of return exactly such that the total funding costs are unchanged. Hence, when the MM holds then funding costs do not depend on the composition of the liabilities. How risky a firm is only depends on the riskiness of its assets, and variations in its capital structure do not affect its funding costs.

The implication of the MM-theorem is that higher capital requirements will have no economic impact in the long-run. Naturally, if it takes time for the banks to adjust to higher capital-requirements then there can be short-term effects on the real economy.

However, and as already mentioned, real world frictions may imply that funding costs depend on the composition of liabilities. Equity can be more costly if, due to various frictions, a decrease in leverage does not lower the required ROE. If as an example, deposits and other debt liabilities are subsidized in the sense that they are under some form of guarantee, then equity financing can be relatively more expensive that debt financing. Equity can also be costly due to asymmetric information: Current shareholders know more about the value of the firm than new shareholders, and therefore new shareholders will demand a premium for providing new capital.

Typically debt has a more favorable tax treatment than equity. If debt is treated more favorably in the tax code than equity, then the funding decision for banks is distorted, and higher capital requirements can counteract distortions in the economy. The social costs can thereby be expected to be lower than the private costs for banks. As an example, assume that new equity replaces debt and the only distortion is the lost tax shield on debt. Assume further that the average coupon on the debt is 5 per cent and the corporate tax rate is 22 per cent. If the capital requirement is increased by 1 percentage point, the value for the bank of the lost tax shield is $0.05 \times 0.22 = 0.011$ per cent. Hence, keeping all else equal, the long run effect of the lost tax shield is around 1 basis point, if banks need to increase their capital requirement by 1 percentage point.

Depending on the model at hand, if the MM does not hold then the likely response for the banks to higher capital requirements is to pass on higher funding costs to borrowers. This will have a negative impact on borrowing in the economy and consequently on investments and ultimately on growth. Hence, capital requirements make borrowing from financial institutions more costly if, firstly, the change from debt to capital financing raises the cost of capital and, secondly, the institutions are able to pass these costs on to borrowers through higher lending margins on loans.

In the end whether the MM theorem holds is an empirical question. This is not the place for a complete literature review of this topic. For this, see for example Cline (2015) or Martynova (2015), who find that the confidence bounds are large, pointing to large uncertainty around these estimates, and to small effects on the funding costs. The literature review in Bengtsson et al. (2012) points to an MM-effect of around 50 per cent.

4.2. Current study – The cost of higher capital requirements in a structural macroeconomic model

4.2.1 The model used in the current study

We will in what follows study the question at hand using the DSGE model documented in Pedersen (2016). We refer to the documentation for details and only present our motivation and the banking side of the model here.

Our motivation for using the model in Pedersen (2016) are many. In the model, banks' balance sheets and credit markets are modelled explicitly. They thus provide a unified framework to analyse how changes in capital affect banking and financial markets and, through general equilibrium, the rest of the economy. That is, changes to regulation not only affect the banking sector, but also directly feed back to the economy. And the explicit modelling of the banking sector allows the user to vary, as an example, dividend payments in response to the regulatory changes.

The use of a structural model also allows for counter-factual experiments and policy scenarios conducted in a consistent manner. This is so as agents' expectations are modeled explicitly and the models are structural built upon a micro foundation. Expectations therefore react to policy changes. This can especially be important for the current study, as financial markets inherently involve the study of forward-looking variables with asset price behaviour. Further, the models feature a well-defined steady state.

One additional advantage of the model in Pedersen (2016) is that the model includes several possibilities or instruments for the banks to meet the extra capital requirements. This can be key to assessing the effects of higher capital requirements.

4.2.2 The possibilities for the banks

The effect on the real economy from higher capital requirements can be expected to depend on whether the denominator or nominator changes; capital or assets. Intuitively, if the banks are able to meet the capital requirements through increases in capital only, then lending does not need to change. But if the capital ratio is met through decreases in lending only, then the effects are likely to be large. That is, the banks can respond to capital requirements through the following instruments:

1. Increase retained earnings by raising lending margins, keeping dividends unchanged
2. Increase retained earnings by reducing dividend payments and/or return on equity
3. Increase retained earnings by being more efficient
4. Cut the overall size of the loan portfolio
5. Issue new equity

The effects on the real economy from increasing the target capital ratio can be expected to depend on which of these instruments the banks choose to apply. Points (1) and (4) can be seen as mainly meeting the higher capital ratio through downsizing the asset side, while points (2)-(3) only work through higher capital. We notice that increasing lending margins is equivalent to increasing fees.

The model at hand can study the first four points. Following Roger and Vlček (2011), we do not consider raising new equity, though it is a natural way to raise capital, partly because the model does not allow for it in a structural way and partly because raising new capital on capital markets dilutes existing shareholders investment and must therefore be considered as a last resort measure. If the fundamentals of the banking sector are healthy it will be possible to issue capital on market terms without extra high risk premia. Before we discuss the results and the scenarios, we will through the model look at how banks react to higher capital requirements.

4.2.3 The banking sector in the structural macroeconomic model

We will in this section explain in greater detail how higher capital requirements propagate in the model. The banking sector is described in detail in Pedersen (2016). Here, we will only describe the intuition.

Two conditions need to be met for higher capital requirements to lead to more expensive borrowing for firms and households. Firstly, equity needs to be more costly than debt financing for banks. Secondly, banks can pass higher funding costs on to borrowers through higher lending margins. We emphasize that banks in the model can not access capital markets in response to higher capital requirements.

Firstly, it is important to note that without any financial frictions, the addition of a financial sector have no effect on the macroeconomy besides adding an accounting framework. That is, banks would play no role for equilibrium prices and output. The interesting part of a macroeconomic model for the purpose of this study is therefore what is assumed with regards to financial frictions. Secondly, within the model at hand, banks use lending margins as their primary instrument to increase profits and hence capital. It is thus assumed that banks can pass higher costs onto borrowers in the economy. As will become clear later, this relationship is tight in the model: The elasticity between cost-of-capital for banks and cost-of-capital for borrowers is one.

In the model, the banks choose the overall amounts of lending and deposits of the bank so as to maximize profits. The banks operate under monopolistic competition, which allow them, firstly, to set their interest rates above the deposit rate (which is equal to the monetary policy rate imported from the ECB), and secondly, that they earn a profit. Thus banks' profitability is endogenous in the model, and the model can thus take into account endogenous changes in banks' net margins deriving from the new rules. Further, banks' lending rates are assumed to be "sticky": They cannot be adjusted every period reflecting an imperfect pass-through of marginal funding costs for banks to borrowers.

The most important financial friction is capital requirements and cost of deviating from them. Specifically, a bank faces a cost if its bank capital to asset ratio deviates from required ratio. The level for the capital ratio can be interpreted the institutionally set ratio plus a buffer, and thus the target level of capital ratio for the banks. We stress that this is capital to total unweighted assets – e.i. the bank's leverage ratio – as the model does not include a meaningful role for risk weights.[14] The banks take the adjustment costs of deviating from the capital requirement into account when deciding how much to lend and at which rate. A key equation for the current study is therefore the first-order condition with respect to the amount of loans:

$$R_t^L = R_t^D - \Phi^B \left(\frac{K_t^B}{B_t} - \kappa^B \right) \left(\frac{K_t^B}{B_t} \right)^2 . \tag{4}$$

The parameter $\Phi^B > 0$ is the cost of deviating from the target capital ratio, κ^B, R_t^L denotes the gross interest rate charged by the wholesale branch on the loans it makes to the loan branch, and R_t^D is the gross interest rate paid by the wholesale branch on the funds it receives from the deposit branch.[15] In equilibrium that interest rate is equal to the ECB monetary policy rate.

In short, Equation (4) can be interpreted as a loansupply schedule: When loans, B_t, increase, the capital-to-asset ratio falls below target, κ^B, and the bank is induced to raise the lending rate to balance the extra income from giving the loan with the cost of deviating from the optimal capital ratio.

The first-order condition, Equation (4), commands that the loan spread, the difference between the lending rate to the lending branches and the deposit rate, must equal the marginal cost of deviating from the capital ratio. Or banks chose a level of loans that at the margin equalises costs and benefits of reducing the capital-to-asset ratio: If this ratio (or inverse leverage ratio) of the bank falls short of its target ratio, the wholesale branch will charge a lending rate that exceeds the deposit rate, R_t^D, at which it remunerates its deposit branch so as to increase its capital ratio. The further away the actual capital ratio is from the target ratio and the more costly it is to do so, determined by the parameter Φ^B, the higher the spread. It is however costly for banks to raise spreads, since they face a downward sloping demand for bank loans. Naturally, this also helps the banks to reestablish the capital ratio as when assets fall due to higher lending spreads, the bank need to increase capital by less. And as discused in section (4.2), the effects on the macroeconomy of raising capital requirements can be expected to depend greatly on whether the denominator or the numerator changes in the ratio between capital and assets.

[14]By this we mean that the model could include weighted assets and we could set these weights as we see fit. But these weights would not reflect in a meaningful way risk as the model does not include defaults.

[15]Here is considered a symmetric equilibrium, such that we can continue with a representative bank in what follows.

