Macroeconomic Effects of Banking Sector Losses across Structural Models*

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Abstract

The macro spillover effects of capital shortfalls in the financial intermediation sector are compared across five dynamic equilibrium models developed by economists at the Federal Reserve Board. Although all the models considered share antecedents and a methodological core, each model emphasizes different transmission channels. This approach delivers a range of responses reflecting model uncertainty for the real and financial effects of shocks originating in the financial sector.

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1 Introduction

The financial crisis has proved a catalyst for academic research to incorporate financial frictions and an explicit role for an intermediation sector in a general equilibrium framework. In addition, the crisis has reignited the interest in the causes and consequences of shocks affecting the balance sheet of banks, as shown for instance by the increased reliance on regulatory stress tests as an instrument of macroprudential policy.

In this paper, we argue that this research can offer useful insights into the propagation of capital shortfalls in the intermediation sector to the rest of the economy. Prosaically, formulating scenarios for stress tests not only requires identifying macro conditions that are going to be challenging for financial institutions, but also involves sizing the potential ramifications of shortfalls in capital at financial institutions for the rest of the economy. This paper includes models developed by five of groups of researchers working independently at the Federal Reserve Board. Our original contribution lies in the meta-analysis of results from the different models rather than in the formulation of the models themselves.[1] Although all the models presented share common antecedents and a common methodological core, they have evolved in complementary directions. Accordingly, comparisons of simulation results from these models, with an eye to identifying the structural features chiefly responsible for quantitative differences, can provide a useful assessment of the spillover effects of shortfalls in capital to the rest of the macroeconomy.

To the extent that quantitative models are needed for policy analysis, and to the extent that different models give starkly different quantitative predictions, it is useful to investigate the origins of these differences. We find that not only do different modeling approaches to capture financial frictions affect the propagation of financial shocks, but also that seemingly less-relevant differences related to the non-financial aspects of the models can generate important differences in the propagation of financial shocks.

Each of the models presented emphasizes different aspects of the nexus between a financial sector and the rest of the economy.

1. The model by *Iacoviello* allows two financial frictions to coexist in that both bankers and entrepreneurs are constrained in how much they can borrow from patient savers. A key feature of the model is that entrepreneurs own commercial real estate, which enters the production function for final goods and which which can be posted as collateral against loans.

2. The model by *Covas and Driscoll* also features credit constraints on bankers and entrepreneurs. In addition, a corporate sector is included so that the banking sector need not fund the entire economy. A key distinction of their approach is that the model is solved with global nonlinear methods, rather than by a linear approximation that imposes that all credit constraints are

[1] Each of the 5 models in this paper is described more fully in related work cited below.

always binding.

3. The model by *Kiley and Sim* is set up to study the interaction between financial frictions and monetary policy. In all the models covered here, financial intermediaries have access to debt markets and retained earnings. In addition, a key feature of the model developed by Kiley and Sim is that financial intermediaries can access external equity markets to finance their investments, which allows them an explicit treatment of dilution costs related to the expansion of external equity.

4. The interaction between inside and outside equity is also at the center of *Queralto*'s model. An agency problem justifies the constraints on borrowing faced by the financial sector in his model. The agency problem is devised in such a way that financial intermediaries face a trade off between short-term debt and outside equity. In turn, this endogenous tradeoff is affected differently by different sources of fluctuations.

5. Finally, the model developed by *Guerrieri and Jahan-Parvar* is geared to the analysis of monetary policy and takes into account the zero lower bound on nominal interest rates. A salient characteristic of the model is the interaction between two groups of firms. One group of firms can only raise external funds through financial intermediaries, while the other group of firms has direct access to financing from households.

To facilitate comparisons across models, each of the self-contained model sections to follow considers one particular form of capital shortfall, namely a transfer of funds from the banking sector to the household sector. This transfer takes place in a lump-sum fashion and does not distort at the margin the actions of the household sector. Accordingly, it could also be thought of as shock that simply destroys some assets on the balance sheet of the banking sector. While each model has features that can be used to analyze a plethora of distinct financial shocks, the baseline transfer shock has the virtue of being easily implemented and comparable across all models. In addition, the baseline transfer shock is a initially a "pure" financial shock in that it does not imply, per se, the depletion of real resources. In that respect, it is fair to characterize the macro repercussions as "spillover effects" from the financial sector to the the rest of the macroeconomy.

Each model section presents results for the evolution of key macro variables, such as aggregate output, consumption and investment. It also reports some key financial variables, such as bank capital and spreads between interest rates on deposits and on loans. Sensitivity analysis with respect to key parameters focuses on plausible changes in calibration that can result in large differences in macro outcomes.

In addition to the baseline transfer shock each model section presents the effects of a distinct financial shock that leads to a shortfall in capital for the banking sector, e.g. a housing shock or a change in capital requirements. These additional shocks are calibrated to produce a capital shortfall that is comparable to that of the transfer shock. Because each distinct shock considered has different propagation channels this exercise provides additional insights on the mechanisms by which financial shocks affect the macroeconomy.

This approach can deliver "model-based confidence intervals" relative to the effects of financial shocks. Comparison of results across models is informative about the importance of different modeling approaches in influencing the quantitative implications of standardized shocks. Moreover, the sensitivity analysis regarding parameter choices is meant to produce envelop results relative to the possible spillover effects of capital shortfalls. Finally, the comparison of shocks other than the baseline transfer shocks across models reinforces the intuition that the underlying causes of a capital shortfall in the financial sector are important in predicting the subsequent spillover effects to the rest of the economy.

The rest of the paper proceeds as follows. Section 2 describes the calibration of the baseline transfer shock. Section 3 provides a horizontal comparison of the effects of the baseline transfer shocks across models. Each of the sections from 4 to 8 are dedicated to the description of results from individual models as well as sensitivity analysis on the source of the capital shortfall. Section 9 concludes.

2 Calibration of the Baseline Transfer Shock

In order to provide informative comparisons across the linear and nonlinear models considered, the calibration of the size for the baseline transfer shock from the financial sector to the household sector is chosen to be large, but empirically-realistic. The shock size is in line with the results from the stress tests for the U.S. banking sector mandated by the the Financial Reform Act. These stress tests, whose main goal is to assess the solvency of the banking system in the face of rapidly deteriorating macroeconomic conditions, provide useful information regarding the magnitude of empirically-relevant capital shortfalls. We use the results for the Comprehensive Capital Analysis and Review (CCAR) of 2013. According to these results, under a severely adverse scenario for the U.S. economy, total projected losses of the 18 bank holding companies included in the stress test amounted to a cumulative total of $462 Billion for the 9 quarters from 2012q4 through 2014q4. For context, these losses are conditional on a scenario designed to be comparable to the Great Recession.[2].

These losses amount to about 3% of 2012 GDP. Only the top 18 banks by assets were included in the stress test exercise. To calibrate the baseline transfer shock to capture plausible losses for the entire banking system and not just the largest banks, we scale up the magnitude of the transfer to reflect that the CCAR banks account for about 60% of banking assets (the sum of assets of depository institutions and bank holding companies in the Flow of Funds). Furthermore, a second rescaling is

[2] Cumulative losses are disclosed in a press release issued by the Federal Reserve, available at http://www.federalreserve.gov/newsevents/press/bcreg/dfast_2013_results_20130314.pdf

applied to reflect that traditional banks account for about 70% of the asset of the banking sector, defined as traditional banking institutions in addition to bank-like institutions.[3]

Accordingly, the baseline transfer shock entails a reduction in assets equal to 7.5% of GDP (=3 %/0.6/0.66) cumulatively over the first 9 quarters following the transfer. The shock is phased in using an autoregressive process of order 1 with a persistence equal to 0.9. The desired cumulative transfer over 9 quarters is used to pin down the initial innovation to the shock process.

3 Horizontal Comparison of Results

Before describing each of the models in greater detail, this section provides a horizontal comparison of the transfer shock from the financial sector to the household sector. To highlight the similarities and differences across the various models, Table 1 shows the choices available to financial intermediaries that are salient in the reaction to a capital shortfall for the various models in this paper. The summary in the table hews closely to the action set available to banks in reaction to changes in capital requirements, as summarized in an interim report of the BIS Macroeconomic Assessment Group BCBS (2010). In addition to issuing new equity and to increasing retained earnings, the BIS report highlights that banks may in fact attempt to increase risk-weighted assets by shifting balance sheet composition towards less risky assets in ways not captured by any of the models presented here. Another feature not captured by any of the models presented is the possibility that banks could speed up the recapitalization process by increasing fees or, more generally, other sources of non-interest income. The table highlights that the models presented do in fact expand a core framework in complementary directions. However, one source of homogeneity across models is that the financial sector is engaged in liquidity provision, and not in liquidity transformation, which could contribute to understating the macroeconomic repercussions of financial shocks.

Figure 1 compares the effects of the baseline transfer shock across models. As shown in the top left portion of the chart, taking into account differences between yearly and quarterly frequency of the different models, the size of the transfer shock is standardized. Despite the standardization of the cumulative transfer, the hit to bank equity across models differs greatly. In the general equilibrium approach common to all the models, the exogenous shortfall has drastically varied implications for bank net equity. Apart from additional model-specific mechanisms, bank net equity does not simply reflect the size of the exogenous transfer shock because the general equilibrium nature of the models

[3] The share of assets of traditional banking institutions is derived from the following FF series: 1-((FL704090005.Q+FL734090005.Q)/((FL413065005.Q+FL674090005.Q+FL614090005.Q+FL664090005.Q+FL504090005.Q)+(FL704090005.Q+FL734090005.Q))) 1-((Total Financial Assets of Private Depository Institutions + Total Financial Assets of Holding companies)/((Agency-and GSE-backed mortgage pools; total mortgages; asset + Issuers of asset-backed securities; total financial assets + Finance companies; total financial assets + Security brokers and dealers; total financial assets + Funding corporations; total financial assets) + (Total Financial Assets of Private Depository Institutions + Total Financial Assets of Holding companies)))

imply important movements in asset prices, which feed back into the determination of the hit to bank net equity. At one end of the extreme, the multi-sector model of Guerrieri and Jahan-Parvar implies only a modest drop in bank net equity which mounts as the transfer shock builds in size. Demand from firms not reliant on bank credit keeps asset prices afloat.[4] At the other end of the spectrum, in the model by Covas and Driscoll, the anticipated drop in credit resulting from the mounting transfer shock leads to a sizable fall in bank equity since their nonlinear modelling approach does not assume capital constraints that bind all the time. Accordingly banks can lower their equilibrium capital ratios offset the effect of the capital shortfall shock.

Across all models, the drop in net equity leads to a contraction in the supply of credit and an increase in the spread between interest rates on lending and on deposits. Despite differences in magnitudes, the persistence of the movements is elevated across all models and reflects the persistence of the drop in net equity. In this respect, the model of Kiley and Sim is an outlier in our group. In that model, access to outside equity allows for a quicker recapitalization of the financial sector that reduces the persistence of the drop in net equity and of the change in spreads between lending and deposit rates. While firms in the model of Queralto also have access to outside equity that could potentially curb the persistence of the response of bank equity in a similar fashion, in that model outside equity is intertwined with the specification of the principal-agent problem at the core of the model in such a way that financial intermediaries prefer to avoid recapitalizing more quickly and rely more prominently on the accumulation of internal equity through retained earnings. Because these modelling differences ride through general equilibrium channels, a limited information approach to the estimation of the cost of issuance of outside equity would be ill-suited to discriminating between these different results.

Notably, some of the differences in the response of net equity in the model by Covas and Driscoll are made more apparent by a different calibration approach that focuses on matching details of the commercial banking sector, rather than a stylized overall financial sector in the other models, and results in a magnification in the drop of bank capital in percent terms.

The disparities in the behavior of bank equity account to a large extent for the different spillover effects to the rest of the macroeconomy, as made apparent by the right column of Figure 1. Focusing again on outliers, the drop in investment ranges between about 2 and 14 percent. A variety of modelling choices accounts for these disparities. The responses in the model of Guerrieri and Jahan-Parvar and in the model of Covas and Driscoll are compressed due to the interaction among sectors – the sector-specific transfer shock is compensated by increased lending from complementary sources. Such mechanism, by contrast, is muted in the Iacoviello and Kiley and Sim's models. In Iacoviello's model, even if 50 percent of capital is produced by unconstrained firms, the complementarities across

[4] As shown above, even in the model of Guerrieri and Jahan-Parvar, an economy- wide shock would lead to large reductions in asset prices more closely comparable to those obtained in the other models presented.

constrained and unconstrained firms are such that unconstrained firms cannot undo the drop in labor and capital demand that follow a credit crunch. Similar mechanisms also apply to Kiley and Sim's model.

The consumption side reflects an even broader range of outcomes. In fact in some models, the baseline financial shock *boosts* aggregate consumption – the transfer shock considered is a windfall for the household sector. In other models, such as that of Covas and Driscoll and that of Iacoviello, the windfall is offset by the fact that the banking sector cuts dividends sharply in order to boost the recapitalization process by retaining earnings. The models of Queralto and of Guerrieri and Jahan-Parvar do not embed this mechanism as dividends are not explicitly modeled.

Finally all models predict a contraction in output, but the magnitudes differ greatly, ranging from a 5 percent contraction of the model of Iacoviello to a contraction below 0.5 percent in the model by Guerrieri and Jahan-Parvar. Apart from the interaction across sectors, sensitivity analysis to parametric assumptions brings out the importance of the interaction between financial frictions and the labor market to gauge the effects on aggregate output. With capital predetermined in all models and with the transfer shock not able to affect real assets on impact, the immediate fall in output has to ride through a contraction in hours worked. In this respect, apart from extant differences in modeling approaches, different calibration choices regarding the Frisch elasticity of labor supply across the models play an important role in determining disparities in results.

The range of outcomes for GDP spans a wide range of outcomes. Each model emphasizes particular transmission channels and leaves others out, thus it is perhaps no surprise that the response of aggregate output varies greatly across models. In order to check if any of the models presented are outliers relative to simple empirical evidence, we considered a variety of vector auto-regressions. Capital shortfalls can stem from sources ranging from changes in the valuation of available-for-sale assets on the portfolio of banks to reductions in income. The simple empirical evidence presented below focuses on increases in charge-offs on loans and leases.

We run a simple bivariate VAR of GDP growth and charge-off rates on loans and leases for the period 1985:Q1-2013:Q1 using four lags. Using a simple recursive identification scheme, we identify two shocks: a macro shock, an innovation to GDP that contemporaneously affects loan charge-offs; and a loan charge-off shock (a banking shock), which does not affect GDP contemporaneously. We then rescale the loan charge-off shock so that, when expressed as a fraction of GDP, total loan charge-offs rise after 9 quarters so as to imply a shortfall sized at 7.5 percent of GDP, just like in our model comparison exercise. The VAR results are shown in Figure 2. The shock to loan charge-offs, shown in the bottom row, produces a mean contraction for GDP in the neighborhood of 2 percent after 2 years. The 90 percent confidence interval for the GDP response encompasses all the model results presented in Figure 1. These findings mirror a similar range of uncertainty in outcomes from simple empirical frameworks presented in BCBS (2010).

4 Matteo Iacoviello: An Estimated Model of Banks with Financing Frictions

The model in Iacoviello (2013) is a discrete-time economy. The economy features four agents: patient households (savers), impatient households (borrowers), bankers, and entrepreneurs. In the following, we present the key elements of Iacoviello's model abstracting from a variety of frictions that are introduced by Iacoviello in order to take the model to the data.[5]

Each agent has a unit mass.[6] Households work, consume and buy real estate, and make one-period deposits into a bank. The household sector in the aggregate is net saver. Entrepreneurs accumulate real estate, hire households, and borrow from banks. In between the households and the entrepreneurs, bankers intermediate funds. The nature of the banking activity implies that bankers are borrowers when it comes to their relationship with households, and are lenders when it comes to their relationship with the credit-dependent sector – entrepreneurs – of the economy. Iacoviello designs preferences in a way that two frictions coexist and interact in the model's equilibrium: first, bankers' are credit constrained in how much they can borrow from the patient savers; second, entrepreneurs are credit constrained in how much they can borrow from bankers.

Entrepreneurs are subject to a borrowing constraint of the form:

$$L_{E,t} \leq m_H \frac{q_{t+1}}{R_{E,t+1}} H_{E,t} - m_N W_{H,t} N_{H,t}$$

Here, $L_{E,t}$ are loans that banks extend to entrepreneurs (yielding a gross return $R_{E,t}$). Entrepreneurs own housing $H_{E,t}$ (commercial real estate) which, combined with household labor, is used by final good firms to produce the final output Y_t.