Another important relation in the model for the current study is the bank capital accumulation equation. The banks accumulate capital through the bank capital accumulation equation:

$$K_t^B = (1 - \delta_B) K_{t-1}^B + \Pi_{t-1}^B \delta. \tag{5}$$

The parameter δ determines the dividend ratio set to 0.77 per cent following Roger and Vlček (2011). Banks do not choose the dividend ratio; it is set exogenously for the bank. This can be thought of as reflecting a demand from shareholders for a steady stream of dividend income. Π_t^B is bank profit, while the parameter δ_B are resources used in managing bank capital. Hence, capital is accumulated through retained earnings: profits not distributed to shareholders, $\Pi_{t-1}^B \delta$. Clearly, the higher this term is the faster the bank can accumulate capital and meet capital requirements. The parameter δ_B is set such that actual capital ratio, $\frac{K_t^B}{B_t}$, is equal to the institutionally given capital requirement, κ^B, in steady state. Specifically, the value of the parameter δ_B is given by the ratio between the steady state level of bank capital and bank profits according to $\frac{\Pi_t^B}{K_t^B}$, which is also equal to the steady state ROE.

It is thus capital requirements together with equity market imperfections (a constant dividend payout ratio) that bring the bank capital channel into the model. That is, negative shocks to bank capital make banks accumulate additional capital, and influence interest rate spreads and credit supply independent of monetary policy.[16] From here it can also be seen, that if the required ROE and cost of bank debt do not adjust, then banks will increase lending spreads and/or fees to compensate for the higher cost of funding.[17] We will explore the effects of changing the assumption of a constant dividend ratio together with capital requirements in alternative adjustment strategies.

4.3. Effects in the scenarios

We will in this section discuss and motivate the scenarios conducted to study the effects of higher capital requirements. We begin with a scenario, in which banks change neither their demand to the ROE nor their strategy for paying out dividends. We then proceed in steps: We will first let ROE react, then we change dividend payments, and then look at the consequences of front-loading the adjustment. We will finally conduct various robustness checks.

[16]Further, as an unrealistic stylised example, if a benevolent foreign investor with low ROE would provide bank capital to Danish banks, the effects on the real economy of increasing capital requirements would be zero. This is so because in that case, banks would not face any costs as there would be no difference between statutory capital requirements and actual capital requirements, and thus there would therefore be no need to increase lending spreads to accumulate more profits.

[17]The model does not explicitly include fees, but the lending margins can be interpreted as including fees.

4.3.1 Assumptions in the scenario

Our main scenario will be a permanent increase of the capital requirement of 1 percentage point.[18]. We will instead let the bank endogenously determine its response(s) to the demand for more capital. The model used in this analysis has an explicit target for the capital ratio, the parameter κ^B in Equation (4). It is thus straightforward to increase this ratio permanently and let the model endogenously both determine the speed of adjustment and how the new capital ratio will be reached. We simulate the model under perfect foresight and we assume that the change is permanent and thus not expected by the economic agents in the model ever to be reversed. This means that at the beginning of period t, it is revealed to the economic agents in the model that capital requirements will be higher at the end of that period and that no further shocks will happen.[19]

We will assume the following in all scenarios. Monetary policy is kept constant. This is obviously less controversial in the case of Denmark, but, all else being equal, the effects from higher capital ratios can be expected to be higher than in similar studies using similar methodologies but in a monetary policy regime with flexible exchange rates. This is so, because (conventional) monetary policy under a fixed exchange rate regime, like in Denmark, cannot be used to mitigate the contractionary effects from higher lending rates to firms and households.

Related to this, we consider the case in which Denmark single-handedly increases capital ratios; there is no international coordination. We expect that if required capital ratios were increased throughout the euro area, the effects on Danish GDP would be smaller as the ECB could loosen monetary policy in response to higher lending rates, depressed output and inflation below target. This would in turn allow Danmarks Nationalbank to loosen monetary policy as well to keep the exchange rate fixed, and hence mitigate the effects in Denmark. And further, a loosening of the ECB policy rate would depreciate the euro vis-a-vis other currencies, boosting Danish exports. Lastly, public debt is stabilised using lump-sum taxation. We notice that within the model used, lump-sum taxation does have effects on the real economy, as some agents are credit-constrained and thus can not smooth extra lump-sum payments fully.

Some caveats are in order. Firstly, within the model the main benefits of financial regulation are overlooked, i.e. that a better capitalised banking sector will make it more resilient to losses incurred in times of financial distress. This is mainly due to the fact that within the model under study, there are no endogenous defaults; all borrowers always and everywhere pay their debt. Hence, to a first-order approximation there are no differences

[18]The current study we do not consider the impact of implementing the Basel III requirements, as is done in say the Financial Stability Board and the Basel Committee on Banking Supervision (2010a) and in Slovik and Cournède (Slovik and Cournède). We will deviate further from these analyses in that we will not feed a (permanent) interest margin shock into a macroeconomic model. As discussed in the previous section, this approach firstly assumes that banks boost profits to increase capital by using lending rates *only*.

[19]That is how such scenarios typically are conducted, see e.g. Angelini et al. (2015).

between having one level or another for the capital requirement. Secondly, the reform has no effect on the long term growth rate of GDP. That is almost by assumption: The long run growth rate is determined by the rate of technological progress, which is exogenous in the model. This also means that financial crises by assumption are temporary, in the sense that they do not affect the growth in the long run. Lastly, the model at hand is not a model for financial crises. To be so, it neds to include for example non-linearities, asymmetries, and a more explicit role for uncertainty.[20] During a financial crisis banks will not only face write-downs on outstanding loan contracts, and thus lose capital. Uncertainty about which bank sits with the most and worst assets on its balance-sheet, will also be elevated and spreads and funding costs will also rise. These effects are not likely to be present outside financial crises and are not likely to materialise when capital requirements are raised in such a state of the economy, and the model does not include these effects. The results we will show in the following must therefore be interpreted as the case in which capital requirements are raised in normal times – outside financial crises – and little from this analysis can be learned with regards to the effect from financial crises on GDP.

4.3.2 Constant Return on equity and constant dividend ratio, Scenario (1)

With the theoretical setup in the present model, we now look at the quantitative results. In the first scenario, we keep ROE and dividend payments constant. The result on a subset of the variables in the model is shown in Figure (11).

The higher capital requirement implies that the banks have to pay a cost, as the actual capital ratio differs from the now higher level of capital requirement. As explained above, the banks respond by increasing lending margins to increase profits and hence retained earnings. It takes time to reach the new level of capital ratio, both because it is costly to change loan rates, and the banks consequently smooth these costs, and because banks face a downward-sloping demand curve for loans. They therefore balance the extra income from higher lending margins on loans by the lower stock of loans, while a lower stock of assets naturally helps to increase the capital ratio.

Specifically, as shown in Figure (11), the lending spread increases by 60 basis points during the first year, falling to a new level of close to 10 basis points after close to 10 years. This estimate of the effect on the lending rate in response to higher capital requirements is within empirical estimates of between 2.5 and 50 basis points with an average of 16 basis points, see the literature review in Bengtsson et al. (2012).

Higher lending rates depress loan taking – the stock of outstanding loans falls by around 1 per cent – which in turn depresses investments (by 4 percentages compared to steady state), the real house price (0.3 percentages), and consumption (1 percentages). Hence, banks reach the new required capital ratio mainly through changes on the asset side of the

[20] The model at hand is stochastic and the agents do maximize under uncertainty, but the simulation method makes risk premia go away, and uncertainty or volatility shocks cannot play a role in the current setup.

economy. That is, the numerator changes in the ratio between capital and assets. Output falls by 0.35 per cent during the first year and stabilises on a level of around 0.2 percentages below the initial steady state. There is a partial recovery of investments, as the lower activity depresses prices (not shown), increasing competitiveness and thus exports. We notice that the long-run effect is relatively large compared to other studies, see Bengtsson et al. (2012) which points to a long run effect of around 0.10. This can be explained by the fact, that monetary policy in the current study is kept constant, and especially by the fact that in this scenario it is assumed that there are no counteracting MM effects.

The new required capital ratio is reached after approximately 4 years, while lending rates stay elevated. This is because the ROE, $\frac{Profits}{Capital}$, is kept constant in response to higher capital. In the model banks increase lending margins forever relative to the case before the implementation of higher capital requirements, to be able to increase bank profits and hence keep profits per unit of capital constant. What happens is a balance-sheet reduction: Banks increase their capital through a reduction their loan portfolio. The consequence is that output will stay depressed compared to the initial state of the economy with a lower required capital ratio.

In total, the long run costs are 0.2, the short run costs are 0.35, while the transition costs, the area between the zero line and GDP in Figure (11) discounted to the present are close to 1.8 per cent.

4.3.3 Return on equity falls, constant dividend ratio, Scenario (2)

The conclusion from above is that the long run effects, and partly the effects in the short run as well, are greatly influenced by the extent to which the ROE falls. In the scenario presented above, we kept ROE constant. We will in what follows relax that restriction. That is, we let the ROE in the model fall in tandem with accumulation of extra capital. We keep everything else in the model constant with respect to Scenario (1).

The channels are not equivalent to the channels through which ROE should fall accordingly to the MM theorem, see section (4.1). In that theorem ROE falls when the capital ratio increases, as banks has become safer and investors thus receive a lower risk premium in equilibrium. In the model used in the current study, risk premia and defaults are zero. What happens in the model is that, mechanically, ROE falls as banks accumulate capital and thereby revert to the same ratio between bank capital and bank profits.

The result is shown in Figure (12). If ROE is allowed to fall, then the peak decline in GDP is only around 0.2, while the long run costs are close to 0. The mechanism is that if ROE falls, then lending margins can be narrowed once the banks have reached a 1 percentage point higher capital ratio; the banks are not *forced* through a constant required ROE to permanently increase profits per capital through permanently higher lending margins. The short run effects are mitigated through forward-looking banks, households and firms that know that the long run costs will be smaller compared to the effects in Scenario (1). Specifically, households and firms face a term structure of interest to finance their consumption and investments, and given that lending margins are relatively lower than in Scenario (1) they correctly anticipate relatively lower future funding costs. They therefore change their behaviour today relative to the case in which ROE is kept constant.

We have shown what happens within the banking sector, and we here present what happens for the providers of debt and capital in response to the higher capital requirements. The owners of the banks, the patient households, swap their deposits for bank capital. The economic mechanism is that after the banks start to accumulate capital, the owners of the banks receive more and more dividends, now or in the future, and they consequently receive more income. They therefore start to consume more and run down their deposits in the bank changing them with capital. In turn, initially the return on bank capital increases, further inducing the asset swap.

We thus find results similar to the studies previously mentioned, e.g. in Schanz et al. (2011), Jensen (2015), and Copenhagen Economics (2016), namely that the long run effects are determined by the size of the MM effect, and thus to which degree ROE falls in response to higher capital requirements. What Scenario (1) and (2) show is that the effects on the macroeconomy depends on whether the banks change the denominator, assets, or the numerator, bank capital, in response to changes in capital requirements, confirming the intuition in section (4.2.3). In Scenario (1), assets fell by 1 percent, while in Scenario (2), assets initially fall but returns to its previous level. Hence, in Scenario (1) the capital ratio is increased partly through accumulation of retained earnings and partly through a balance-sheet reduction. In scenario (2), the accumulation of capital is mainly through retained earnings.

If the model used in the study does not include a banking sector with endogenous profits, it can be complicated to discuss how ROE is affected by changes in capital requirements. If it is assumed that ROE does not fall, then the result is almost by construction given, as in this case profits must rise in tandem with higher capital requirements, and the main instrument for achieving higher profits is to increase lending margins, as shown in Figure (12). The degree to which banks can pass on higher cost of capital depends especially on the degree of competition on the financial markets. If competition is low and barriers to entry are high, then the threat of price competition through lower interest margins from incumbent banks or existing competitors is low. What we also show here is that in a structural model with forward-looking agents, long run costs will greatly affect the short run costs as well, because agents rationally realize already in the short run, that they have become poorer, thus demanding less goods now, while firms invest less.

In total, in Scenario (2) the long run costs are 0, the short run costs are around 0.2, while the transition costs, the area between the zero line and GDP in Figure (14) discounted to the present is around 0.8 per cent. We note that Scenario (1) is the upper and Scenario (2) the lower bound of the cost of increasing capital requirements within the current model when varying the size of the MM offset keeping the dividend ratio constant.

4.3.4 Return on equity falls and dividends are suspended, Scenario (3)

As shown in section (4.2), the banks increase capital through retained earnings. The more earnings they accumulate per period, the quicker the new level of the capital ratio can be reached, and the interest rate margin needs to increase by less per unit of retained earnings. We quantify the effect in the following scenario, Scenario (3). In addition to demanding lower ROE, we also change dividend payments for the banks, such that banks stop paying dividends the first two years after the change of the capital requirements.[21] We note, again, that dividends are exogenous for the banks in the economy. And 2 is a purely random number set outside the model which serve the purpose of illustrating the main point.

The results are shown in Figure (13). The long run costs are comparable to the costs in Scenario (2), while the peak output decline falls to around 0.06 from 0.35 and 0.2 in Scenarios (1) and (2) respectively. The transition cost are halved compared to the transition costs without the suspension of dividend payments. Hence, real GDP falls by less and returns quicker to baseline compared to Scenarios (1) and (2).

Also, the new level for the capital ratio is reached sooner. In Scenarios (1) and (2), where the new level of the capital requirement is reached after around 5 years. In both scenarios the capital ratio is around 20 basis points from the new target after 3 years. In the current scenario, the actual capital requirement is 5 basis points from the target after 2 years and overshoots.

We assess the effects of the dividend payments in the same scenario as discussed here besides that dividends are permanently lower. This is shown in Figure (14), which confirms the results shown in Figure (13): The dividend ratio greatly influences the short run costs of higher capital requirements for the same reasons as discussed above. Higher dividend payments mean less retained earnings to accumulate. This implies a longer transition to the new level of bank capital, and thus higher lending spreads and a depressed economy for longer.

There are, however, also counter-acting effects from suspending payments of dividends. In the model, the patient households are the owners of the banks and thus receive the dividends. The general equilibrium effects of the dividend freeze thus affect the income of these households and thereby their consumption. However, this effect is not strong enough to overturn the positive effects limiting dividend payments.

In total, while the long run costs are unchanged in the case where dividends are suspended the first 2 years during the transition period to a new level for capital, the short run and transition costs are mitigated. The short run costs fall from 0.2 to 0.06 and the transition costs fall from around 0.8 to around 0.1. This is also the lower bound for the

[21] We notice that during the aftermath of the financial crisis, the bulk of the changes in capital requirements were met through retained earnings and not only through higher lending spreads, see Cohen (2013).

transition costs when dividends are suspended during the first 2 years when varying the size of the MM effect. That is, Scenario (3) is the case in which the MM effect is one in the long run. In Scenario (4), shown in Figure (10(a)) and Figure (15), it is assumed that the MM effect is zero and dividends are suspended for the first 2 years. Here the transition costs are 1 per cent, and can be considered to be the upper bound within this model when varying to which degree the MM theorem holds and dividends are suspended for 2 years.

4.3.5 Return on equity falls, higher cost of dev. from capital requirement, Scenario (5)

A key determinant for the effects on the real economy from changes in capital requirements is the parameter in the model, which determines the cost the banks have to pay, Φ^B, if they deviate from the institutionally set capital requirement, κ^B. This parameter is in the scenarios above calibrated to the value estimated in Pedersen (2016), approximately 22. As was also shown in that paper, the parameter is identified, but only weakly, while it is less obvious how to bridge this value to estimates based on e.g. micro studies.[22] An increase in the cost of deviating from the institutionally set capital requirements tilts the first-order condition with respect to borrowing. That is, the marginal cost of deviating from the capital ratio has increased relatively to the case of a lower cost parameter. Therefore the bank will increase the lending rates by even more. The cost parameter is therefore a key determinant of the speed of adjustment to a new capital ratio.

This is the motivation for conducting Scenario (5). We increase the value of the parameter from its benchmark value of 22 to 50. This scenario can be interpreted, with the previous insight in mind, as banks are front-loading the adjustment to a new level of capital. The results are shown in Figure (16). As can be seen, the transition to the new and higher capital ratio is much faster, as expected. The long run effects on GDP are comparable to the effects in Scenarios (2) and (3), while the short run effects are much higher, increasing from 0.2 per cent in Scenario (3) to 0.35 per cent. However, the transition costs, the area between 0 and the transition path of GDP, are comparable to the transition costs in Scenario (2). This is because the target for the capital ratio in Scenario (2) is hit sooner leading the banks to decrease lending margins sooner compensating for higher costs in the short run.

4.3.6 Further robustness checks

We will in what follows conduct various robustness checks on our results. *Are the effects linear?* To analyse this we increase the capital requirement by 2 percentage points instead of 1, as in all the previous scenarios. The effects of variations in the magnitude of the changes in requirements are close to linear, see Figure (17). This is not surprising, as it reflects that the model is locally linear.

[22] As an example, this is widely done for, say, price or wage stickiness, where micro data for prices set by firms can be used in determining how often prices are changed. Similarly, it is hard to compare the value of the parameter with other estimates from similar DSGE models.

How does our result depend on the dividend payout ratio? As already analysed in Scenario (3), dividend payments to shareholders can greatly influence the transition costs of increases in capital requirements, as dividends directly affect the amount of retained earnings the banks can use to accumulate bank capital. Higher dividend payments mean that it takes longer before the new capital requirements are met with higher costs during the transition path. This is confirmed in Figure (18) showing how the results depend on varying the dividend payout ratio.

What is the dependence on the cost of deviating from the institutionally set capital requirement? We vary the cost parameter from a low value, 11, to the bench-mark, 22, to a relatively high value, 45, and study the effects on a selection of variables. This is shown in Figure (19). The effects confirm the intuition provided above in Scenario (5): The higher the cost of deviating from the institutionally set capital requirement for banks, the greater the effect on GDP is at the short term, but the target for the capital ratio is hit faster.

How do the effects depend on the cost of changing interest rates? In the model, and in data, see Gerali et al. (2010), interest rates are sticky; lending rates do not change immediately in response to changes in the state of the economy. In the model this is captured by a cost of changing interest rates. We analyse the effects of these costs on our results through changing the degree of stickiness or cost of adjusting interest rate. The results are shown in Figure (20). The conclusions we draw from this analysis is that lower costs of adjustment make the banks increase the lending rates by less and keep them elevated less time. This makes the effects on GDP during the first year higher, but also less persistent; loans and the real house price, and investments recover more quickly and GDP moves quicker to its new long run level, when the banks can adjust their interest rate faster in response to the higher capital requirements.