Denoting with $\lambda_{E,t}$ the Lagrange multiplier on the borrowing constraint, the first order conditions for optimization for loans is given:

$$\left(1 - \lambda_{E,t} + \frac{\partial ac_{LE,t}}{\partial L_{E,t}}\right) u_{CE,t} = \beta_E R_{E,t+1} u_{CE,t+1}$$

As the first–order condition show, the credit constraint (as proxied by the Lagrange multiplier $\lambda_{E,t}$) introduce a wedge between the cost of factors and their marginal product, thus acting as a tax on the demand for credit and for the factors of production.

The other key agents in the model are bankers. A continuum of unit measure bankers solve the

[5] The full model description (including the calibrated parameters for the exercises below) can be found in Tables 1 and 2 and in Appendix B of Iacoviello's paper.

[6] Except for the introduction of the banking sector, the model structure closely follows a flexible price version of the basic model in Iacoviello (2005), where credit-constrained entrepreneurs borrow from households directly. Here, banks intermediate between households and entrepreneurs.

following problem:

$$\max \sum_{t=0}^{\infty} \beta_B^t \log C_{B,t}$$

where $\beta_B < \beta_H$, and where β_H is the household's discount factor subject to:

$$C_{B,t} + R_{H,t-1}D_{t-1} + L_{E,t} + ac_{EB,t} = D_t + R_{E,t}L_{E,t-1} - \varepsilon_t$$

where the D are household deposits, L_E are loans to entrepreneurs, and C_B is banker's private consumption. Note that this formulation is analogous to a formulation where bankers maximize a convex function of dividends (discounted at rate β_B), once C_B is reinterpreted as the residual income of the banker after depositors have been repaid and loans have been issued. Iacoviello assumes that the bank is constrained in its ability to issue liabilities by the amount of equity capital (assets less liabilities) in its portfolio. This constraint can be motivated by regulatory concerns or by standard moral hazard problems. Letting $K_{B,t} = L_{E,t} - \varepsilon_t - D_t$ define bank capital at the end of the period (after loan losses caused by redistribution shocks have been realized), a capital requirement constraint can be reinterpreted as a standard borrowing constraint, such as:

$$D_t \leq \gamma_E \left(L_{E,t} - \varepsilon_t \right).$$

Above, the left-hand side denotes banks liabilities D_t, while the right-hand side denotes which fraction of each of the banks' assets can be used as collateral.

Let $m_{B,t} \equiv \beta_B E_t \left(\frac{C_{B,t}}{C_{B,t+1}} \right)$ denote the banker's stochastic discount factor, The optimality conditions for deposits and loans are respectively:

$$1 - \lambda_{B,t} = E_t \left(m_{B,t} R_{H,t} \right) \quad (1)$$

$$1 - \gamma_E \lambda_{B,t} + \frac{\partial ac_{EB,t}}{\partial L_{E,t}} = E_t \left(m_{B,t} R_{E,t+1} \right) \quad (2)$$

The interpretation of the two first-order condition is straightforward. It also illustrates why the different classes of assets pay different returns in equilibrium. Consider the ways a bank can increase its consumption by one extra unit today.

1. The banker can borrow from household, increasing deposits D_t by one unit today: in doing so, the bank reduces its equity by one unit, thus tightening its borrowing constraint one–for–one and reducing the utility value of an extra deposit by $\lambda_{B,t}$. Overall, today's payoff from the deposit is $1 - \lambda_{B,t}$. The next-period cost is given by the stochastic discount factor times the interest rate R_H.

2. The banker can consume more today by reducing loans by one unit. By lending less, the bank tightens its borrowing constraint, since it reduces its equity. The utility cost of tightening the

borrowing constraint through lower loans is equal to $\gamma_E \lambda_{B,t}$. Intuitively, the more loans are useful as collateral for the bank activity (the higher γ_E is), the larger the utility cost of not making loans.

For the bank to be indifferent between collecting deposits (borrowing) and making loans (saving), the returns across assets must be equalized. Given that R_H is determined from the household problem, the banker will be borrowing constrained, and λ_B will be positive, so long as $m_{B,t}$ is sufficiently lower than the inverse of R_H. In turn, if λ_B is positive, the required returns on loans R_E will be higher, the lower γ_E is. Intuitively, the lower γ_E is, the lower is the liquidity value of loans for bank in relaxing its borrowing constraint, and the higher the compensation required by the bank to be indifferent between lending and borrowing. Moreover, loans will pay a return that is (near the steady state) higher than the cost of deposits, since, so long as γ_E is lower than one, they are less liquid than the deposits.

Both the bankers' credit constraint and the entrepreneurs' credit constraint create a positive wedge between the steady state output in absence of financial frictions and the output when financial frictions are present. The credit constraint on banks limits the amount of savings that banks can transform into loans. Likewise, the credit constraint on entrepreneurs limits the amount of loans that can be invested for production. Both forces lower steady state output. The same forces are also at work for shocks that move the economy away from the steady state, to the extent that these shocks tighten or loosen the severity of the borrowing constraints.

How do financial shocks affect the economy? Consider the effects of a redistribution shock ε_t. An interpretation of this shock is that it captures losses for the banking system caused by a wave of defaults. Figure 3 plots a dynamic simulation for the model economy. The stochastic process for ε_t follows

$$\varepsilon_t = 0.9\varepsilon_{t-1} + \iota_t \tag{3}$$

Iacoviello feeds in the model a shock to ι_t, equal to 4.9 percent of GDP, which causes cumulated losses for the banking system to rise from zero to 7.5 percent of annual GDP after 9 quarters. Note that the losses for the banking system are equal to the gains of household sector. As such, the shock is a pure redistribution shock. From the standpoint of the bank, the loan losses closely mimic the losses of financial system during the Great Recession.

The shock impairs the bank's balance sheet, by reducing the value of the banks' assets (total loans minus loan losses) relative to the liabilities (household deposits): at that point, in absence of any further adjustment to either loans or deposits, the bank would have a capital asset ratio that is below target. The bank could restore its capital-asset ratio either deleveraging (reducing its deposits from households), or reducing consumption in order to restore its equity cushion. If reducing consumption is costly, the bank cuts back on its loans, and begins a vicious, dynamic circle of simultaneous reduction both in loans and deposits, thus propagating the credit crunch. In particular, the decline in loans to the credit-dependent sector of the economy (entrepreneurs) acts a drag on both consumption and productive investment. It drags investment down because credit–constrained entrepreneurs reduce their real estate holdings and labor demand as credit supply is reduced. And it drags consumption down because the decline in labor demand and the reduction in entrepreneurial investment induce a decline in total output. All told, the peak decline in GDP is almost 6 percent after about one year.[7]

Figure 4 presents robustness analysis around the baseline parameterization. In the benchmark case, labor supply elasticity is around 2, and the capital share of credit-constrained entrepreneurs is about one half. A higher labor supply elasticity and capital share of constrained entrepreneurs both work to reinforce, as one would expect, the effects of a shock to bank capital. With a lower labor supply elasticity (about 1) and a 25 percent share of credit-constrained entrepreneurs, the peak decline in output drops from 5 to 3 percent. Conversely, a higher labor supply elasticity (around 5) and a 75 percent share of credit-constrained entrepreneurs produce a larger decline in economic activity, with a peak decline in output of 7 percent at the trough.

Figure 5 considers the effects of another shock that endogenous leads to a reduction in bank capital, namely a decline in housing prices. Through a decline in lending activity, consumption and investment, the shock to housing prices leads to a reduction in bank capital, even in absence of direct shocks to bank capital (such as those taking place with the transfer shock). When the housing price shock is sized to reduce bank equity by 10 percent (namely, the same percent decline in bank equity following the transfer shock), aggregate output falls by approximately 4 percent, slightly less than in the case of the transfer shock.

5 Francisco Covas and John Driscoll: A Nonlinear Model of Borrowing Constraints

The first set of simulations is based on Covas and Driscoll (2013). Their paper evaluates the aggregate effects of imposing a liquidity coverage ratio requirement in addition to a risk-based capital requirement on the banking sector. Key features of their model below are sketched below. The model is based on that of Aiyagari (1994), in which a continuum of heterogeneous workers are subject to idiosyncratic labor income risk under the presence of a borrowing constraint. In addition, the model adds heterogeneous entrepreneurs who face investment risk under the presence of a borrowing constraint and heterogeneous bankers which are subject to profitability risk and a capital requirement.[8] The model with workers and entrepreneurs is very similar to the model specifications used by Covas (2006) and Angeletos (2007). The banker's problem is similar to the partial equilibrium setup analyzed by

[7] An additional force that reduces output in the wake of a redistribution shock is a negative wealth effect on labor supply for the households who receive funds from the bank. This effect contributes to less than one quarter of the decline in output.

[8] To better preserve comparability with the other models, for the simulations below the liquidity requirement is not included.

De Nicolò, Gamba, and Lucchetta (2013). The key frictions in the banking sector are the capital requirement and the inability of bankers to issue outside equity, that is all the increase in equity occurs via retained earnings. The combination of these two frictions and the fact that entrepreneurs are assumed to be bank-dependent create a setting in which the Modigliani-Miller theorem does not work.[9] As a result, an exogenous shock to bankers' equity leads to adjustments in the supply of credit by banks and loan spreads, with corresponding real effects.

Workers supply one exogenous unit of labor to the entrepreneurs and a corporate sector. They are subject to labor productivity shocks that affect their earnings. They choose consumption, deposits, and asset holdings to maximize utility subject to a borrowing constraint. Entrepreneurs can invest in an individual-specific risky technology and in riskless securities. They supply one exogenous unit of labor to their entrepreneurial businesses and also to the corporate sector. Entrepreneurs choose consumption, investment and loans (from the banking sector) to maximize lifetime utility subject to a borrowing constraint. The reliance on bank loans as a form of finance and the presence of a borrowing constraint violate the Modigliani-Miller theorem for the entrepreneurial sector, in which changes in the quantity and price of bank loans forces entrepreneurs to chance the consumption and investment choices.

Bankers hold loans and riskless securities; the latter, which are assumed to be in positive net supply, may also be used to fund loans, and therefore net securities holdings may be negative. Loans mature at a constant rate and have a constant servicing cost; to capture the illiquidity of loans relative to securities, banks pay (asymmetric) adjustment costs to changing the quantity of loans outstanding. In addition, loans and other banking activities generate noninterest income which is a concave function of the size of the loan portfolio and is subject to idiosyncratic profitability shocks. Loans are funded through deposits and equity. Banks face a risk-based capital constraint, in which the amount of equity must be at least equal to a risk-weighted sum of loans and securities (the latter of which has a zero risk weight). Bankers maximize utility subject to the above constraints. In equilibrium, banks will choose to hold a (precautionary) buffer of equity capital above the requirement, however the capital constraint may still bind for some banks. As mentioned earlier, bankers are not allowed to issue outside equity and the increase in capital has to be done via retained earnings.

The model is completed by a corporate sector, which produces output with capital supplied by workers and labor supplied by both workers and entrepreneurs. This sector is included so that the banking sector need not fund the entire economy.

In steady-state equilibrium, the loan, security and deposit markets clear, factor prices equal marginal products, and distributions of agents' characteristics are invariant. The model is calibrated so that parameters from the bankers' problem match certain moments from bank holding company

[9] The assumption of bank-dependence for the entrepreneurial sector is in accordance with the literature on the credit channel of monetary policy, which also assumes that some firms, particularly smaller ones, do not have the same amount of access to other forms of finance.

call report data as summarized in Table 2.[10] The model is solved numerically by iterating the policy function over time, as in Coleman (1990). The steady state solution also solves for the loan rate, the return on securities and the capital-labor ratio of the corporate sector using a quasi-Newton method. Finally, the simulation results presented below are based on transition dynamics which simulate the evolution of the density function for each sector using the optimal policy functions and the time path for the loan rate, the return on securities and the capital-labor ratio of the corporate sector.

5.1 Transfer Shock

The baseline simulation involves a transfer of wealth from bankers to entrepreneurs and workers equivalent to 7.5 percent of steady state output. Furthermore, 60 percent of the transfer occurs in the first year, and 40 percent in the second year. The transfer of wealth between the three sectors is unexpected in both years. Table 3 gives the size of the transfer in each year relative to the level of steady-state wealth of each sector.

The large reduction in bankers' wealth drives down bank equity by about 35 percent in the first year and 50 percent in the second year, as seen in Figure 6. The average tier 1 ratio drops 300 basis points in the first year and 70 basis point in the second year. Despite the larger decrease in wealth in the second year, the decrease in the tier 1 ratio is lower in the second year because the large majority of banks have a binding tier 1 capital ratio which cannot go below 6 percent. In order to meet the capital requirement, banks slash consumption (i.e., dividends) by 40 percent in the first year and 60 percent in the second year, reduce loan outstandings by about 8 percent in the first year and 23 percent in the second year and increase holdings of securities by 10 and 35 percent in years 1 and 2, respectively.[11] The abrupt reduction in loans hinges partially on the assumption that bankers do not have access to outside equity and in our model all equity capital accumulation is done via retained earnings. The magnitude of the transfer shock would likely be dampened if banks had access to outside equity or started the exercise with a larger capital buffer. The reduction in the supply of loans by banks causes the loan rate to increase by about 30 basis points in the first year and 65 basis points in the second year, and similarly, the rate on securities to fall by 40 and 110 basis points, respectively. The change in these two interest rates combined implies that the loan spread would increase by 70 basis points in the first year and 170 basis points in the second year.

The transfer shock initially benefits the entrepreneurs, with both wealth and consumption increasing by small amounts for the first two years. However, the increase in the loan rate reduces investment by entrepreneurs and causes their wealth and consumption to fall in subsequent years. As a result, entrepreneurs' capital and securities holdings fall, as do their labor demand and output. Investment is initially negative, before rising as the economy returns to its steady-state.

[10] Further details on the calibration of the model are given in a technical appendix.

[11] Based on call report data total loans at commercial banks declined by 10 and 6 percent in 2009 and 2010, respectively.

Throughout the transition period workers are always better off as they receive the benefit of increased wealth without incurring the direct cost of higher loan rates since they do not borrow from banks. In response to an increase in wealth, workers increase consumption and savings. Some of the increase in savings is done through the accumulation of capital that is rented to the corporate sector, whose output rises as a result.

In the aggregate, consumption and output both fall by about 3 percent in the second year of the transfer shock, and investment declines by about 1 percent. The decline in investment is less pronounced relative to the decline in output because of the large boom in investment in the corporate sector.[12]

5.2 Sensitivity Analysis

A key feature of the model is the capital requirement for bankers. As shown in Table 2, the capital requirement constraint binds for less than one-third of banks in the steady state. The capital constraint is the key friction in the banking sector and for that reason Covas and Driscoll conduct two types of sensitivity analysis. In the first exercise, the fraction of capital-constrained bankers is reduced to about half of the steady state share. This reduction is achieved by increasing the discount factor of bankers, which increases the size of the capital buffer above the minimum capital requirement. In the second exercise, the amount of equity held by bankers is increased. However, this increase is achieved by raising the capital requirement, and so the capital buffer remains relatively unchanged. Figure 7 shows that these two experiments generate different sets of aggregate responses and substantiating that the key driver of bankers' responses following the transfer shock is the share of capital constrained banks.

Reducing the share of capital-constrained banks reduces the effects of the transfer shock—output and consumption now both decline by about 0.6 percent in the first year and 1 percent in the second year. Since bankers have larger capital buffers when the transfer shock occurs, the responses of bank loans and the corresponding interest rate are considerably less pronounced in this case. In particular, the transfer shock now increases the loan rate only by 20 basis points and the return on securities declines by 10 basis points. As a result, the spillover effects of the shock in the banking sector to the entrepreneurial and worker sectors are considerably smaller.

Finally, increasing the size of the capital requirement and requiring bankers to hold more equity prior to the transfer shock generates very similar responses in aggregate output and consumption relative to the baseline case. This suggests that the key mechanism in this model is driven by likelihood of banks to be capital constrained and not the level of equity held by banks. An important assumption

[12] This result is a bit counterintuitive. The reason is that the transfer shock is very large and bankers cannot absorb more deposits because the capital constraint binds for almost all banks. In equilibrium, workers invest even more in the corporate sector. In the next section, the share of constrained banks is reduced leading to the standard result that the response of investment is larger (more negative) than the response of output.

in the model is that banks are not allowed to violate the capital requirement of 10 percent. Taken together, these two experiments suggest that allowing banks to go below the capital requirement at the same time the transfer shock occurs, would yield sizable welfare gains relative to the case in which capital requirements are left unchanged.

5.3 Responses to an Alternative Shock Affecting the Balance Sheet of Banks

A final alternative looks at the effect of a persistent reduction in the non-interest component of bank revenues. The shock is calibrated so that the change in wealth of bankers is roughly the same as the change of wealth induced by the transfer shock in the baseline calibration.

As seen in Figure 8, the effect of the revenue shock reduces aggregate output by about 5 percent in the first year and 4.5 percent in the second year, which is considerably more than the response found above for the case of the transfer shock. This is not surprising since in this exercise bankers' wealth is no longer transferred to the entrepreneurial and workers' sectors. As a result, the reduction in output driven by the entrepreneurial sector is not partially offset by the increase in output in the corporate sector. Finally, consumption falls by substantially less–bottoming out at about a 3 percent reduction since bankers have perfect foresight of the shock and are able to smooth consumption more effectively.

6 Michael Kiley and Jae Sim: Intermediary Leverage, Macroeconomic Dynamics and Macroprudential Policy

Kiley and Sim (2013, KS below) studies the nexus between macroprudential policy and monetary policy. To that end, KS develops a macroeconomic model in which the financial intermediaries mix debt and equity capital to finance their investments subject to financial frictions that make intermediary choice of capital structure deviate from the predictions of the Modigliani-Miller theorem within an otherwise standard dynamic general equilibrium model of the type used in monetary policy analysis such as found in Smets and Wouters (2007). Thus, the capital structure of intermediaries in KS is optimized to balance the benefits of leverage and the costs of bankruptcy under costly recapitalization option rather than imposed by a regulatory fiat, a feature that helps understand the role of unregulated financial sector in the propagation of macroeconomic shocks.

The model economy consists of (i) a representative household, (ii) a representative firm producing intermediate goods, (iii) a continuum of monopolistically competitive retailers, (iv) a representative firm producing investment goods, and (v) a continuum of financial intermediaries. A key assumption that makes the model's asset pricing implication in sharp contrast with that of frictionless neoclassical models is that the representative household lack the knowledge needed to manage financial investments, and thus turns to the financial intermediaries that have special knowledge in selecting and managing financial projects, but face financial friction in funding their operations. This delegation of investment function from a financially unconstrained agent to a constrained agent with limits of arbitrage makes the model's propagation mechanism of financial disturbances drastically different from that of frictionless business cycle models through the dynamics of pecuniary externality.[13]

The important role of liquidity condition of financial intemediaries in asset price dynamics can be seen in the following asset pricing equation of KS:

$$1 = \mathbb{E}_t \left\{ M^B_{t,t+1} \cdot \frac{1}{m_t} \left[\frac{\mathcal{R}^A_{t+1}}{\Pi_{t+1}} - (1 - m_t) \frac{R^B_{t+1}}{\Pi_{t+1}} \right] \right\} \tag{4}$$

where $M^B_{t,t+1}$ is the intermediary pricing kernel, m_t is the capital ratio optimally chosen by the intermediaries, $\mathcal{R}^A_{t+1}/\Pi_{t+1}$ and R^B_{t+1}/Π_{t+1} are intermediaries' real return on assets and borrowing rates. (4) summarizes all the important deviations of the model from standard asset pricing models: (i) (4) is a levered asset pricing formula, and the *net* asset returns is scaled up by a factor $1/m_t$; (ii) the intermediary pricing kernel is a filtered version of the household's stochastic discounting factor, where the filter is due to the liquidity condition of the intermediaries measured by the ratio of shadow value of internal funds today vs tomorrow, i.e., $M^B_{t,t+1} = \mathbb{E}_{t+1}[\lambda_{t+1}|\Omega_{t+1}]/\mathbb{E}_t[\lambda_t|\Omega_t] \cdot M_{t,t+1}$ where $\mathbb{E}_t[\lambda_t|\Omega_t]$ measures the *ex ante* shadow value of internal funds based on all the available macroeconomic information (Ω_t); (iii) the return on asset deviates from the frictionless counterpart because, first, raising outside capital is costly due to dilution effects[14], and thus lowers the effective return on equity, second, the limited liability of financial intermediaries create a strictly positive value of default option, which then interacts with risk-taking of intermediaries.[15]

6.1 Calibration

For the calibration of parameters regarding preferences and technology, conventional values are used. The constant relative risk aversion, habit formation and the elasticity of labor supply are set equal to 3, 0.8. and 3, respectively, to be consistent with the micro-level evidence. The capital share of production function is set equal to 0.4. The quadratic adjustment cost of investment is chosen as 2.

[13] A similar assumption also plays an important role in the majority of the recently developed macroeconomic models featuring intermediary funding constraints such as He and Krishnamurthy (2012), Brunnermeier and Sannikov (2013), Gertler and Karadi (2011), and Gertler and Kiyotaki (2010).

[14] Dilution costs arise when firms announce new offering of seasoned equities and the announcement leads to a drop in the market value of existing shares. The dominant interpretation of the phenomenon in the literature is provided by Myers and Majluf (1984), who show that asymmetric infromation in capital market may lead uninformed investors to discount the value of new shares to avoid *lemons*, which then causes the market value of existing shares to drop by arbitrage.

[15] In contrast to the majority of this literature, defaults of financial institutions are equilibrium outcomes. In this aspect, the model is akin to Brunnermeier and Sannikov (2013).

KS does not posit a utilization cost of capital and takes a constant depreciation rate of 0.025. The quadratic cost of price adjustment is set equal to 120. This choice is equivalent to a quarter fraction of firms resetting prices at any point in time given the steady state mark up of 1.11. Inflation indexation and wage rigidity are not considered for the transparency of the results. The monetary policy reaction function parameters are chosen as 1.5, 0.125 and 0.8 for inflation gap, production based output gap and monetary policy inertia, respectively.

Other parameters govern the with long run capital structure, the dilution cost of equity issuance, the corporate income tax shield, the bankruptcy cost of failed institution, and the idiosyncratic volatility. The dilution cost is set equal to 0.15 in the steady state, which is in the middle of the range reported in corporate finance literature. The tax differential between corporate and personal income tax rates are set as 0.20. Given all other parameters, the idiosyncratic volatility is chosen to match 0.40 capital ratio, to make the comparison with other papers in this literature straightforward. The bankruptcy cost is then specified as 3 percent of the size of the balance sheet to match the steady state, short-term funding spreads.[16]

6.2 Impact of Balance-Sheet Shock: Baseline Results and Robustness

To illustrate the importance of intermediary liquidity condition on macroeconomic outcomes, KS consider a financial shock that transfers a certain amount of resources from financial intermediaries to the representative household in a lump sum fashion. The shock, regardless of its realism, helps highlight the role of financial market friction in the model since it does not directly affect the marginal productivity of physical capital in the economy, and thus would have no impact on the allocation of real resources in a frictionless economy because, first, the investment decisions of the financial intermediaries are not affected by their liquidity condition, and second, the loss in the wealth of households due to the decline in the value of equities of financial institutions are exactly offset by the positive wealth transfer to households. The size of the shock is designed to generate a cumulative wealth transfer of 7.5 percent of a normal level of GDP nine quarters after the shock is introduced. To that end, KS the persistence the shock is chosen to be 0.9.

Figure 9 shows the impact of the shock on the real economy and financial markets. By construction, the shock does not have any impact if the financial friction in the model is taken out. However, as shown in the figure, the shock leads to a massive contraction in the real economy: maximum contraction on output, consumption, and investment amount to 2.5%, 0.6%, and 11%, respectively.

The reason for this strong reaction of the real economy can be found in the response of financial markets also shown in Figure 9. On the impact, the default rate of intermediaries shoots up 0.5

[16] All parameter values are broadly consistent with the original choices made in KS. However some minor variations are made in this assessment of balance sheet transfer shock to facilitate comparisons with others.

percentage point. This is due to both the direct hit to the internal funding condition by the transfer shock and the indirect result of the endogenous decline in the asset prices. While the financial intermediaries try to raise outside capital as shown by the stiff increase in equity issuance, as much as 20 percent relative to its normal level, doing so in the KS model is costly due to a dilution cost. Finally, the increase cost of capital is passed through to the lending spreads, resulting in a large reduction in overall credit and a sizable contraction in economic activity.

The results shown in Figure 9 are sensitive to calibration choices. Among others, the relative risk aversion turns out to be very important in assessing the overall impact of the balance sheet transfer shock, as shown in Figure 10. On impact, household consumption increases moderately as a decline in household wealth, stemming from the reduced value of intermediary shares, is not perfectly offset by the transfer shock under the financial friction. This initial increase in consumption plays an important role in determining the overall size of the impact, as consumption accounts for about 80 percent of total spending in the model. Having a lower degree of relative risk aversion makes the initial hump of household consumption bigger, reducing the size of overall impact on the economy. For instance, setting the parameter equal to 1 (log utility) reduces the maximum impact on the output to 2 percent, about 50 bps lower than what is shown in the figure.[17]

6.3 Alternative Financial Shock: Dilution Cost Shock

KS uses the balance sheet shock to illustrate some of the effects of financial frictions, but this shock has a bit of an ad hoc element. In their analysis, they consider other shocks that may have similar qualitative effects but may also be amenable to further empirical validation (through, for example, consideration of a wider set of financial developments). A respresentative example of such financial shocks is a shock to the cost of raising outside equity. Such a shock may capture situations in which financial intermediaries face elevated costs of raising funds in capital markets, perhaps because investors are uncertain the quality if intermediary assets and hence demand a ?lemons premium?. Figure 11 reports the impact of an increase in the cost of outside equity on the real economy and financial markets; the shock is calibrated to match the initial capital shortfall induced by the transfer shock. The persistence of the shock is the same as for the transfer shock.

The contours of the responses of real variables are broadly similar to the contours of the responses to a transfer shock. However, the peak impacts on output, consumption and investment are about two-thirds the size of the peak impacts of the transfer shock .

[17] The degree of nominal rigidity, and hence the flatness of Phillips curve is also important. For instance, halving the price adjustment cost to let the impact of the shock absorbed by greater adjustment in prices reduces the maximum response of output by 30 bps. However, even with completely frictionless price setting, the maximum impact is reduced only by 60 bps. Finally, the size of investment adjustment friction also matters. While a greater adjustment friction in this sector increases the asset price volatility in general, it leads to a smoother response in aggregate investment and output. As a result, for instance, doubling the size of this friction can reduce the maximum impact on the output by 60 bps.

7 Albert Queralto: Banks and Outside Equity

7.1 Model

The model presented here builds on the recent papers that introduce financial intermediation in a business cycle framework, for example Gertler and Karadi (2011) and Gertler and Kiyotaki (2010). These papers extend the basic financial accelerator mechanism developed by Bernanke and Gertler (1989) and Kiyotaki and Moore (1997) to financial intermediaries (banks) in order to capture a disruption of intermediation. In this class of models, banks borrow short-term noncontingent debt from depositors and use these funds (together with their own internal funds) to make loans to non-financial firms. As in the earlier literature on the financial accelerator, financial market frictions are endogenized by introducing an agency problem that potentially constrains banks' ability to obtain funds from depositors. When the constraint binds, banks' balance sheets limit their ability to obtain deposits. In this instance, the constraint effectively introduces a wedge between loan and deposit rates, which rises as banks' balance sheets deteriorate. This raises the cost of credit that non-financial borrowers face. In this way, when banks are highly leveraged, adverse returns to their balance sheet may lead to sharp increases in credit spreads and declines in investment and economic activity.

Key to motivating a crisis within these frameworks is the heavy reliance of banks on short term debt. This feature makes these institutions highly exposed to the risk of adverse returns to their balance sheet in way that is consistent with recent experience. Within these frameworks and most others in this class, however, by assumption the only way banks can obtain external funds is by issuing short term debt. Thus, in their present form, these models are not equipped to address how the financial system found itself so vulnerable in the first place.

In the model analyzed here, banks are allowed to issue outside equity as well as short term debt.[18] This makes bank risk exposure an endogenous choice, as outside equity allows banks to share risk with equity holders. The goal is to have a model that can not only capture a crisis when financial institutions are highly vulnerable to risk, but also account for why these institutions adopt such a risky balance sheet structure in the first place. Accordingly, the model extends the agency problem between banks and savers to allow intermediaries a meaningful trade-off between short term debt and equity. Ultimately, a bank's decision over its balance sheet will depend on its perceptions of risk. Thus, the model allows a quantitative analysis of the interplay between risk perceptions by banks, the liability structure that they choose, and the vulnerability of the economy to a crisis.

The production side of the model is analogous to a standard frictionless Real Business Cycle (RBC) economy. The production function, capital accumulation and resource constraint are as follows:

[18] The structure of the model closely follows Gertler, Kiyotaki, and Queralto (2012). See their paper for a complete description.

$$Y_t = AK_t^{\alpha} L_t^{1-\alpha} \tag{5}$$

$$K_{t+1} = \psi_{t+1} \left[(1-\delta)K_t + I_t\right] \tag{6}$$

$$Y_t = C_t + \left[1 + f\left(\frac{I_t}{I_{t-1}}\right)\right] I_t \tag{7}$$

In (6), ψ_{t+1} is a capital quality shock, which serves as a trigger of movements in the quality of banks' assets. It can be thought of as capturing a form of economic obsolescence.[19]

The preference structure follows Miao and Wang (2010), in turn based on Greenwood, Hercowitz, and Huffman (1988) (GHH, 1988):

$$\mathbb{E}_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \frac{1}{1-\gamma} \left(C_\tau - hC_{\tau-1} - \frac{\chi}{1+\varphi} L_\tau^{1+\varphi}\right)^{1-\gamma} \tag{8}$$

The preference specification allows for (internal) habit formation and, as in GHH, abstracts from wealth effects on labor supply. The household's problem is as follows:

$$\max \qquad \mathbb{E}_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \frac{1}{1-\gamma} \left(C_\tau - hC_{\tau-1} - \frac{\chi}{1+\varphi} L_\tau^{1+\varphi}\right)^{1-\gamma}$$

subject to

$$C_t + D_{h,t} + q_t e_t = W_t L_t + \Pi_t - T_t + R_t D_{h,t-1} + \left[Z_t + (1-\delta) q_t\right] \psi_t e_{t-1}$$

Note that the household has access to non-contingent riskless short term debt (deposits), denoted $D_{h,t}$, and bank (outside) equity, e_t.[20] The price of a unit of outside equity is q_t, and Z_t denotes the flow returns at t generated by one unit of the bank's assets. The units of outside equity are normalized so that each unit is a claim to the future returns of one unit of the asset held by the bank.

Each bank raises funds by issuing deposits d_t and outside equity to purchase producers' equity, s_t:

$$Q_t s_t = n_t + q_t e_t + d_t \tag{9}$$

The evolution of a bank's net worth (or inside equity), n_t, is as follows:

[19] See the appendix of Gertler, Kiyotaki, and Queralto (2012) for a microfoundation of the capital quality shock along these lines. The appendix is available as supplementary material at Elsevier's website: http://www.journals.elsevier.com/journal-of-monetary-economics/.

[20] Outside equity refers to equity issued by banks and held by households, while inside equity (or net worth) refers to the accumulated retained earnings of a banker who manages an intermediary and is involved in the operation.

$$n_t = [Z_t + (1-\delta)Q_t]\,\psi_t s_{t-1} - [Z_t + (1-\delta)q_t]\psi_t e_{t-1} - R_t d_{t-1} - \xi_t \tag{10}$$

Above, ξ_t is a capital transfer which subtracts from the bank's resources at the beginning of the period. It is assumed to be taken from the bankers and given to the households, and therefore only has effects insofar as net worth constrains banks' ability to obtain funds. Accordingly, in the RBC version of the model, the effects of the transfer are nil, as it is just a redistribution of wealth within the representative household.

The value of the bank at the end of period t is

$$V_t = V(s_t, x_t, n_t) = \mathbb{E}_t \sum_{\tau=t+1}^{\infty} (1-\sigma)\sigma^{\tau-t}\Lambda_{t,\tau} n_\tau \tag{11}$$

where $x_t = \frac{q_t e_t}{Q_t s_t}$, and σ is the banker's survival probability. After obtaining funds, the banker may default on its debt and divert a fraction $\Theta(x_t)$ of assets. The incentive constraint for the bank not to steal is

$$V(s_t, x_t, n_t) \geq \Theta(x_t) Q_t s_t \tag{12}$$

The divertable fraction is a convex function of x_t:

$$\Theta(x_t) = \theta\left(1 + \epsilon x_t + \frac{\kappa}{2} x_t^2\right) \tag{13}$$

By assumption, the amount divertable is increasing in the extent of outside equity finance x_t, and therefore the bank's constraint is tighter the larger is x_t.[21] This represents a cost of outside equity which the bank trades off against its hedging benefit.

7.2 Calibration and Model Solution

Table 4 reports the baseline parameter values. The preference and technology parameters are set to reasonably conventional values. The banking sector parameter are chosen to match salient features of the U.S. financial intermediation sector.