4.4. Insight and findings from cost of increasing capital requirements

We repeat in this section some caveats with regard to the above estimates and summarise our findings. All the estimates are upper bounds. There are many reasons behind this. The funding costs for banks in the model increase in response to higher capital requirements, in the short run because it takes time to build up capital, in the long run because the costs can increase depending on what is assumed about MM. In the model at hand, higher funding costs can be passed on fully to firms and households, as they are unable to offset the higher cost of bank loans. A more reasonable assumption is that they can access alternative means of financing; that when cost-of-capital for banks increases, cost-of-capital for firms and household increase by less. And if costs of capital for banks increases due to higher capital requirements *and* costs of capital increases for firms, then it implies a double failure of the MM-theorem. Firstly, the banks' shareholders do not adjust their required return on equity, and, secondly, firms absorb the extra funding costs. According to the MM-theorem, if debt-financing has become more expensive, the firms should use more equity financing and hence undue the higher costs-of-capital. Lastly, competition can be expected to push down lending margins and profits per unit of bank capital, as financial innovation steps in if banks operate permanently with higher profit margins.

In the model, banks can only increase their level of capital through higher profits. The model is a general equilibrium model, so resources need to come from somewhere; here domestic patient households. However, outside the model, banks can access the international financial market for funds. This leads us to the international dimension of the model. In the scenarios we have assumed that only Danish banks must increase their capital requirement. But there can be international spill overs: If as an example, capital requirements are increased in the euro area simultaneously, then the ECB is likely to use (conventional) monetary policy to ease the transition to a new and higher level for capital. This would in turn allow Danmarks Nationalbank to lower its policy rate and thus lower cost-of-capital for firms and households.

We study non-risk-weighted capital ratios, or leverage ratios. This is due to a lack of good data for risk-weighted capital ratios and, on the modelling side, a lack of a meaningful role for risk weights. The model could include weighted assets and we could set these weights as we see fit. But these weights would not reflect in a meaningful way risk as the model does not include defaults. However, it does imply that banks cannot change the composition of their portfolio of assets in response to higher capital requirements, e.g. shifting from relatively risky lending to safer lending.

We have chosen to use the model at hand as the benefits from doing so greatly out weight the disadvantages. The general equilibrium gives direct feed back from developments on the financial markets to the real economy. Our analyses have shown the structural modelling of the behavior of banks and the market structure under which the banks operate. This allows us to study in greater detail how banks act to changes in policy – as an example, different assumptions about dividends. Further, we have shown that it can be important to consider formations of expectations when analysing the question at hand. The impact on the costs today in terms of output can be dependent on economic agentss expectations about the impact of the policy change in the future.

With these caveats in mind, we summarise our findings. Key to both the long-run and short-run effects is the size of the MM effect. This is to a large extend an empirical question, which the model at hand only implicitly provides an answer to. We show in Figure (21) the effects on GDP from varying the size of the MM effect. The upper and lower bound for the transition costs of raising capital requirements for Danish banks when varying the size of the MM effect are 0.8 to 1.8 per cent of GDP. We also point to an additional insight: short-run costs also depends on the size of the MM effect through forward looking economic agents, who, in the case where the MM effect is zero, correctly anticipate a worse economic outcome in the future. They consequently lower their demand for investments and consumption already today. While the effects on GDP are highly dependent on whether ROE falls, we show that the speed of adjustment to the new capital ratio is almost unaffected by this assumption.

We take the a MM effect of one as a bench mark in the long run and for relatively low levels of capital seen today in Danish banks; if capital requirements are increased from 90 per cent to 91 per cent a bank has gone from being extremely safe to be slightly more safe. There are non-linearities at high levels of bank capital. The assumption that the MM-theorem holds in the long run is partly motivated by the implication of not lowering ROE within the model, as this would open up for an intruder with a slightly lower ROE to step in, lower the lending margins and capture customers.

We show that the costs of raising capital can be close to 0 if banks suspend dividend payments during the accumulation of bank capital. This is shown in Figure (22): Suspension of dividends shifts the set of possible outcome upwards when varying the MM effect, lowering the transition costs of raising capital for all assumptions with regards to the size of the MM effect. The intuition is that capital is built up faster and thus lending rates are kept less elevated and for a shorter time. Hence, the upper and lower bound for the transition costs of raising capital requirements for Danish banks, when varying the size of the MM effect and at the same time suspending dividends for 2 years, is between close to 0.1 and 1. We lastly stress that even in the case in which the MM-effect is 0, costs equal benefits if dividends are suspended during 2 years.

5. Conclusion and policy recommendations: Higher capital requirements for Danish banks are likely to increase welfare

In this paper we have analysed the costs and benefits of increasing capital requirements for Danish banks. On costs, we find that their size depends greatly on the banks' behavior in response to regulation. We argue that our estimates must be considered as upper bounds. We find that the costs can be close to 0 under two conditions. Firstly, banks suspend dividend payments during the 2 years after the announcement of the policy change, and secondly, investors' required return falls as new capital is accumulated. The latter implies an MM effect of 1 in the long run. No matter what is assumed about the size of the MM effect, suspension of dividend payments mitigates the costs of increasing capital requirements.

Key to the long-run effects is thus the size of the MM effect, or put differently, by how much shareholders change their demand for return when banks become safer investments. While there must be decreasing benefits of raising capital in terms of lowering the risk of bank failure, we have also shown that we are far from the point where costs outweigh benefits. Keeping ROE constant in response to a higher capital-to-asset ratio seems less convincing in equilibrium in a frictionless market. As we have shown, this implies permanently higher lending margins. These can and should be competed away in equilibrium. A well-functioning financial market with easy access to providing financial services and a competitive market are prerequisites for this to happen. Based on this, we believe that the MM theorem to a large extent holds in the long run.

Financial recessions are costly and are associated with large output losses, substantially larger than in regular business cycle recessions. It is therefore desirable to reduce the risk of future crises. Increasing capital ratios for Danish banks will make them more resilient to losses that can occur in periods of financial distress, and this will contribute to a more stable financial system. Naturally, there is a high degree of uncertainty about the costs of a future financial crisis. The output loss ultimately depends on the length and depth of a financial recession. We find the expected benefits from a 1 percentage point increase in capital ratios to be around 1 per cent of GDP. Curtailing excessive growth in credit and housing prices during an upswing can be expected to reduce the risk of future crises further, thereby increasing benefits.

We conclude that if shareholders in Danish banks decrease their required return on investment – not necessarily fully – when the banks become safer, and if the Modigliani-Miller effects are large, the benefits outweigh the social costs of increasing capital ratios. Increasing the capital ratios for Danish banks is therefore beneficial for Denmark as a whole. We thus confirm findings in similar studies for other economies. The difference is that we have shown this using Danish data and a model built to study the Danish economy.

Our study also provides the following insight and policy advice. If there is a political wish for higher capital requirements, these can be accompanied by a demand for suspension of dividend payments during a period. If the required return on equity does not fall in response to higher levels of capital, this outcome could imply, not that equity is more expensive than debt, but a lack of competition. This must be addressed with other instruments. If banks choose to use retained earnings as their primary source of capital, which apparently they chose to do in the accumulation of bank capital during the period 2009-12, see Cohen (2013), it is of course more difficult to raise capital in a recession, when profits are relatively low and write-downs are relatively high, than in an expansion when profits can be expected to be high. Moreover, we have shown that the reduction in the crisis probability is relatively high in expansions with relatively high growth in credit and house prices.

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6. Tables and figures

Year	AU	BE	CA	CH	DE	DK	ES	FI	FR	GB	IT	JP	NL	NO	PT	SE	US
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Note: AU - Australia. BE - Belgium. CA - Canada. CH - Switzerland. DE - Germany. DK - Denmark. ES - Spain. FI - Finland. FR - France. GB - United Kingdom. IT - Italy. JP -Japan. NL - Netherlands. NO - Norway. PT - Portugal. SE - Sweden. US - USA.

Table 1: **List of systemic financial crises**

	Loan to GDP growth$_{t-2}$	House price to GDP growth$_{t-2}$	Capital ratio$_{t-1}$
Parameters	0.107	0.112	-0.246
$p-$value	0.038	0.004	0.000
AUC	0.784		
AUC$_{const}$	0.630		
Number of observations	467		

Table 2: **Estimation result for logit model:**
The first row reports the estimated parameter values. The second row is robust $p-$values, clustered on the country level. Country-fixed effects included, but not reported. The AUC statistic with all predictors included are in the third row, and AUC$_{const}$ is the statistic with only country fixed effects included. AUC is significantly different from AUC$_{const}$ at the 1 per cent level.

	OLS	OLS, 1960-2013	OLS, 1980-2006	OLS, housing and loans	GLS
0	-2.038**	-2.018***	-2.608**	-1.725**	-1.359***
1	-3.590***	-3.462***	-5.250***	-2.924***	-2.847***
2	-4.485***	-4.493***	-6.278***	-3.640***	-3.441***
3	-5.396***	-5.249***	-6.102***	-4.563***	-3.981***
4	-6.107***	-5.893***	-5.287***	-5.460***	-4.692***
5	-5.734***	-5.560***	-4.706**	-5.355***	-4.041***
6	-4.617***	-4.474**	-4.486**	-4.318***	-2.608**

Table 3: **Impulse responses of GDP to financial crises:**
The first column is the number of years after a crisis. Columns 2-6 show the percentage change in output ($100 \cdot \beta^h$) relative to its pre-crisis trend for zero to 6 years after a financial crisis. ***, **, and * indicate significance at 1 per cent, 5 per cent, and 10 per cent level, respectively, using robust standard errors clustered at the country level.