In the model, bank balance sheet structure depends on risk perceptions. It is thus important to take account of risk in the computation of the model. Similar to Coeurdacier, Rey, and Winant (2011), a "risk-adjusted" steady state is constructed, where given agents perceptions of second moments, variables remain unchanged if the realization of the (mean-zero) exogenous disturbance is zero. The risk-adjusted steady state differs from the non-stochastic state only by terms that are second order. These second order terms, which depend on variances and covariances of the endogenous variables, pin

[21] The idea is that short term deposits give banks less discretion over payouts than equity, and therefore offer more discipline over bank managers than does outside equity. This idea is due to Calomiris and Kahn (1991).

down banks' balance sheet. Model dynamics are then analyzed by computing a first order log-linear approximation around the risk-adjusted steady state.

To calculate the relevant second moments an iterative procedure is used. First the model is log-linearized around the non-stochastic steady state. Then the second moments calculated from this exercise are used to compute the risk-adjusted steady state. These first two steps are repeated but the the moments are calculated anew from the risk-adjusted steady state. Successive iterations are produced in this fashion until the moments generated by the first order dynamics around the risk-adjusted steady state are consistent with the moments used to construct it.[22]

7.3 Transfer Shock

The following subsections describe results from model simulations. Figure 12 plots a dynamic simulation of the model economy following a transfer shock. Here the amount of exogenous volatility is calibrated as the average between a low risk economy (meant to reproduce the Great Moderation period) and a high risk economy (which captures the period of volatility in the two decades prior to the Great Moderation). The idea is that the aftermath of the Global Financial Crisis is characterized by heightened uncertainty relative to the Great Moderation, but risk is still not as high as in the high volatility period of the 1960s and 70s.

The transfer shock is assumed to persist as a first-order autoregressive process with a coefficient of 0.9.[23] The size of the impulse is calibrated so that the cumulative transfer is -7.5% of annual steady state GDP after two years (i.e. by the ninth quarter). Results are reported in Figure 12.

The loss in capital in the intermediation sector worsens the agency problem between banks and their creditors, leading the credit spread to rise by more than 100 basis points. With their balance sheets impaired, banks' ability to lend is diminished, and aggregate investment and asset prices drop as a result. Along the way, the financial accelerator mechanism operates, as drops in bank net worth and in the asset price Q_t reinforce each other. All told, output falls by about one percentage point, and investment drops by more than 3 percentage points.

7.4 Robustness Analysis

Several authors have suggested that the low volatility during the Great Moderation period may have induced a sense of complacency about risk in financial markets, which ultimately contributed to the vulnerability of the system once the crisis hit. To illustrate this possibility, Figure 13 performs robustness analysis by modifying the level of exogenous risk. The low risk economy features standard deviations of the shock processes so that the standard deviation of annual output growth corresponds

[22] See the appendix of Gertler, Kiyotaki, and Queralto (2012) for details.

[23] In particular, each bank's transfer is assumed to be proportional to their net worth, where the fraction of capital that they lose follows an exogenous AR(1) process.

roughly to that in the Great Moderation period, while the high risk economy features a level of risk corresponding to the period of volatility in the two decades prior. Queralto also performs comparative statics relative to the labor supply elasticity, by raising it to 4.5 from its benchmark value of 3, and also by lowering it to 1.5.

When risk is high, the effects of the shock are weaker, and with low risk the effects are stronger. The reason is straightforward: the anticipation of high risk induces banks to substitute outside equity for short term debt, as higher risk increases the hedging value of outside equity. When the shock hits, outside equity acts as a buffer in two ways. First, it moderates the drop in inside equity induced by the decline in assets values. Second, as the effects of the shock unfold after the initiating disturbance, banks are able to relax their borrowing constraint a bit by substituting short term debt for outside equity (recall that short term debt permits creditors greater discipline over bankers).

In the case with high risk and low labor supply elasticity, the peak decline in output drops from 1 to about 1/2 percentage points. This is due to the greater extent of hedging and to the lower labor supply elasticity in roughly equal parts. Conversely, with low risk and high labor supply elasticity, the drop in output is almost 1.5 percent. A final point to note is that while varying the labor supply elasticity exerts a large influence in the macroeconomic spillover effects (via movements in employment), the calibration of this parameter has only a small bearing on financial outcomes: for the financial variables (investment, asset price, spread and net worth) the comparative statics illustrated in Figure 13 are almost entirely driven by the differing degree of hedging in the financial sector that is driven by different levels of exogenous volatility.

Figure 14 compares the effects of the transfer shock (in the low risk economy) with those of a decline in capital quality, where the magnitude of the latter is calibrated to induce the same average decline in bank net worth as the transfer shock over the five years following the shock. The effects of the capital quality shock are considerably larger, leading output to drop more than 2 percent at the trough. The reason is that the decline in capital quality effectively leads to a reduction in the amount of physical capital in the economy, and therefore has adverse effects even in an economy with no financial frictions, as indicated by the dotted line. Nonetheless, the degree of financial sector spillovers (i.e. the contraction over and above what would happen in a frictionless economy) is comparable across the two shocks (recall that the transfer shock is only a redistribution of resources within the representative household, and therefore has no effects in a frictionless economy).

8 Luca Guerrieri and Mohammad Jahan-Parvar: Capital Shortfalls in a Two-Sector Production Economy

Guerrieri and Jahan-Parvar (GJP henceforth) consider the effects of sectoral and aggregate financial shocks in a two sector model. Firms in one sector have access to equity markets, while firms in the other sector can only finance capital purchases through credit extended by financial intermediaries (hereafter, banks, for short). The interactions of these two types of firms can buffet the macro effects of shocks that reduce the equity position of banks. The demand for capital by equity-financed firms acts to curb equilibrium movements in the price of capital which otherwise amplifies the macro response to variation in credit from the banking sector. However, aggregate valuation shocks that affect both equity markets and banks continue to have sizable macro repercussions. Apart from sensitivity analysis relative to the size of the credit-dependent sector, GJP highlight the implication of the zero lower bound on policy interest rates for the transmission of the baseline transfer shock.

The model is an extension of Gertler and Karadi (2011), hereafter abbreviated as "GK." The extension is that not all firms are dependent on bank credit. Firms in the equity-financed sector are able to write a financing contract directly with households. A special case of our model with all firms financed by household equity reproduces the one-sector model considered by Boldrin, Christiano, and Fisher (2001). In GJP's model, final goods are a Cobb-Douglas composite of goods produced by firms that are credit-dependent and by firms that are equity-financed. A retail sector purchases the intermediate goods and repackages them for consumers in a way that supports the inclusion of nominal rigidities. Monetary policy is determined by an interest rate reaction function that responds to current inflation and allows for interest rate smoothing. Production subsidies are introduced so that, in the absence of financial frictions, the efficient steady-state allocations are achieved. In the description that follows focuses on the credit-related friction and leaves the full description of the model for an appendix.

The key financial friction for bank dependent firms follows Gertler and Karadi (2011). Banks lend funds obtained from households to non-financial firms. Let $N_t(j)$ be the amount of wealth – or net worth – that a banker j has at the end of period t.

$$Q_t S_t^b(j) = N_t(j) + D_t(j). \tag{14}$$

Deposits $D_t(j)$ pay a return $(1 + R_t)$ at time $t+1$. Thus $D_t(j)$ may be thought of as the debt of bank j, and $N_t(j)$ as its capital. Credit extended to firms $S_t^b(j)$ earns the stochastic return $(1 + R_{t+1}^{bs})$ at time $t + 1$.Over time, the capital of banks evolves as the difference between earnings on assets and interest payments on deposits:

$$N_{t+1}(j) = (1 + R_{t+1}^{bs})Q_t S_t(j) - (1 + R_t)D_t(j). \tag{15}$$

Because banks may be financially constrained, they have an incentive to retain earnings, but bank capital does not expand indefinitely because bankers cease operations with i.i.d. probability $1 - \theta$ each period. Upon exiting a banker becomes a worker and all retained earnings are transferred back to his original household. Each period a fraction $1 - \theta$ of all workers is selected to join the existing bankers and receives a startup transfer, so that the fraction of household members acting as workers and bankers is constant over time.

The objective of bank j is to maximize expected terminal wealth, given by:

$$\max_{S^b_{t+i}(j)} V_t(j) = E_t \sum_{i=0}^{\infty} (1-\theta)\, \theta^i \psi_{t,t+1+i} \left[\left(R^{bs}_{t+1+i} - R_{t+i} \right) Q_{t+i} S^b_{t+i}(j) + (1 + R_{t+i}) N_{t+i}(j), \right] \quad (16)$$

where $\psi_{t,t+1+i}$ is the stochastic discount factor of households.

An agency problem limits the ability of banks to attract deposits. At the beginning of each period, a banker can choose to transfer a fraction λ of assets (in period t those assets equal $Q_t S_t(j)$) back to his household. If the banker makes the transfer, depositors will force the bank into bankruptcy and recover the remaining fraction $1-\lambda$ of assets. Thus, households are willing to make deposits only if the incentive-compatibility constraint is satisfied:

$$V_t(j) \geq \lambda Q_t S_t(j). \quad (17)$$

The standard first-order perturbation solution assumes that this constraint binds with equality at all times.

The setup of GK is nested and is reproduced when the share of equity-financed firms in production is zero. GJP depart from GK along a few dimensions. Notably, in the model capacity utilization is constant; monetary policy responds only to inflation and to a lag of the monetary policy rate, and does not attempt to stabilize output around its steady state value; the Frisch elasticity of labor supply equal to 1, at the upper range of micro estimates, but well below the elasticity in GK. In the two-sector model, the equity- and credit-dependent firms produce intermediate goods that are necessary to produce an undifferentiated final good using a Cobb-Douglas production function. The sectoral shares are set to 0.5. A retail sector produces differentiated goods that are subject to nominal rigidities.[24]

8.1 Baseline Shock and Comparisons with One-Sector Model

Figure 15 shows the effects of the baseline transfer shock from banks to households in our two-sector model. The macro effects of the shock are modest. The drop in aggregate output grows in magnitude over two years to a peak of 0.45% of its steady state value. The modest size of the spillover effects of the shock is related to the fact that the reduction in the demand for capital by credit-dependent firms is compensated by an increase in demand from the equity-financed firms.

As shown in Figure 16 the macro spillover effects of the baseline transfer shock are greatly amplified in a one-sector model in which all firms are credit-dependent. The main reason for this amplification

[24] Notice that when either $\lambda = 0$, or when all firms are equity financed, a monetary policy rule that stabilizes inflation would reproduce the allocations chosen by the benevolent planner.

is that lack of access to alternative funding leads to a large reaction in the equilibrium price of capital. In turn, in the one-sector model, the drop in the price of capital boosts the magnitude of the drop in bank capital and leads to a further curtailing of credit supply. By contrast, in a two sector model, the price of capital barely responds to a transfer shock. Higher demand for capital from equity-financed firms acts to reduce downward pressures on the equilibrium price of capital. This stability in the price of capital has one principal implication – it reduces the endogenous response of bank equity to the exogenous transfer shock.

8.2 Sensitivity Analysis: The Response to an Economy-Wide Shock

The benchmark model introduced in Section 8.1 focuses on a sector-specific shock whose aggregate effects are buffeted by the reaction of the other sector. This section presents the implications of an economy-wide shock. Following Albuquerque, Eichenbaum, and Rebelo (2012), the the economy faces a valuation shock. Accordingly, the discount factor of households drops and the risk-free interest rate increases. To make results comparable to the benchmark model, GJP match the average *endogenous* shortfall in bank capital from the baseline transfer shock (taking into account the equilibrium response of capital prices) over the first 9 quarters.

Figure 17 reports the comparison of the impact of a valuation shock with that of a transfer shock in the baseline two-sector model. In this case, the macro effects of a financial shock are much closer to those that obtain in the special case of one-sector model in which all firms are credit-dependent. Similar to GK and in contrast to the benchmark model, an economy-wide shock can cause a significant drop in output and investment. Since households own all the assets in the economy, a shock that lowers the discount factor implies less appetite for risk and a reduction in the the funds available to both equity-financed firms and banks. The aggregate nature of the valuation shock dampens the role played by the equity-financed firms in counterbalancing the shocks to banks in the benchmark model. Accordingly, the equilibrium loan rate rises to compensate the shortage of available funds, resulting in a large drop in investment. Similar to GK, the macro spillovers of the financial shocks are amplified by a fall in the price of capital.

The benchmark model implies that the presence of additional financial assets issued by firms that are capable of direct intermediation with the households can mitigate the impact of a financial shock to banks. However, shocks that affect in concert both equity- and credit-financed firms still lead to sizable macro spillover effects comparable to those that obtain in a one-sector model with all firms credit-dependent. The analysis also highlights that shocks that have comparable impacts on the equity position of banks can have dramatically different macro spillover effects.

8.3 The Response to the Baseline Transfer Shock at the Zero Lower Bound

GJP revisit the effects of the baseline transfer shock against the background of a deep recession that brings the economy to the zero lower bound. In the model, the deposit contract between banks and households is tantamount to an indexed bond with maturity equal to 1 quarter. In normal times, the real return on deposits hews closely to the nominal deposit rate and to the monetary policy rate. However, at the zero lower bound there can be a decoupling between the real return on deposits and nominal short-term interest rate.

The stylized shock that leads the economy to the zero lower bound is a shock to preferences. The utility function of the representative household is modified as follows:

$$U_t = E_t \sum_{i=0}^{\infty} \beta^i \left[\log(C_{t+i} - \gamma C_{t+i-1} + \epsilon_{ct}) - \frac{\chi}{1+\varepsilon} L_{t+i}^{1+\varepsilon} \right] \tag{18}$$

where, again, C_t denotes consumption of final goods, and L_t denotes hours worked. The term ϵ_{ct} is a shock to consumption preferences. The shock itself is assumed to follow an autoregressive process of order 1, with a persistence coefficient equal to 0.7. The shock is sized so that households expect the policy interest rate to remain at the zero lower bound for 6 quarters in the absence of additional shocks. For the purpose of this section, the model is solved using a piecewise linear solution technique as developed by Guerrieri and Iacoviello (2013). As shown in Bodenstein, Erceg, and Guerrieri (2009) the particular mix of shocks that lead to recession and the attainment of the zero lower bound have a role in determining the marginal effects of additional shocks that is well summarized by the expected duration of the zero lower bound.

Figure 18 shows the effect of the transfer shock from banks to households under two configurations. In one case the transfer shock occurs against the background of a deep recession and the responses are shown in deviation from the outlook for the economy that agents expected prior to the realization of the transfer shock. In the other case, the responses are shown in deviation from their steady state values (interpreted as "normal times" given the linear approximation used to solve the model).

In GJP's setup, banks cannot attract deposits at negative nominal rates. In that case, in the face of deflationary shocks, such as the transfer shock considered, the real return on deposits *rise* instead of falling. The unexpected rise in real deposit rate, equal in size but opposite in sign to the response of inflation in deviation from baseline, amplifies the drop in bank equity relative to normal times. In turn, the further drop in bank equity amplifies the rationing of credit and the contraction of investment and output relative to normal times, away from the zero lower bound.

It is well understood that the amplification of the responses of the economy to contractionary shocks in a liquidity trap is driven by the evolution of inflation expectations. In our model, the deflationary effects of the shock are kept to a relatively modest size – inflation drops $\frac{1}{4}$ percentage point at its nadir

– principally by monetary policy. The policy rule is anticipated to respond aggressively to stabilize inflation away from the zero lower bound. The credible response of monetary policy away from the zero lower bound provides forward guidance. By contrast, with a less aggressive monetary policy rule, inflation is more volatile and the zero lower bound would amplify the effects of contractionary shocks in a more pronounced fashion. Similarly, the expected duration of the zero lower bound is a key determinant of the non-linear amplification effects at the zero lower bound. For an extended discussion of these issues see Bodenstein, Erceg, and Guerrieri (2009) and Bodenstein, Guerrieri, and Gust (2013).

9 Conclusions

Even models that have a common methodological core but have been developed to emphasize a complementary set of linkages between the financial sector and the macroeconomy produce a wide array of quantitative predictions relative to the macroeconomic effects of a shortfall in capital. All the models presented, imply that the baseline shock that produces a capital shortfall similar in size to that gauged under the stress test scenarios of CCAR 2013, albeit rescaled to apply to a broad intermediary financial sector rather than the largest banks, would lead to a contraction in output. However, the size of this contraction varies greatly across models.

A few general conclusions emerge:

1. General equilibrium channels can exert a large influence on the spillover effects of capital shortfalls through the response of asset prices such as the price of capital and interest rate spreads.

2. The interaction between alternative sectors that can provide financing is an important determinant of the availability of credit and of the size of the macroeconomic consequences of shortfalls in capital. In turn, important implications of this interaction ride through asset prices.

3. The modeling of alternative sources of financing can lead to large differences in results. The interaction among alternative financing sources can generate subtle differences across models. For instance, recapitalization associated with outside equity can be influenced by readily measurable costs, such as costs of issuance, as well as by more subtle structural features of the economy, such as the effect of outside equity on incentives of banks.

4. If the financial shock does not imply the destruction of physical resources, as for our baseline transfer shock, the macroeconomic spillover has to work through a contraction in hours worked on impact. Accordingly, refinements of the linkages between financial frictions and frictions in the labor market would bolster our understanding of the macro effects of financial shocks.

5. Finally, sensitivity analysis shows that the sources of shocks to financial positions can have a large influence on their macroeconomic effects.

Table 1: Model Characteristics

	Iacoviello	Covas Driscoll	Kiley Sim	Queralto	Guerrieri Jahan-Parvar
Choices available to banks					
Issue new equity	no	no	yes	yes	no
Reduce dividend payments	yes	yes	yes	no	no
Increase operating efficiency	no	no	no	no	no
Raise interest spread	yes	yes	yes	yes	yes
Increase non-interest income	no	no	no	no	no
Services offered by banks					
Liquidity provision	yes	yes	yes	yes	yes
Liquidity transformation	no	no	no	no	no
Other Features of the model					
Multiple sources of funding(*)	yes	yes	no	no	yes
Nominal rigidities	no	no	yes	no	yes
Solution Method	1st order	nonlinear	1^{st}-2^{nd}order	1st order	piecewise lin.

(*) "Multiple sources of funding" refers to the presence of sources of funding other than bank credit.

Table 2: Selected Moments of Covas and Driscoll's Model

Moments	Data	Model
Tier 1 capital ratio	10.0	9.7
Share of constrained banks	0.1	0.3
Leverage ratio	7.0	6.3
Adjusted return-on-assets	2.9	3.4
Cross-sectional volatility of adjusted return-on-assets	1.3	1.4
% Safe assets held by banks	33.1	34.4
Ratio of interest income to noninterest income	1.3	0.3
Share of noninterest expenses	3.0	8.5
Return on securities	0.5	0.5
Loan rate	4.0	4.1
Consumption to output	0.7	0.7
Banking assets to output	0.9	1.2
Safe-to-total assets	0.3	0.3
Memo: Deposit rate	0.1	0.1
% Labor in entrepreneurial sector	—	58.5
% Labor in corporate sector	—	41.5
% Output of entrepreneurial sector	—	63.8
% Output of corporate sector	—	24.7
% Output of banking sector	—	11.5

NOTE: Moments are based on sample averages using quarterly observations between 1997:Q1 and 2012:Q3, with the exception of the percentage of safe assets held by banks which is only available starting in 2001:Q1, and averages for the ratio of interest income to noninterest income and banking assets to output are calculated only for the period after the fourth quarter of 2008 when investment banks became bank holding companies. The adjusted return on assets is defined as net income excluding income taxes and salaries and employee benefits. The percentage of safe assets held by banks includes all assets with a zero risk weight plus assets with a 20 percent risk weight. The sample includes all bank holding companies and commercial banks that are not part of a BHC, or that are part of a BHC which does not file the Y-9C report. The share of constrained banks is estimated using banks' responses in the Senior Loan Officer Opinion Survey and reported by Bassett and Covas (2013). The safe-asset share is obtained from Gorton, Lewellen, and Metrick (2012).

Table 3: Details of the Transfer Shock in Covas and Driscoll's Model

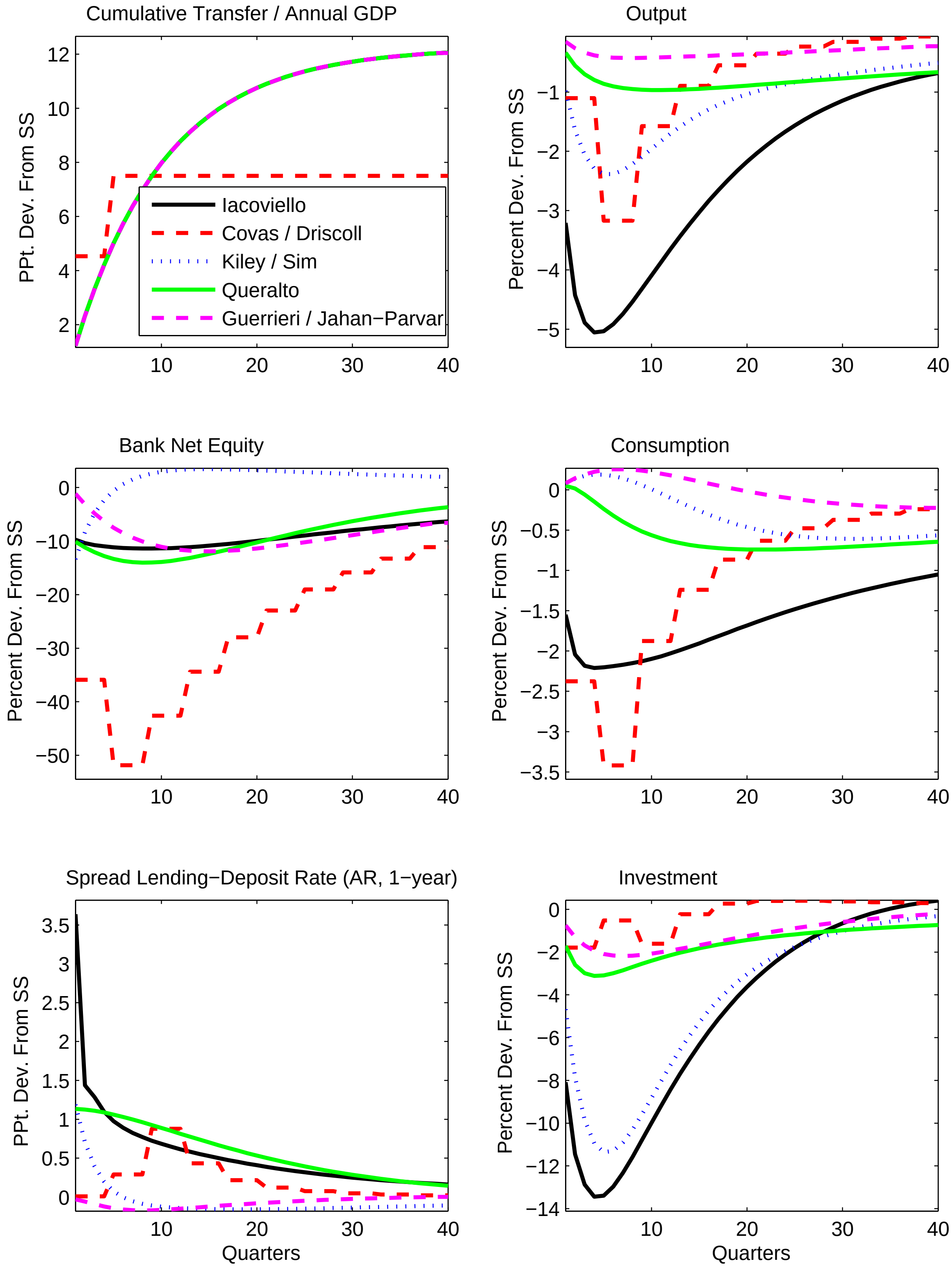
Sector	Year 1	Year 2
Workers	0.9	0.6
Entrepreneurs	0.2	0.2
Bankers	-37.3	-24.5

NOTE: Entries in the table denote the size of transfer in each year as a percent of the steady-state level of wealth of each sector.

Table 4: Calibrated Parameters in Queralto's Model

γ	2	Risk aversion
β	0.99	Discount factor
α	0.33	Capital share
δ	0.025	Depreciation rate
χ	0.25	Utility weight of labor
φ	1/3	Inverse Frisch elasticity of labor supply
If''/f'	1	Inverse elasticity of investment to the price of capital
h	0.75	Habit parameter
σ	0.9685	Survival rate of bankers
ξ	0.0289	Transfer to entering bankers
		Asset diversion parameters:
θ	0.264	
ε	-1.21	
κ	13.41	

Figure 1: Horizontal Model Comparison



The model of Covas and Driscoll is calibrated to reflect an annual frequency. In all the panels above, the responses of their model that apply to any given year have been repeated for each quarter of that year.