	Transitory GDP loss	Permanent GDP loss	Mean
GDP loss (per cent)	26.764	141.954	84.359
Decline in crisis probability	1.210		
Expected benefit	0.324	1.717	1.020

Table 4: **Expected benefits of a 1 percentage point higher capital ratio:**
Present value of GDP loss assuming either transitory or permanent effects of a financial crisis, and the mean of the two. The discount rate is 4 per cent. The associated expected benefit is in the bottom row.

Modigliani-Miller effect	1	$\frac{1}{2}$	0
Constant dividend ratio	0.8	1.25	1.8
Dividends suspended 2 years	0.1	0.5	1

Table 5: **Estimates of costs of raising capital requirements:**
By Modigliani-Miller effects is meant to which degree that return-on-equity falls as the capital ratio increases. The figures in the table is calculated as explained in the text in section (4.3), and shown in the figures.

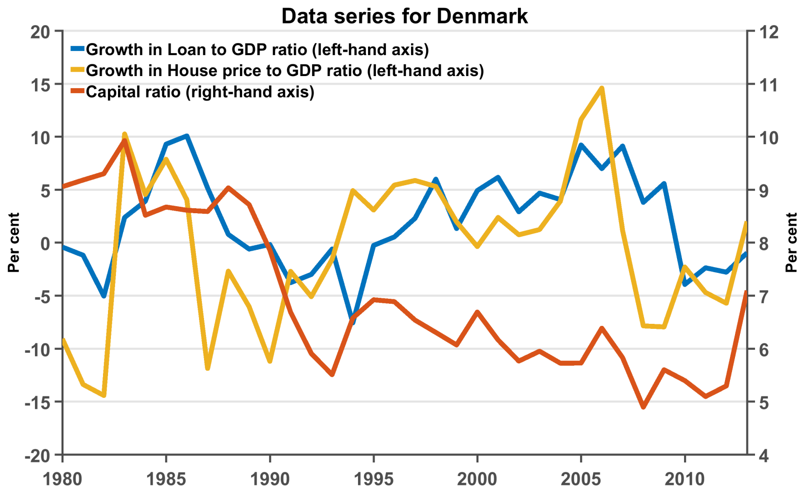


Figure 1: **Data series for Denmark**
In the figure is shown the growth rate in the loan to GDP ratio, the growth rate in house price to GDP ratio, and the capital ratio for Danish banks.

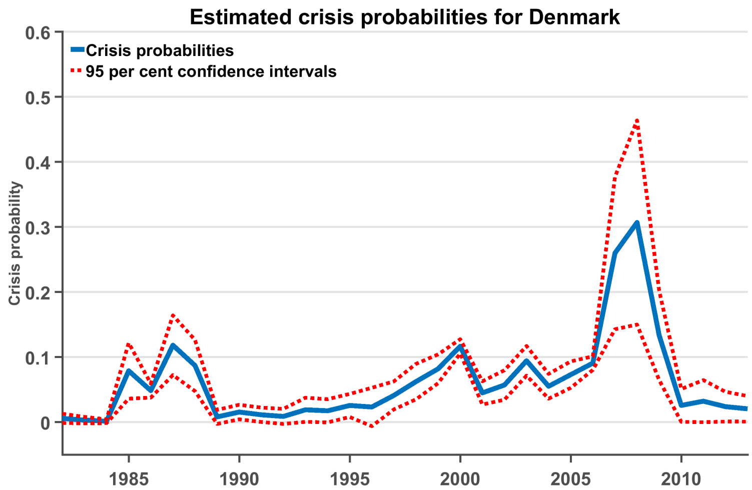


Figure 2: **Crisis probabilities for Denmark**
The figure shows the estimated probabilities through time of ending in a financial crisis in Denmark. The methodology is presented in section (3.3).

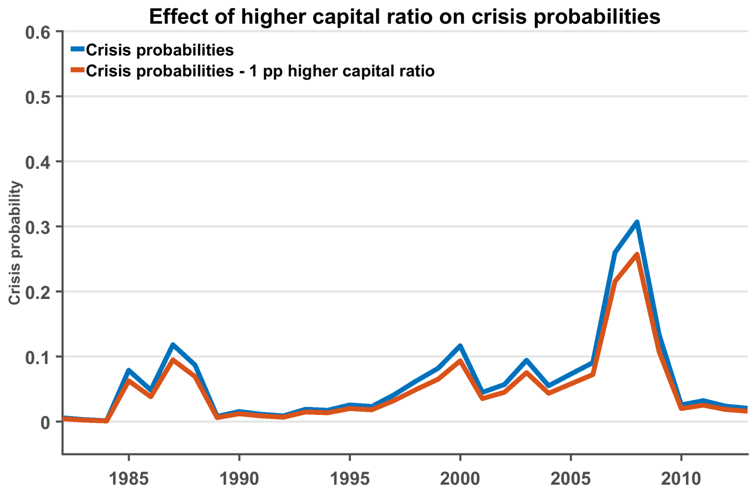


Figure 3: **Effect of a higher capital ratio**
The figure shows the estimated probabilities through time of ending in a financial crisis in Denmark at actual and a 1 percentage point higher capital ratio. The methodology is presented in section (3.3).

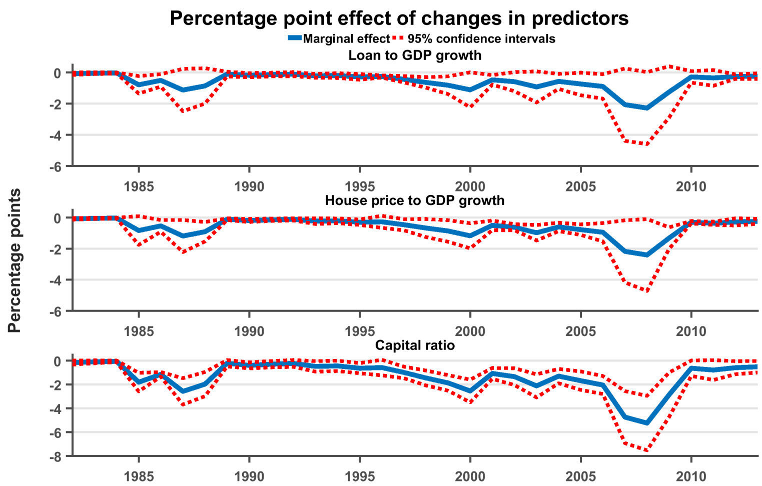


Figure 4: **Marginal effects of a chance in variables**
The solid lines are marginal effects of a 1 percentage point decrease in loan and house price growth relative to GDP, and a 1 percentage point increase in the capital ratio. Dashed lines are 95 per cent confidence intervals.

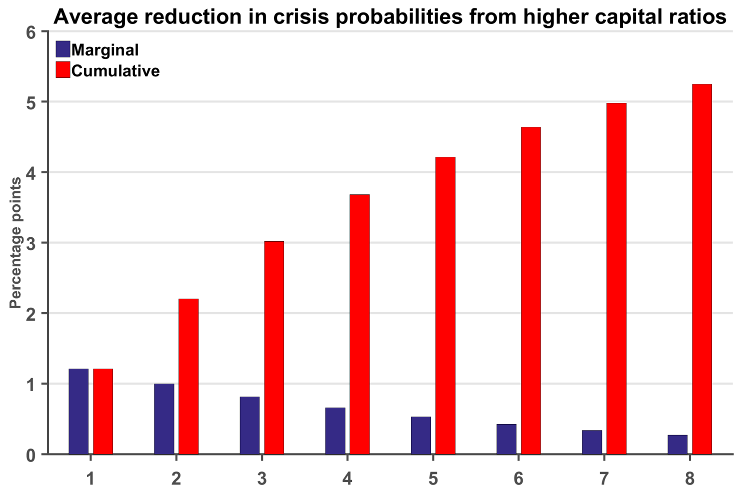


Figure 5: **Effect of further increases in capital ratios**
The bars show the average reduction through time in the risk of a financial crisis from a 1-8 percentage point higher capital ratio. The blue bars show the marginal reduction, and the red bars show the cumulative reduction.

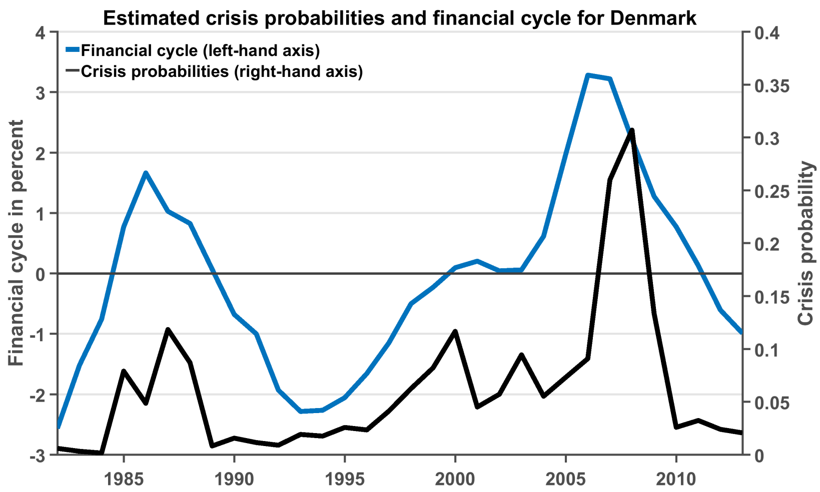


Figure 6: **Crisis probabilities and financial cycle**
In the figure is shown the financial cycle estimated on Danish data (left-hand axis), and the estimated probabilities through time of ending in a financial crisis (right axis), also shown in Figure (2). The financial cycle is estimated in Grinderslev et al. (2017).