Figure 2: Results from a VAR

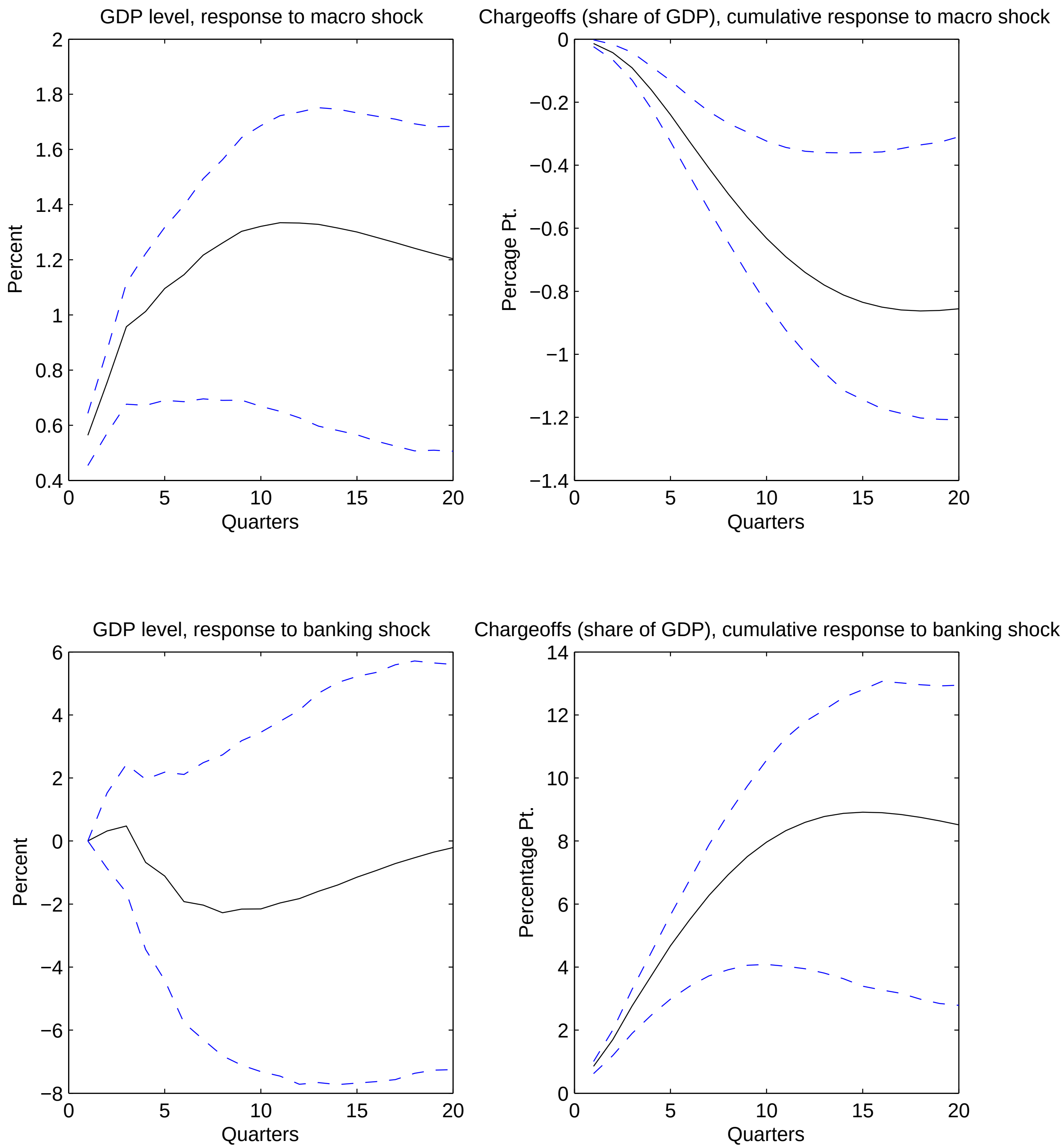


Figure 3: A Transfer Shock in Iacoviello's model

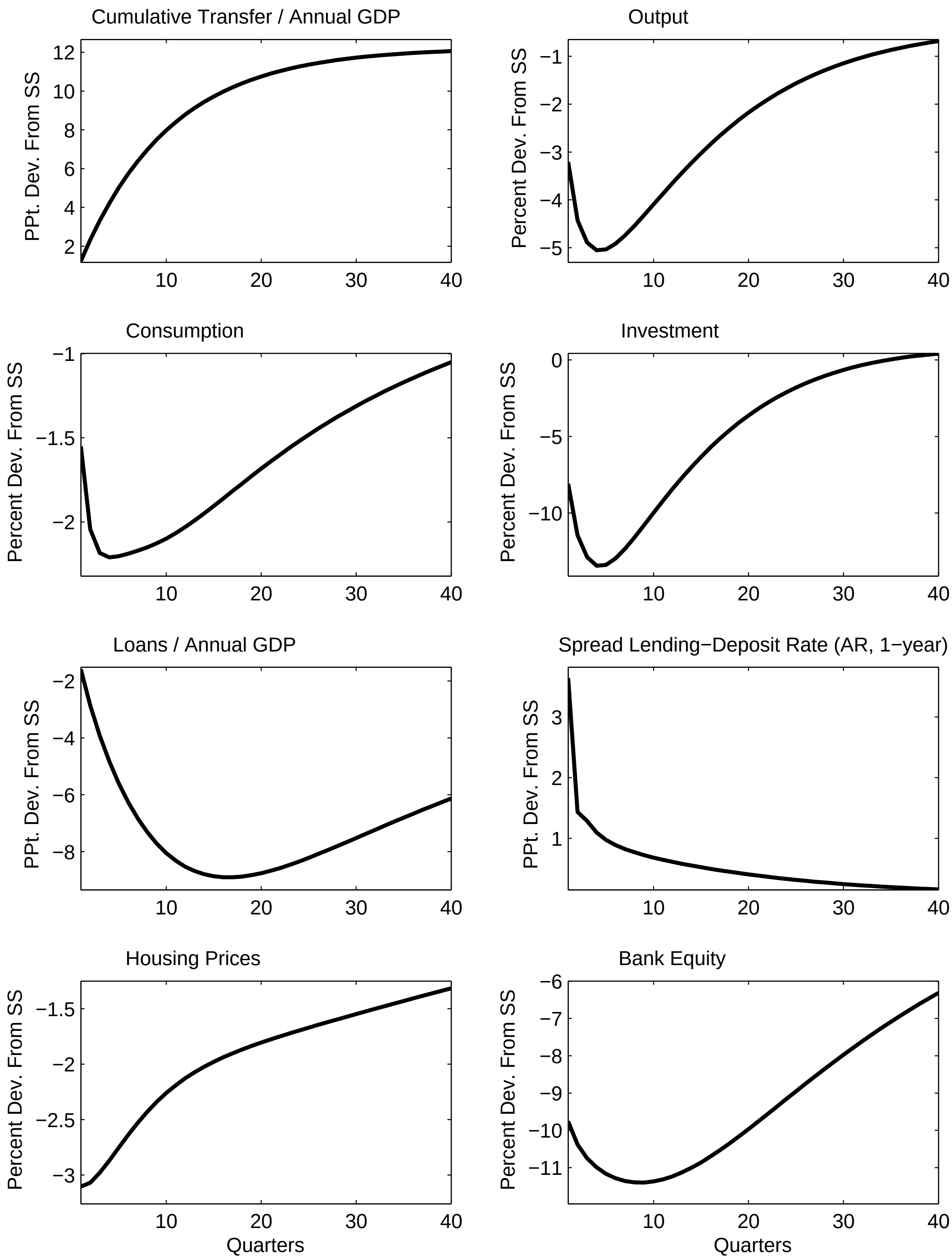


Figure 4: A Transfer Shock in Iacoviello's model: Robustness Analysis

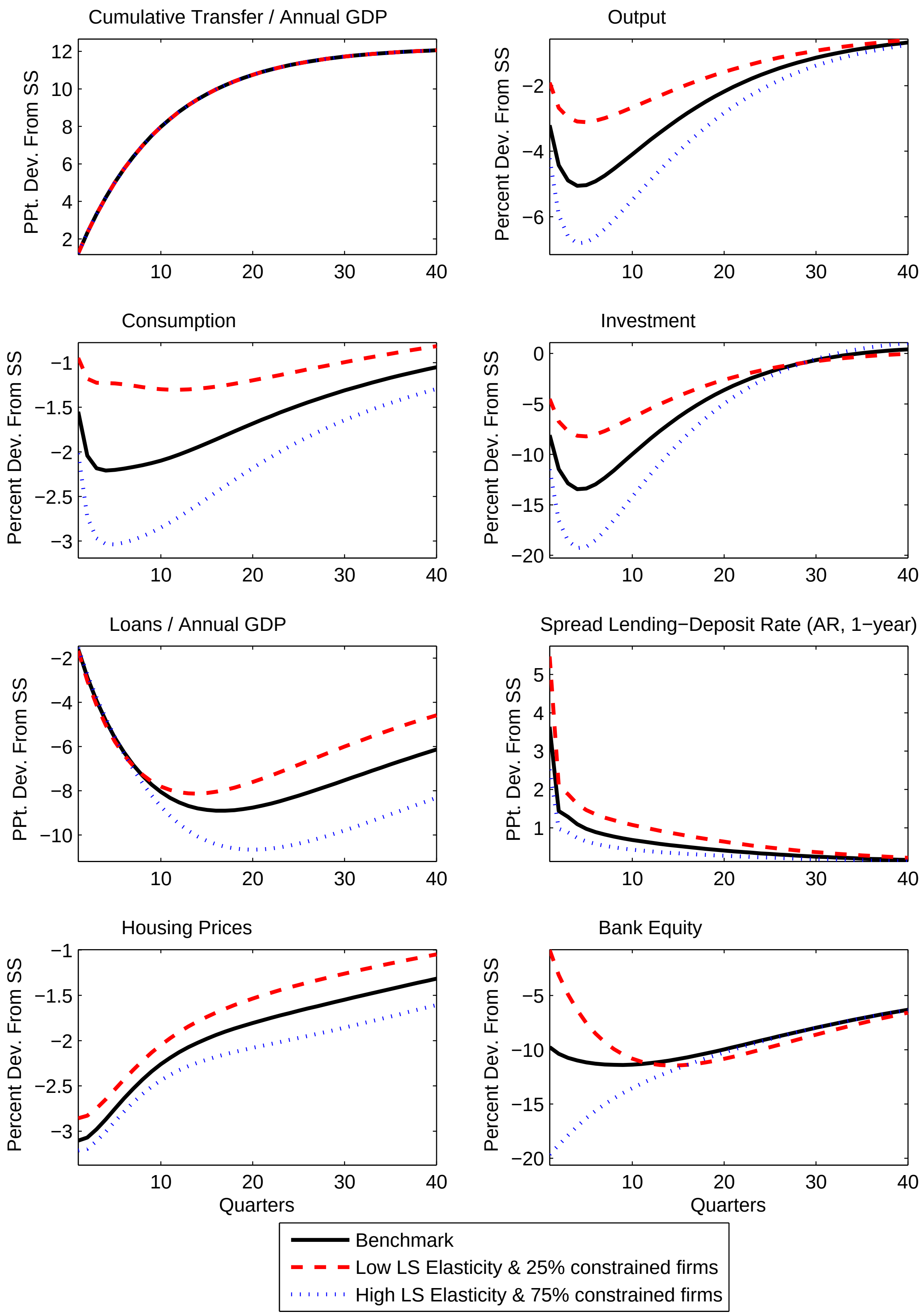


Figure 5: A Transfer Shock vis-a-vis A Housing Price Shock in Iacoviello's model

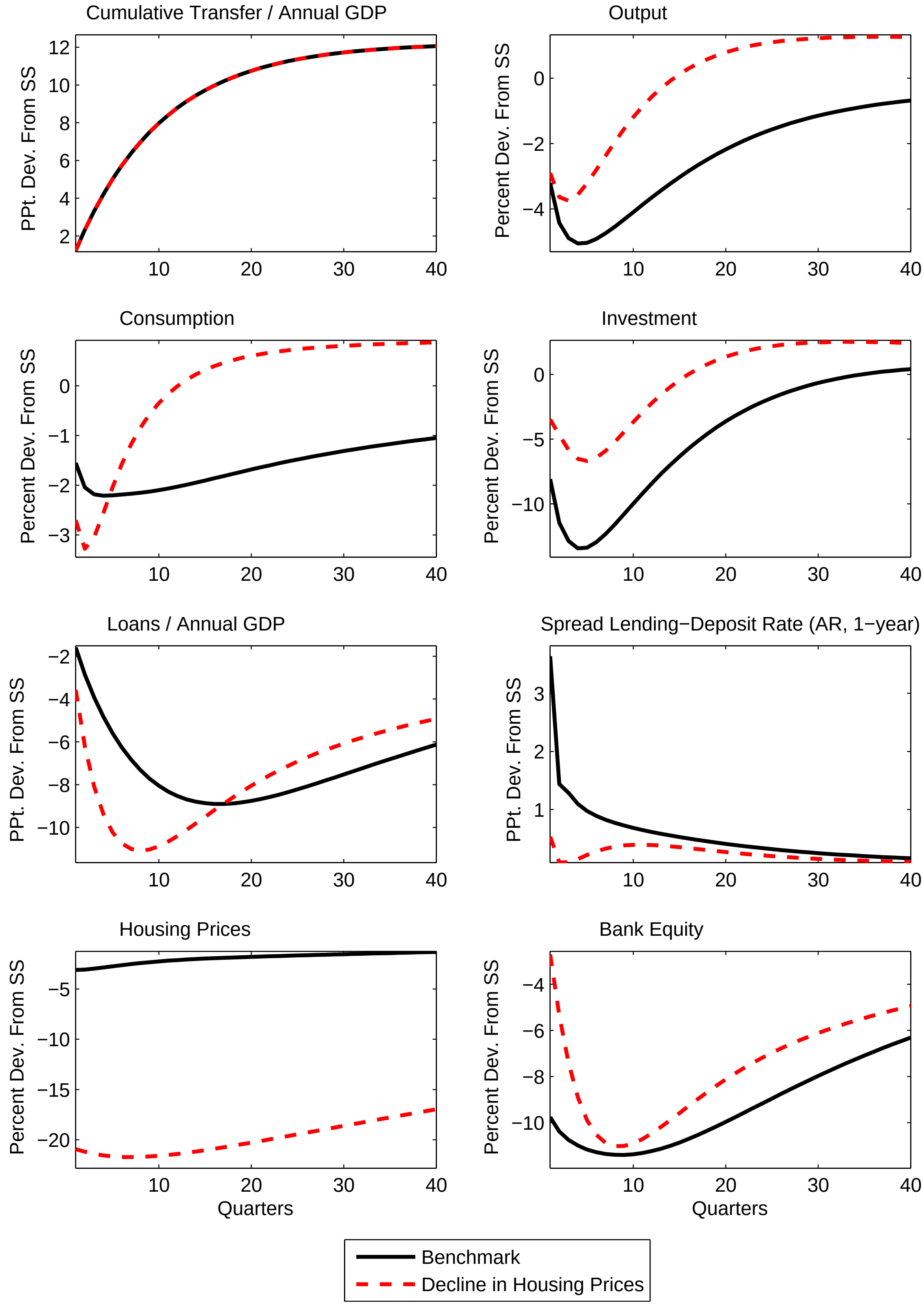


Figure 6: A Transfer Shock in the Covas/Driscoll Model

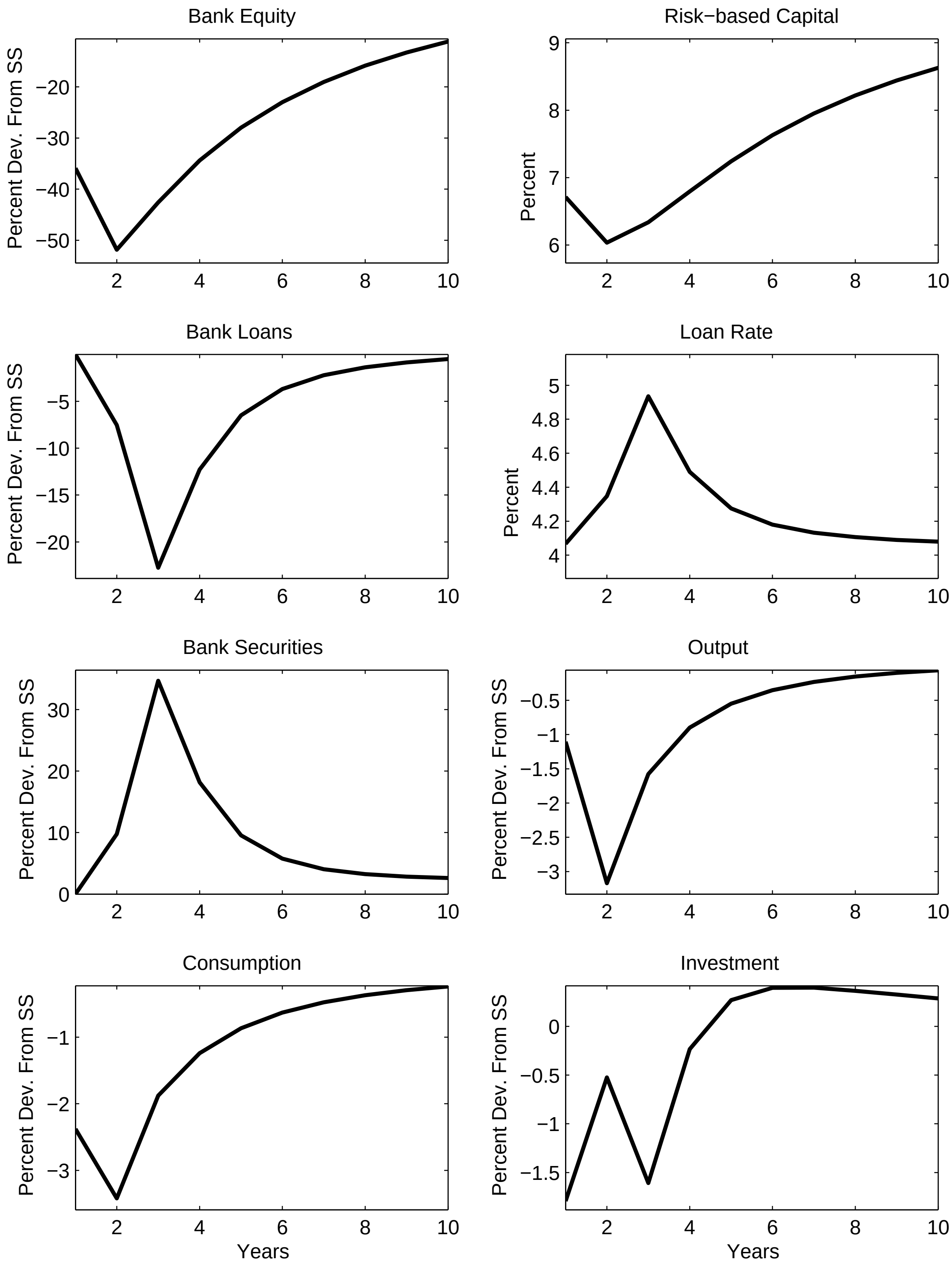


Figure 7: A Transfer Shock in the Covas/Driscoll Model: Robustness Analysis

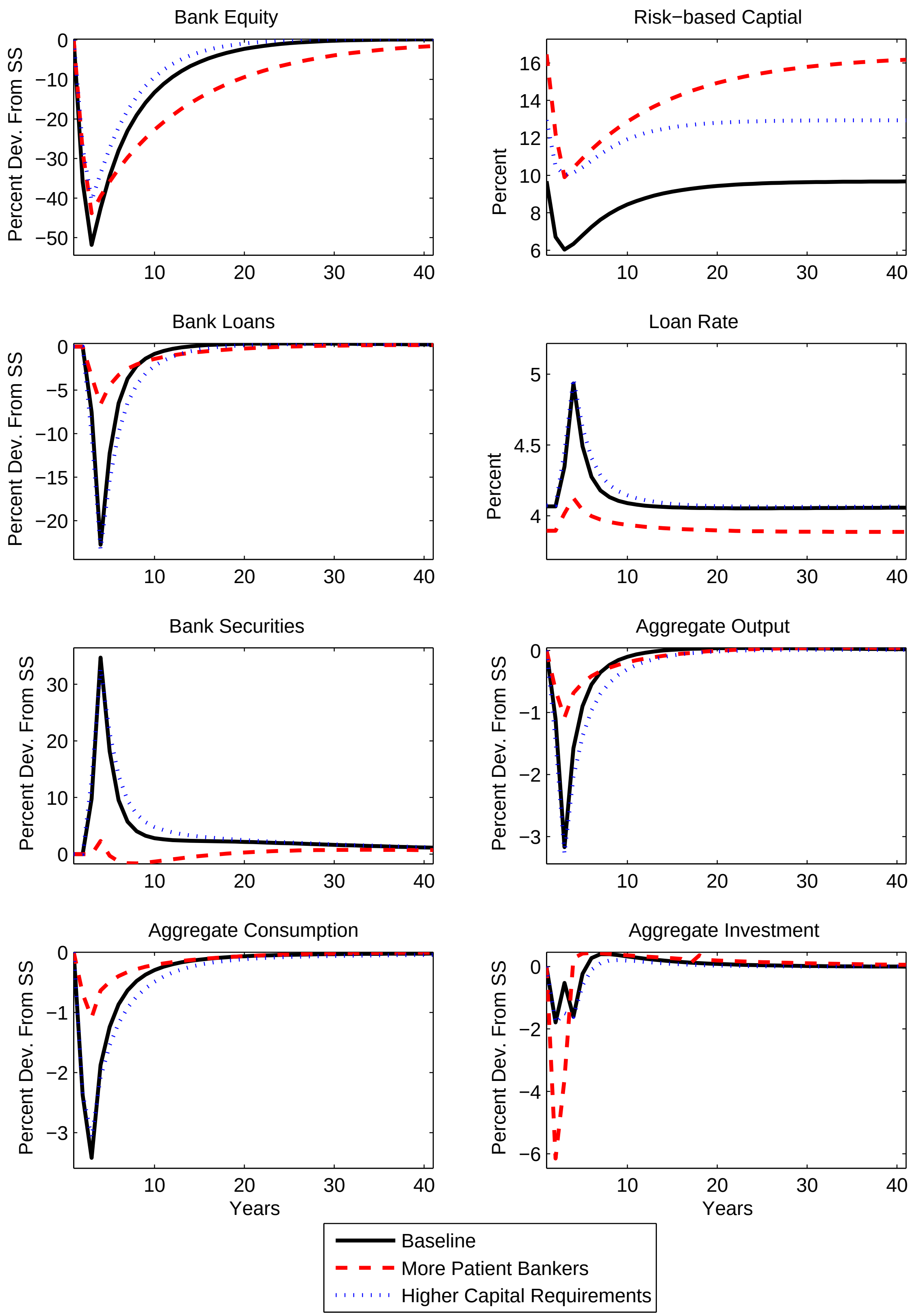