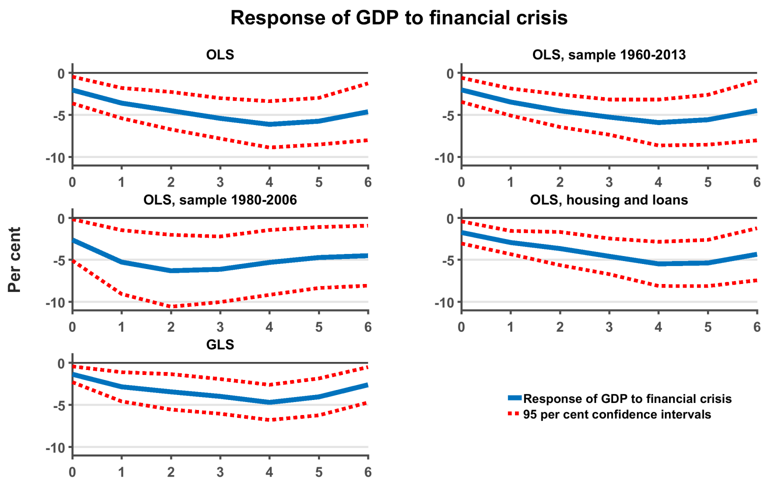


Figure 7: **Response of GDP to financial crisis**
The solid lines show the response of GDP to a financial crisis (per cent). The dashed lines are 95 per cent confidence bands.

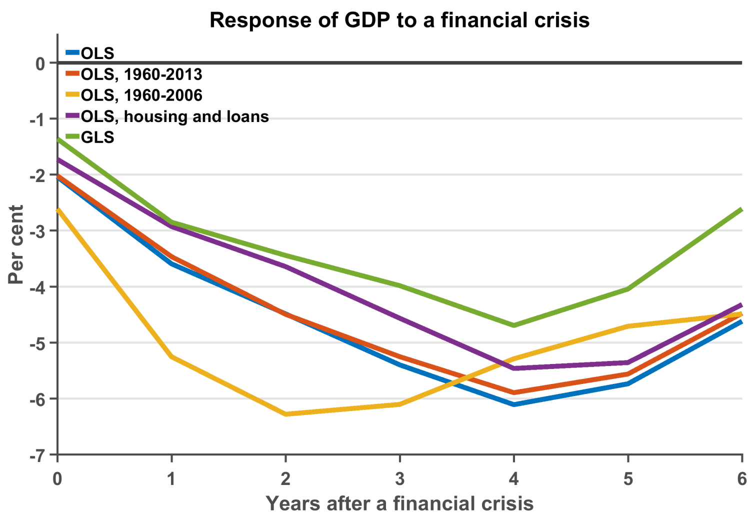


Figure 8: **Response of GDP to a financial crisis**
In the figure is shown the response of GDP to a financial crisis for 5 different specifications of the model described in the text. The responses are identical to the ones shown in Figure (7) and shown here to facilitate comparison.

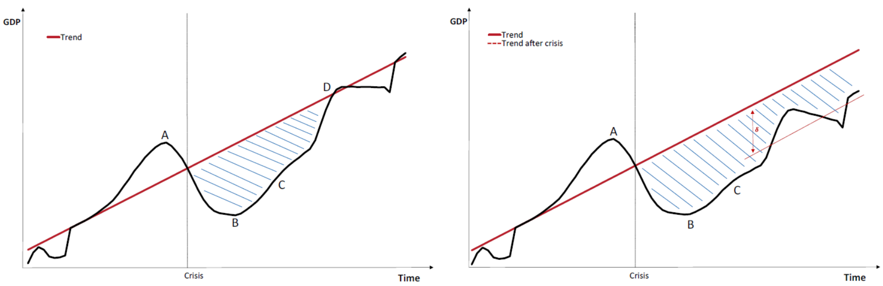
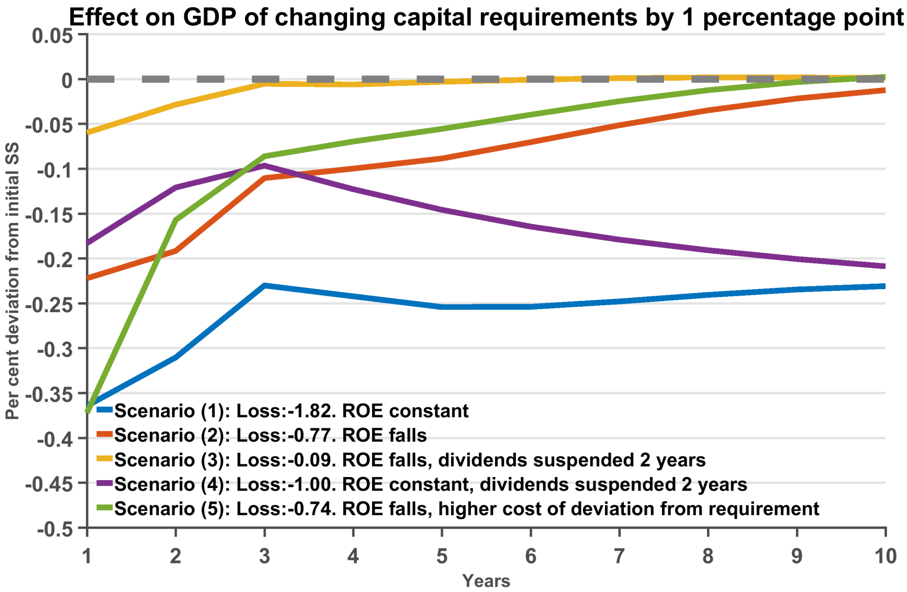


Figure 9: **Illustration of permanent and temporary costs of a financial crisis**
Source: Staff memo, Sveriges Riksbank, May 2017.



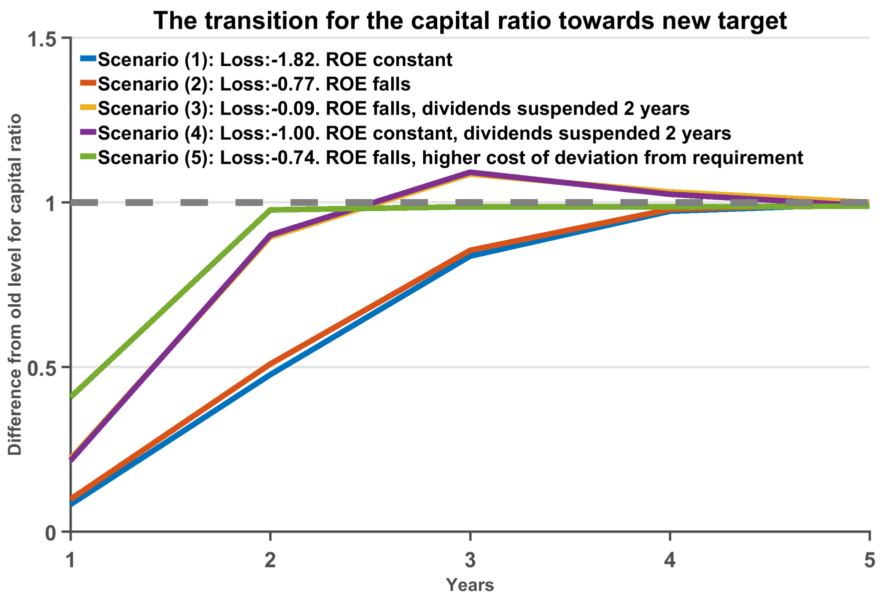


Figure 10: **The effect of a 1 percentage point permanent increase in capital requirement**
In the top figure is shown the effect on GDP from changing the capital requirement for banks permanently by 1 percentage point. The x-axis denotes years and the y-axis denotes percentage deviations from the initial steady state. As an example, -0.2 must be interpreted as GDP being -0.2 per cent lower than it would otherwise have been if the capital requirement had not been changed. Loss refers to the difference between the base-line scenario and the respective transition paths for GDP from period 0 until the economy has reached its new steady state discounted to the present using the steady state discount factor in the model.
In the bottom figure is shown the transition path for the capital ratio in the different scenarios.

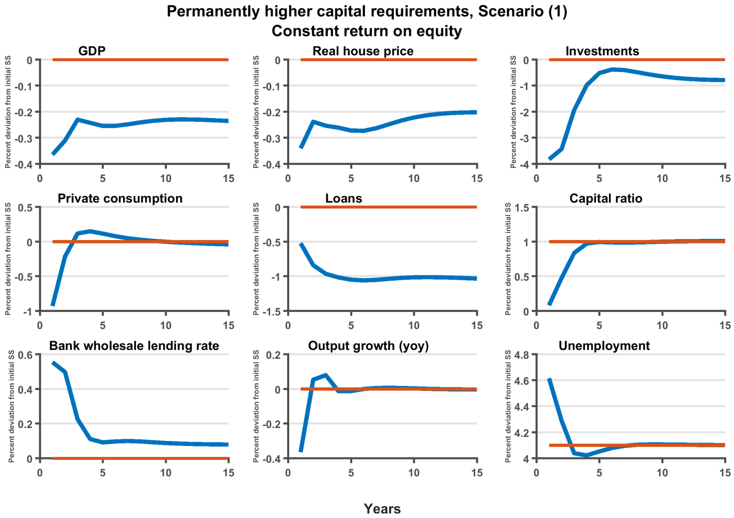


Figure 11: **The effect of a 1 percentage point permanent increase in capital requirement: - ROE and dividend ratio kept constant**
In the figure is shown the effect from changing the capital requirement for banks permanently by 1 percentage point. The x-axis denotes years and the y-axis denotes percentage deviations from the initial steady state. As an example, -0.1 must be interpreted as GDP being -0.1 per cent lower than it would otherwise have been if the capital requirement had not been changed.