Figure 8: A Transfer Shock vs. Bank Revenue Shock in the Covas/Driscoll Model

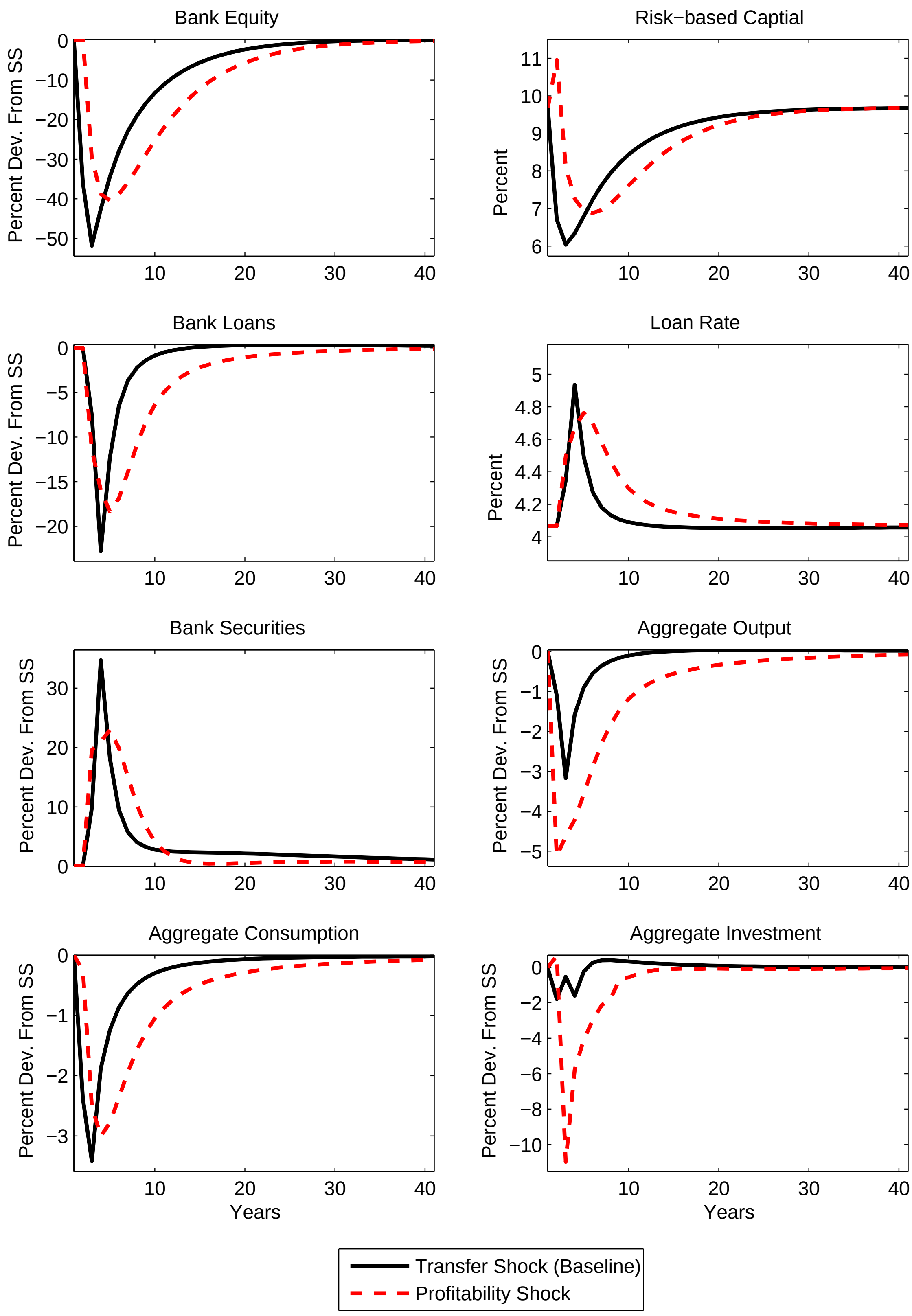


Figure 9: Effects of a Transfer Shock in the Kiley/Sim Model

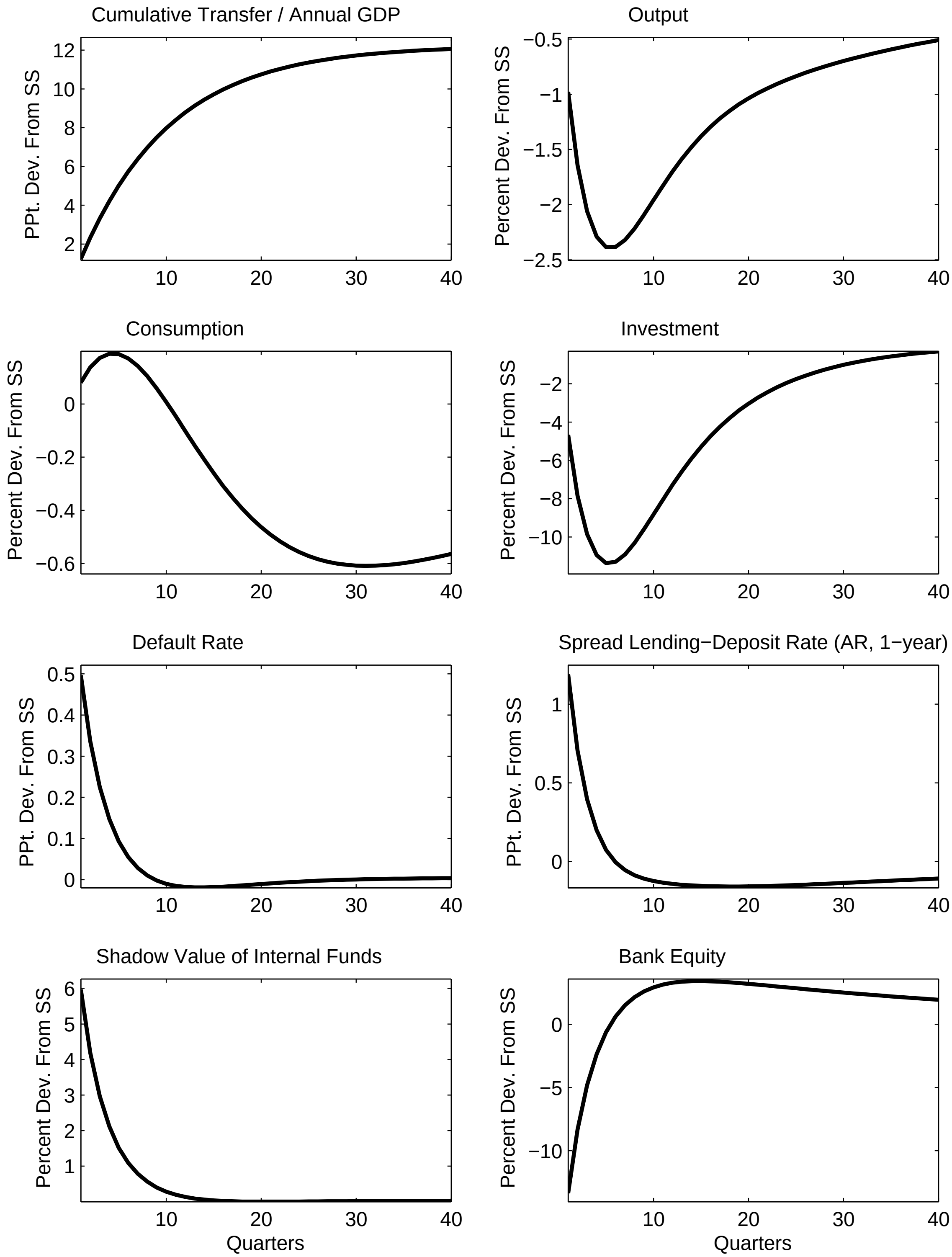


Figure 10: Effects of a Transfer Shock in the Kiley/Sim Model: Sensitivity Analysis

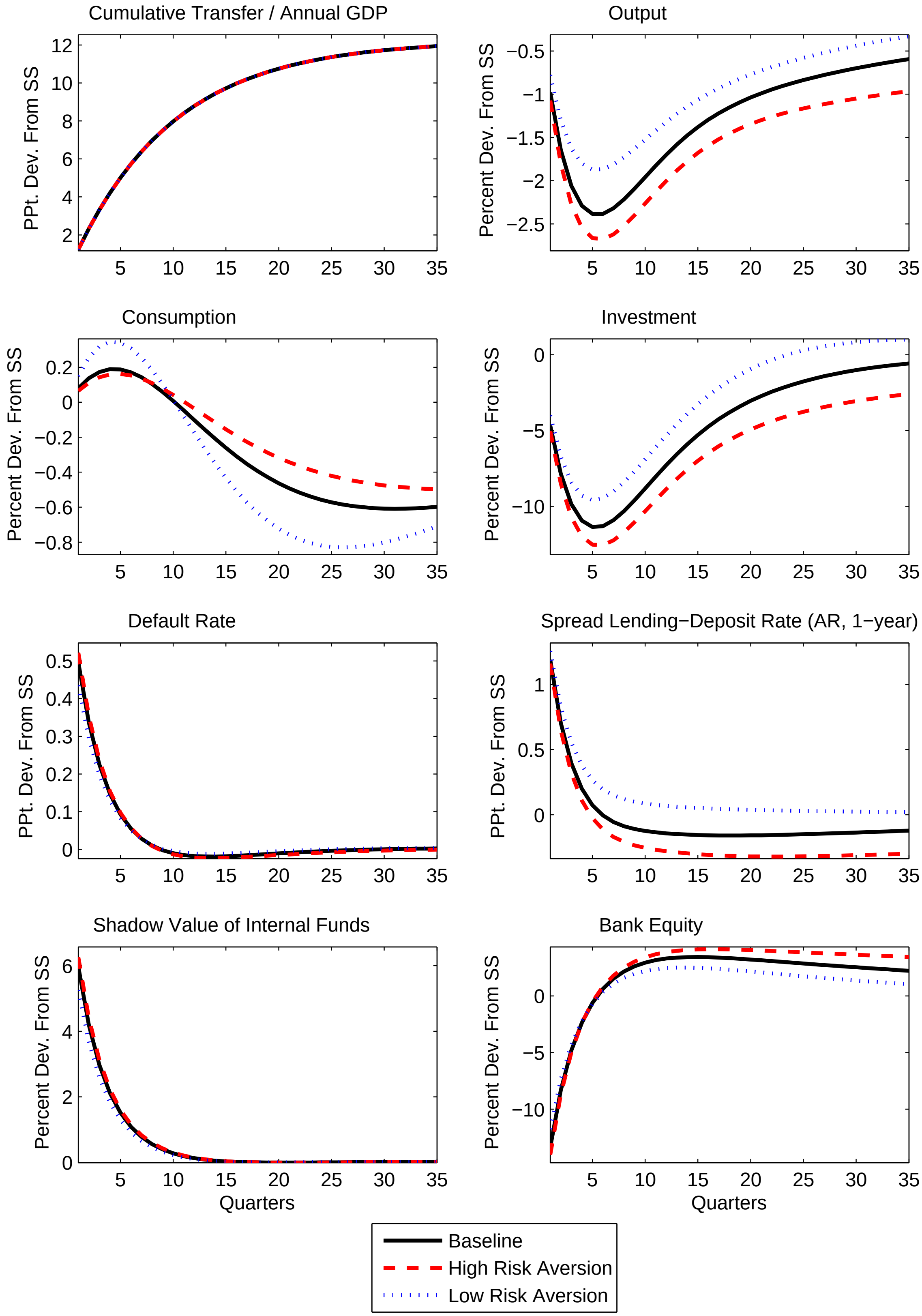


Figure 11: Effects of A Dilution Cost Shock vs. a Transfer Shock in the Kiley/Sim Model

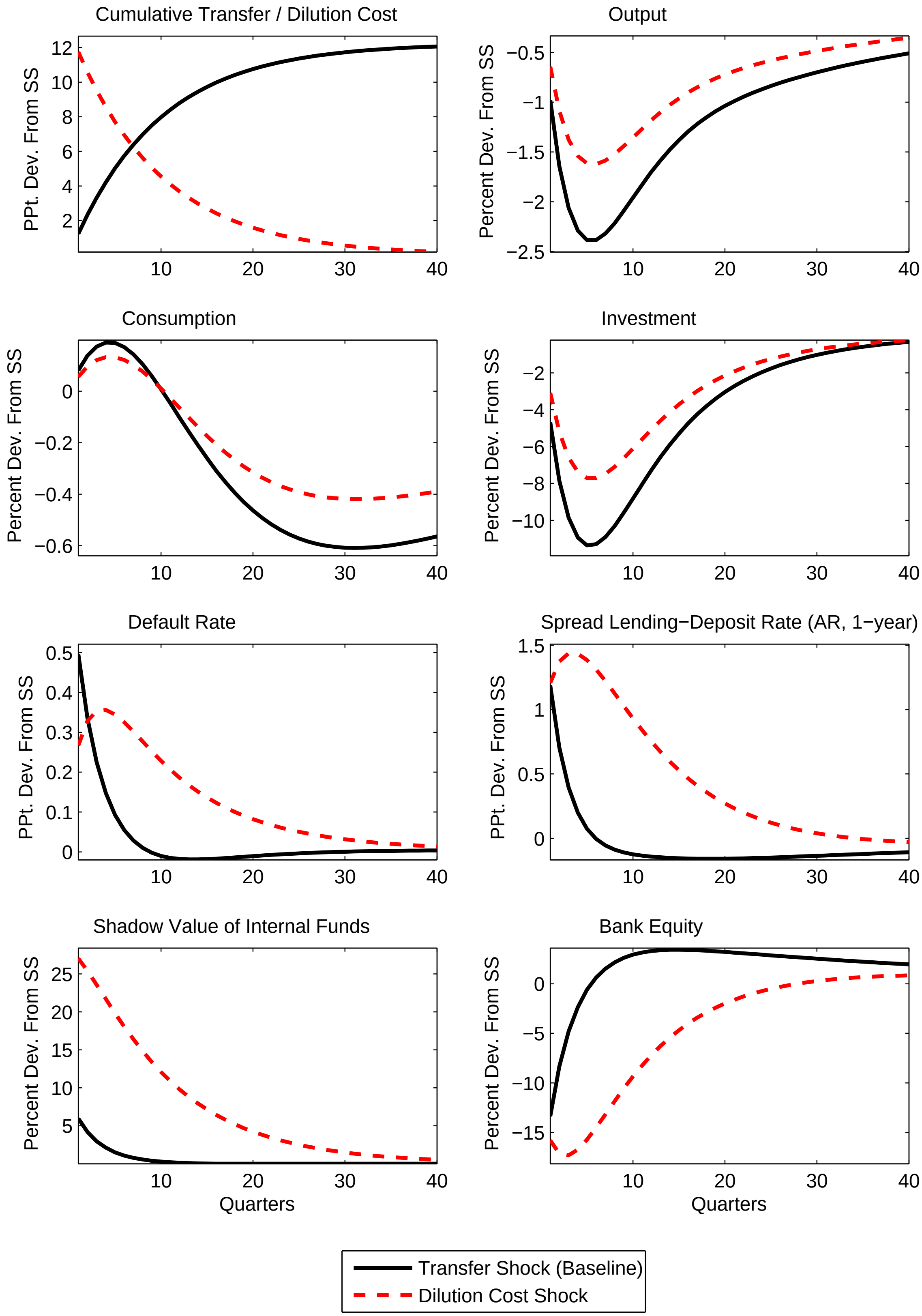


Figure 12: Effects of a Transfer Shock in the Queralto Model

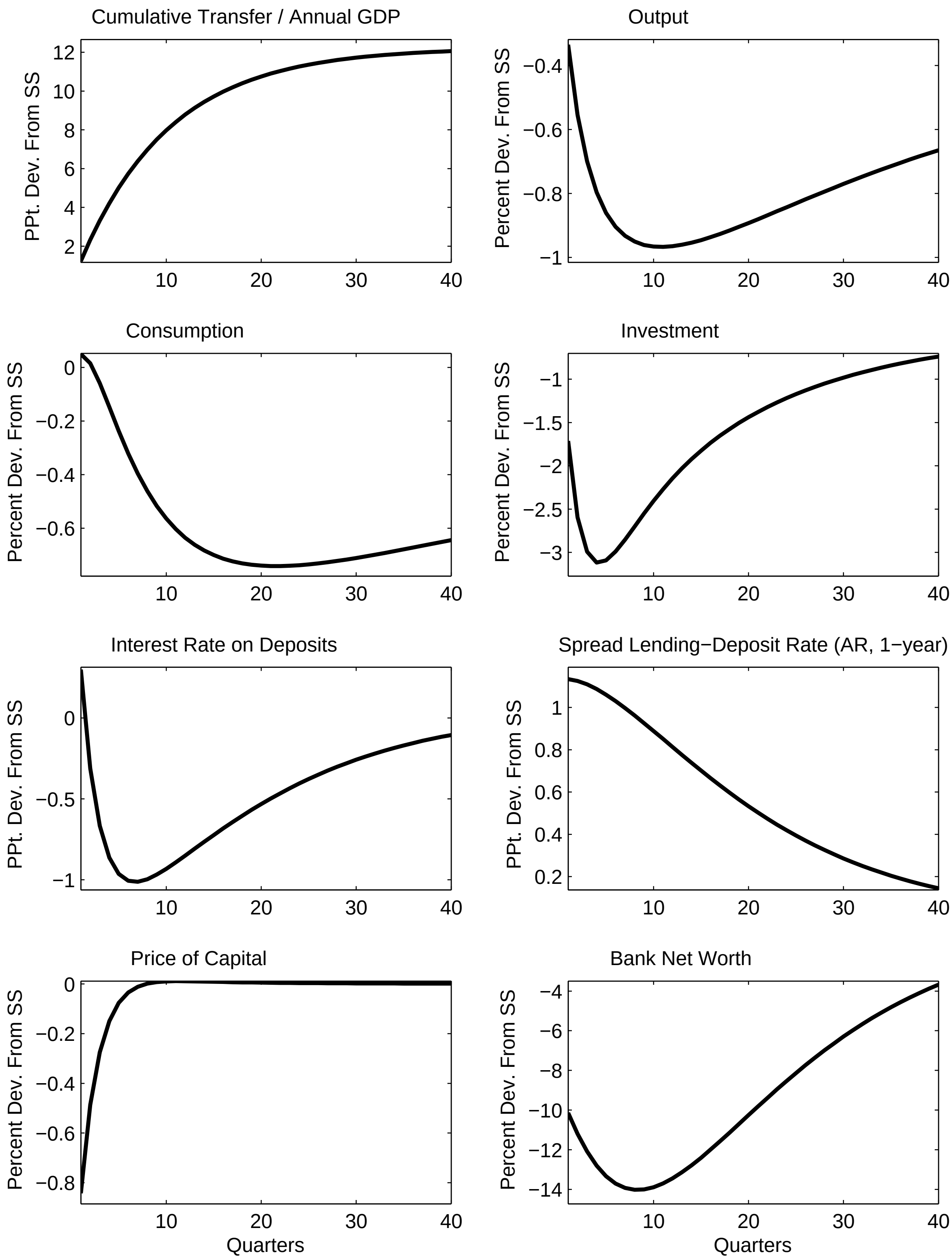


Figure 13: Effects of a Transfer Shock in the Queralto Model: Sensitivity Analysis