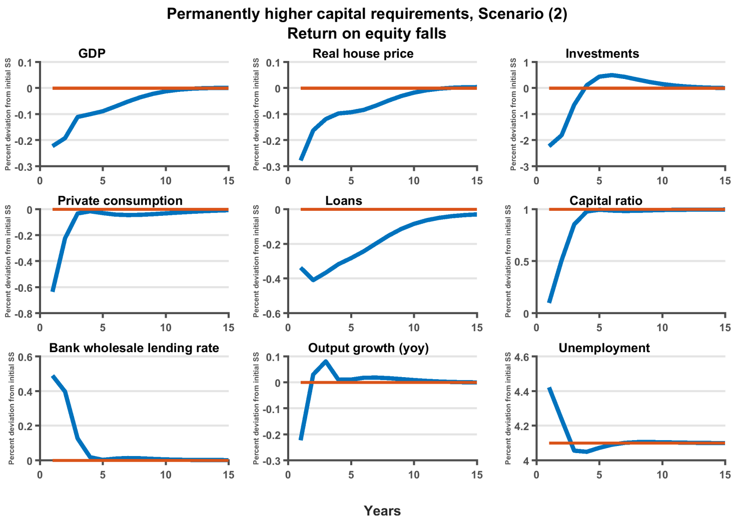


Figure 12: **The effect of a 1 percentage point permanent increase in capital requirement: - ROE is allowed to fall, dividend ratio kept constant**
In the figure is shown the effect from changing the capital requirement for banks permanently by 1 percentage point. The x-axis denotes years and the y-axis denotes percentage deviations from the initial steady state. As an example, -0.1 must be interpreted as GDP being -0.1 per cent lower than it would otherwise have been if the capital requirement had not been changed.

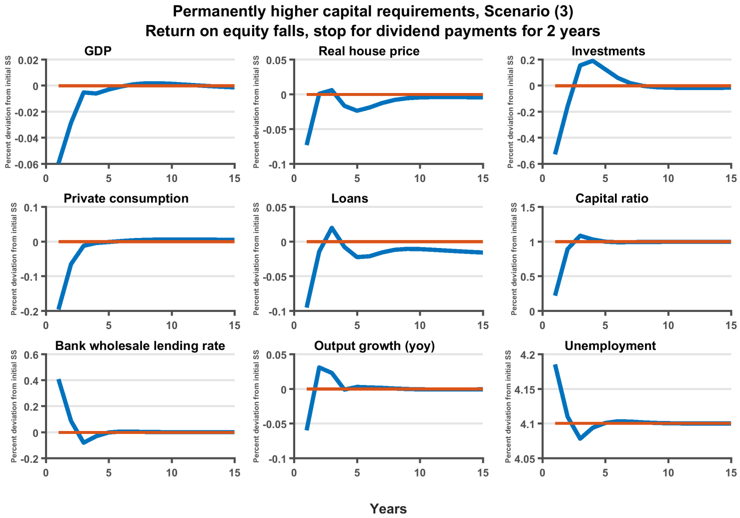


Figure 13: **The effect of a 1 percentage point permanent increase in capital requirement: - ROE is allowed to fall, 0 dividends for two years**

In the figure is shown the effect from changing the capital requirement for banks permanently by 1 percentage point. The x-axis denotes years and the y-axis denotes percentage deviations from the initial steady state. As an example, -0.1 must be interpreted as GDP being -0.1 per cent lower than it would otherwise have been if the capital requirement had not been changed.

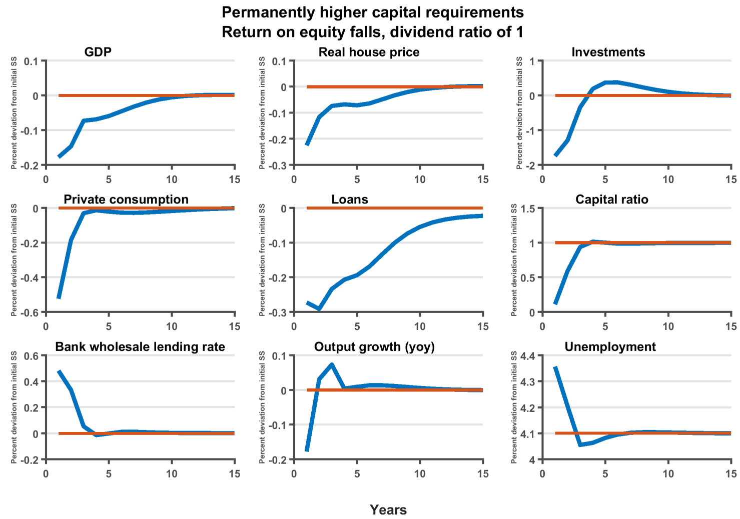


Figure 14: **The effect of a 1 percentage point permanent increase in capital requirement: - ROE is allowed to fall, no dividends**

In the figure is shown the effect from changing the capital requirement for banks permanently by 1 percentage point. The x-axis denotes years and the y-axis denotes percentage deviations from the initial steady state. As an example, -0.1 must be interpreted as GDP is -0.1 per cent lower than it would otherwise have been if the capital requirement had not been changed.

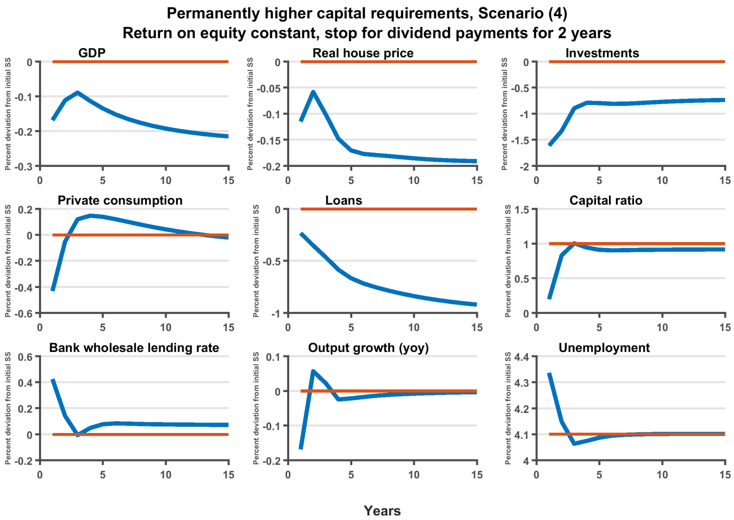


Figure 15: **The effect of a 1 percentage point permanent increase in capital requirement: - ROE is constant, 0 dividends for 2 years**
In the figure is shown the effect from changing the capital requirement for banks permanently with 1 percentage point. The x-axis denotes years and the y-axis denotes percentage deviations from the initial steady state. As an example, -0.1 must be interpreted as GDP is -0.1 per cent lower than it would otherwise have been if the capital requirement had not been changed.

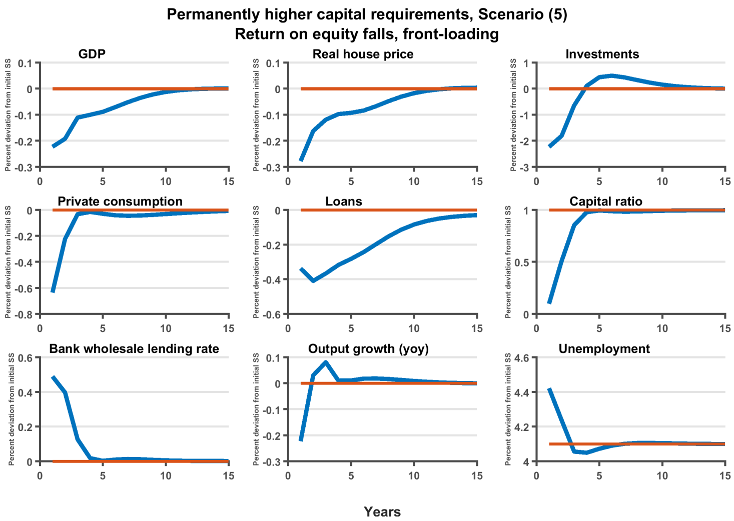


Figure 16: **The effect of a 1 percentage point permanent increase in capital requirement: - ROE is allowed to fall, dividend-ratio kept constant, higher costs of deviating from required capital ratio**
In the figure is shown the effect from changing the capital requirement for banks permanently with 1 percentage point. The x-axis denotes years and the y-axis denotes percentage deviations from the initial steady state. As an example, -0.1 must be interpreted as GDP being -0.1 per cent lower than it would otherwise have been if the capital requirement had not been changed.

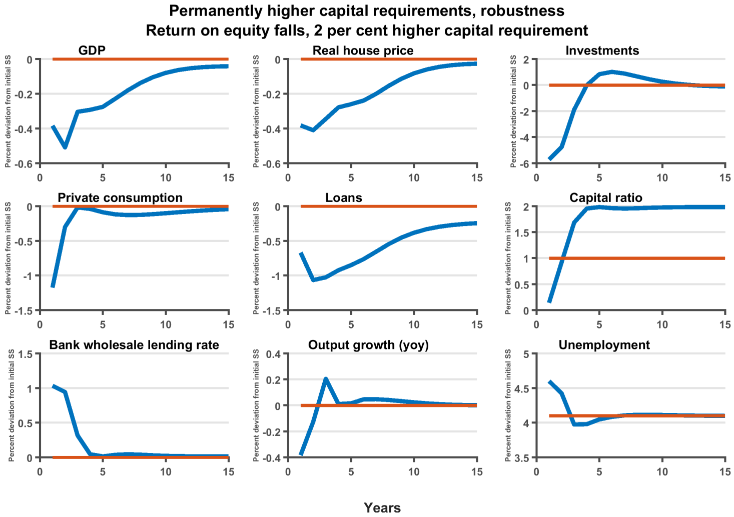


Figure 17: **The effect of a 2 percentage point permanent increase in capital requirement: - ROE and dividend ratio kept constant**
In the figure is shown the effect from changing the capital requirement for banks permanently with 1 percentage point. The x-axis denotes years and the y-axis denotes percentage deviations from the initial steady state. As an example, -0.1 must be interpreted as GDP is -0.1 per cent lower than it would otherwise have been if the capital requirement had not been changed.

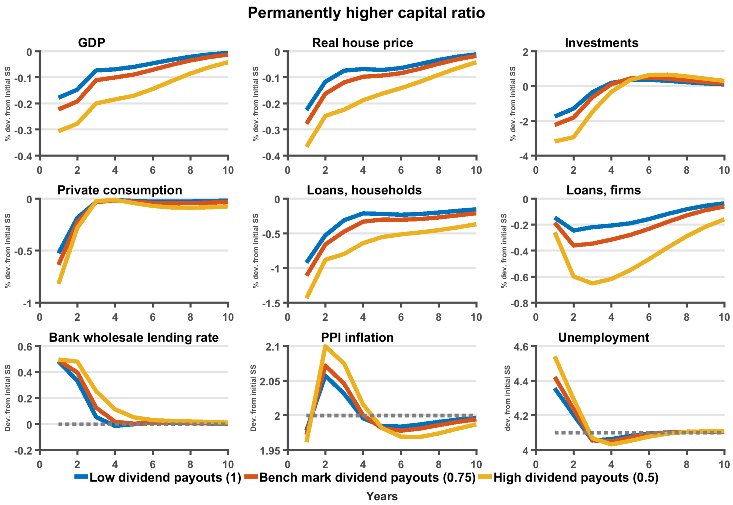


Figure 18: **The effect of a 1 percentage point permanent increase in capital requirement: - ROE is allowed to fall, effect of different dividend ratios**
In the figure is shown the effect from changing the capital requirement for banks permanently with 1 percentage point. The x-axis denotes years and the y-axis denotes percentage deviations from the initial steady state. As an example, -0.1 must be interpreted as GDP is -0.1 per cent lower than it would otherwise have been if the capital requirement had not been changed.

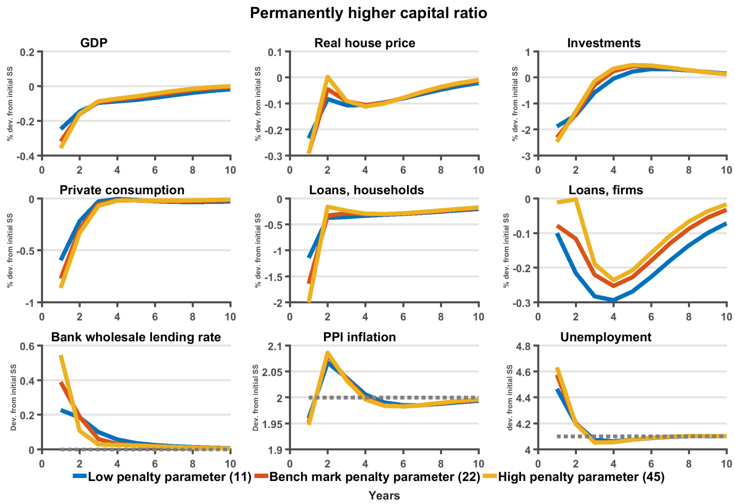


Figure 19: **The effect of a 1 percentage point permanent increase in capital requirement: - ROE is allowed to fall, effect of different cost of deviating from required capital ratio**
In the figure is shown the effect from changing the capital requirement for banks permanently with 1 percentage point. The x-axis denotes years and the y-axis denotes percentage deviations from the initial steady state. As an example, -0.1 must be interpreted as GDP is -0.1 per cent lower than it would otherwise have been if the capital requirement had not been changed.

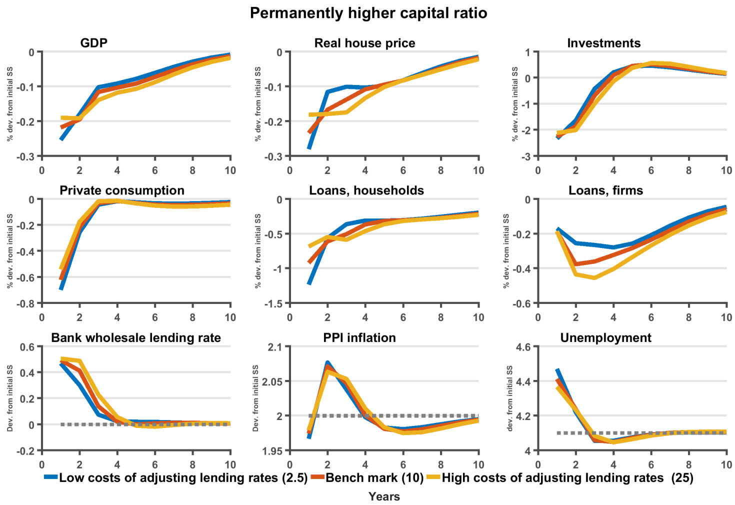


Figure 20: **The effect of a 1 percentage point permanent increase in capital requirement: - ROE is allowed to fall, effect of different cost of changing interest rates**
In the figure is shown the effect from changing the capital requirement for banks permanently with 1 percentage point. The x-axis denotes years and the y-axis denotes percentage deviations from the initial steady state. As an example, -0.1 must be interpreted as GDP being -0.1 per cent lower than it would otherwise have been if the capital requirement had not been changed.

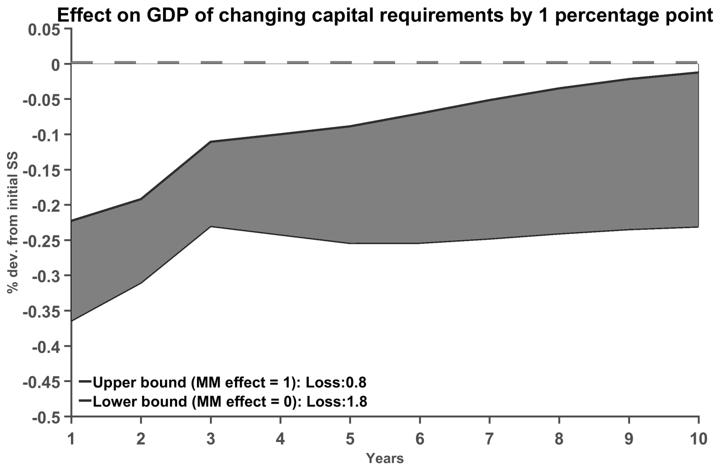


Figure 21: **Effect on costs of 1 percentage point permanent increase in capital requirement and the MM-effect**
In the figure is shown the bounds for the costs of increasing capital requirement for banks by 1 percentage point for varying degrees of the MM effect. That is, the lower part of the figure is the case when the MM effect is zero: Return on equity is constant and equal to the value in the old steady state. The upper bound is the case in which the MM effect is 1 in the long run such that return on equity falls in tandem with higher level of capital.

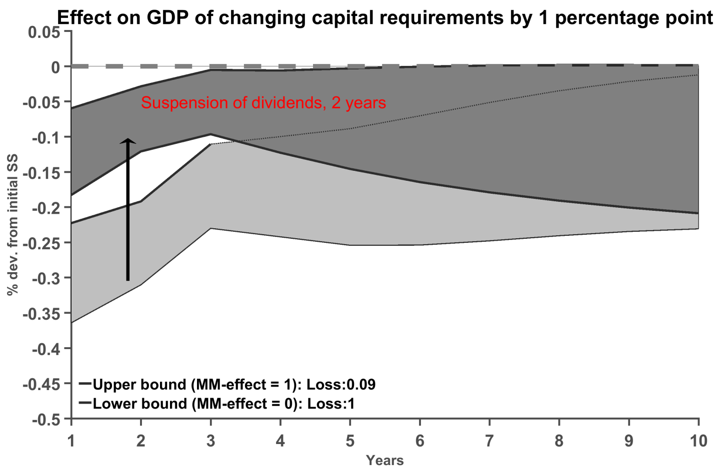


Figure 22: **Effect on costs of 1 percentage point permanent increase in capital requirement and the MM effect – Case in which dividends are suspended for 2 years**
In the figure is shown the bounds for the cost of increasing capital requirement for banks by 1 percentage point for varying degrees of the MM effect. That is, the lower part of the figure is the case when the MM effect is zero: Return on equity is constant and equal to the value in the old steady state. The upper bound is the case in which the MM effect is 1 in the long run such that return on equity falls in tandem with higher level of capital.