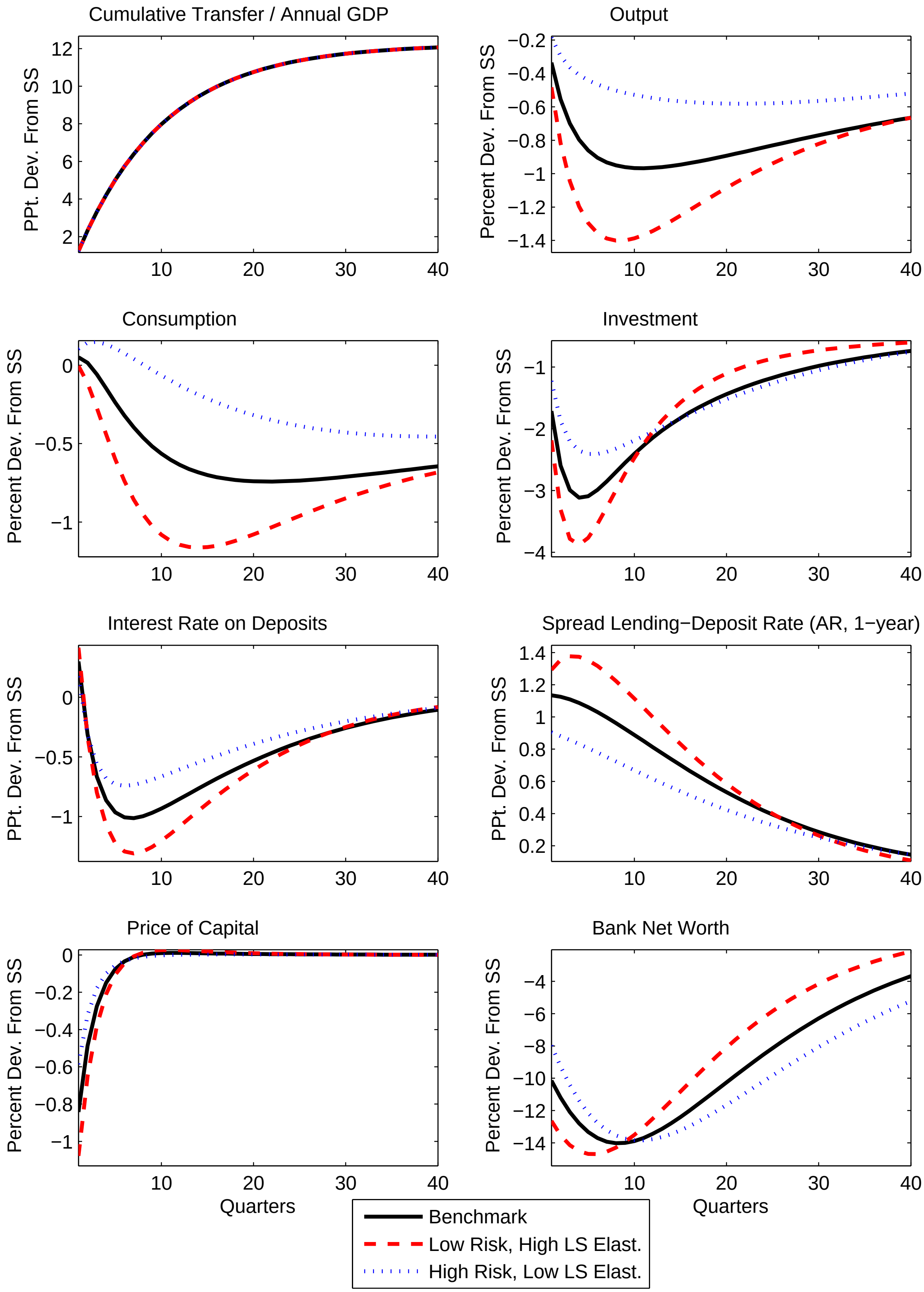


Figure 14: Transfer Shock vs. Capital Quality Shock in the Queralto Model

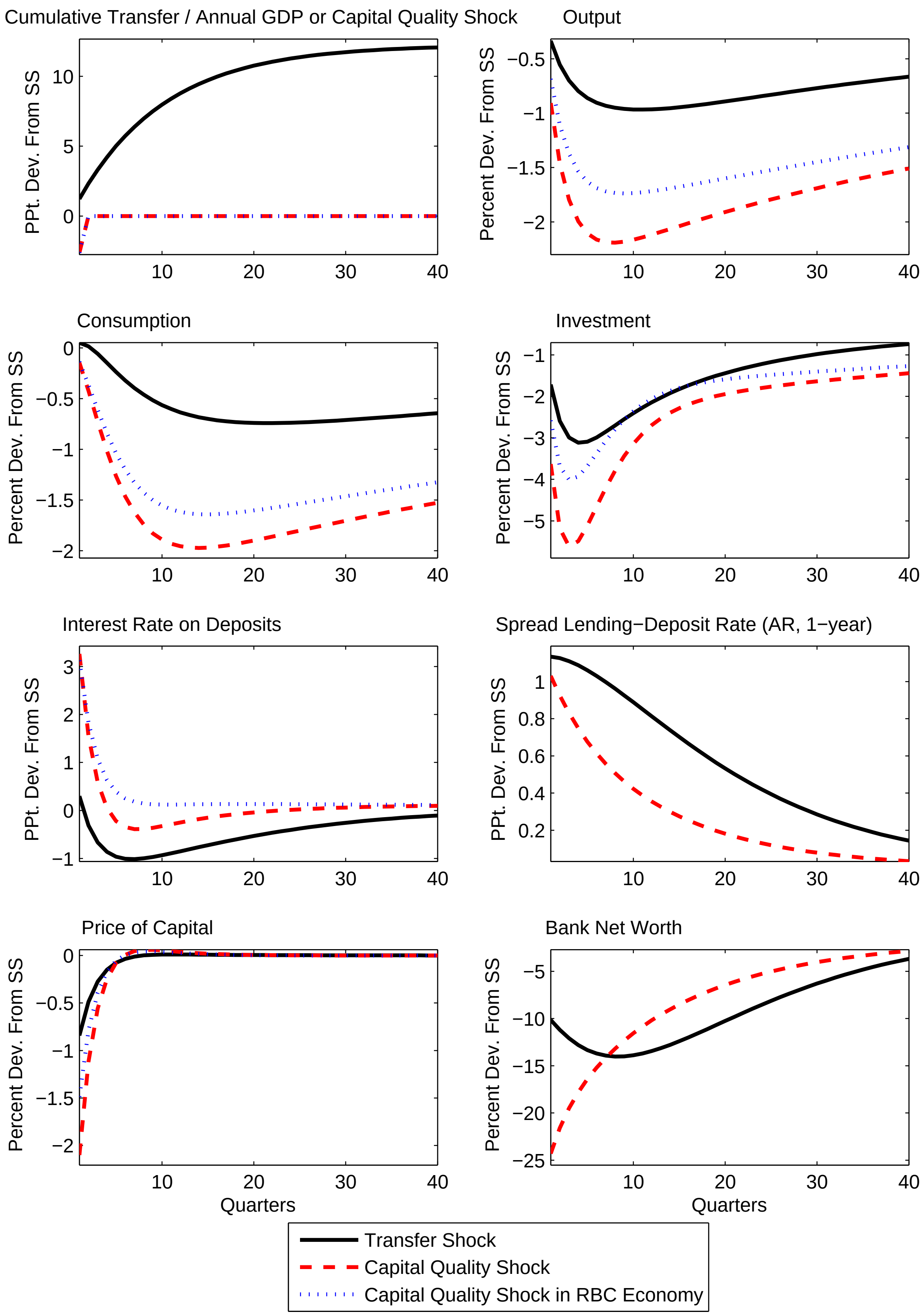


Figure 15: Effects of a Transfer Shock in the Guerrieri/Jahan-Parvar Model

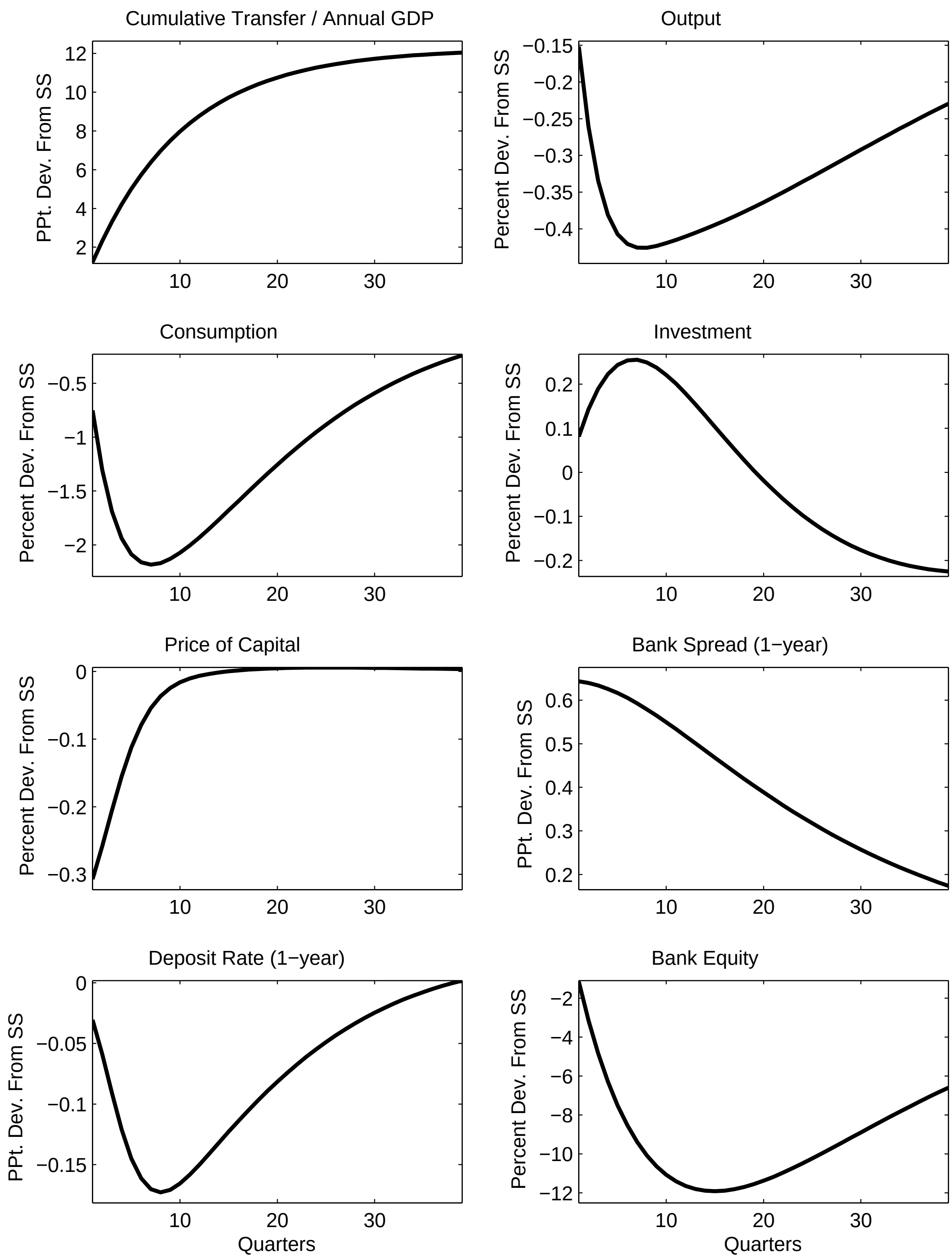
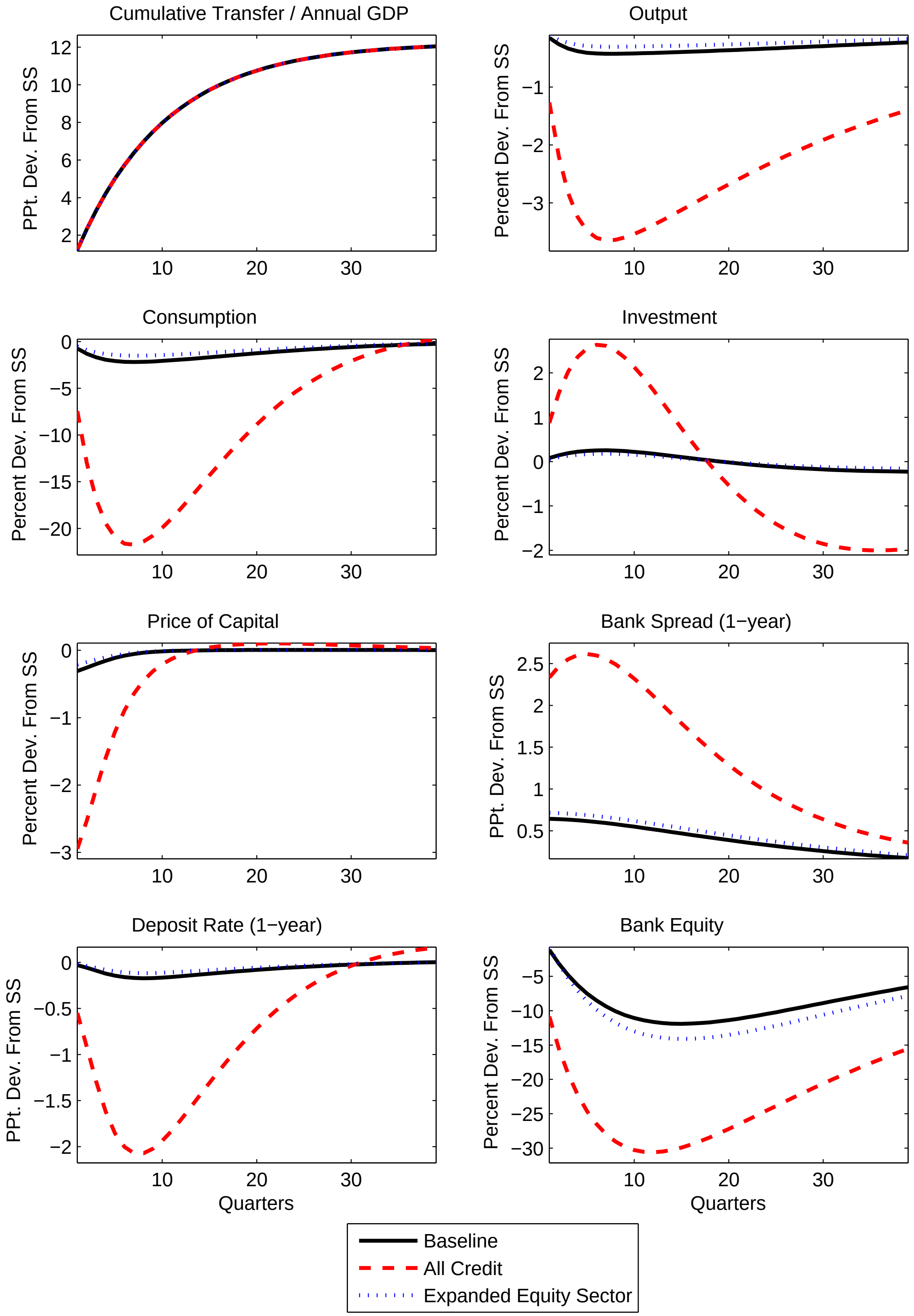


Figure 16: Effects of a Transfer Shock in the Guerrieri/Jahan-Parvar Model: Sensitivity Analysis



"All Credit" refers to a 1-sector model in which all firms are credit-dependent. Under "Expanded Equity Sector" firms with access to equity financing account to 75% of aggregate output.

Figure 17: Transfer Shocks vs. Valuation Shocks in the Guerrieri/Jahan-Parvar Model

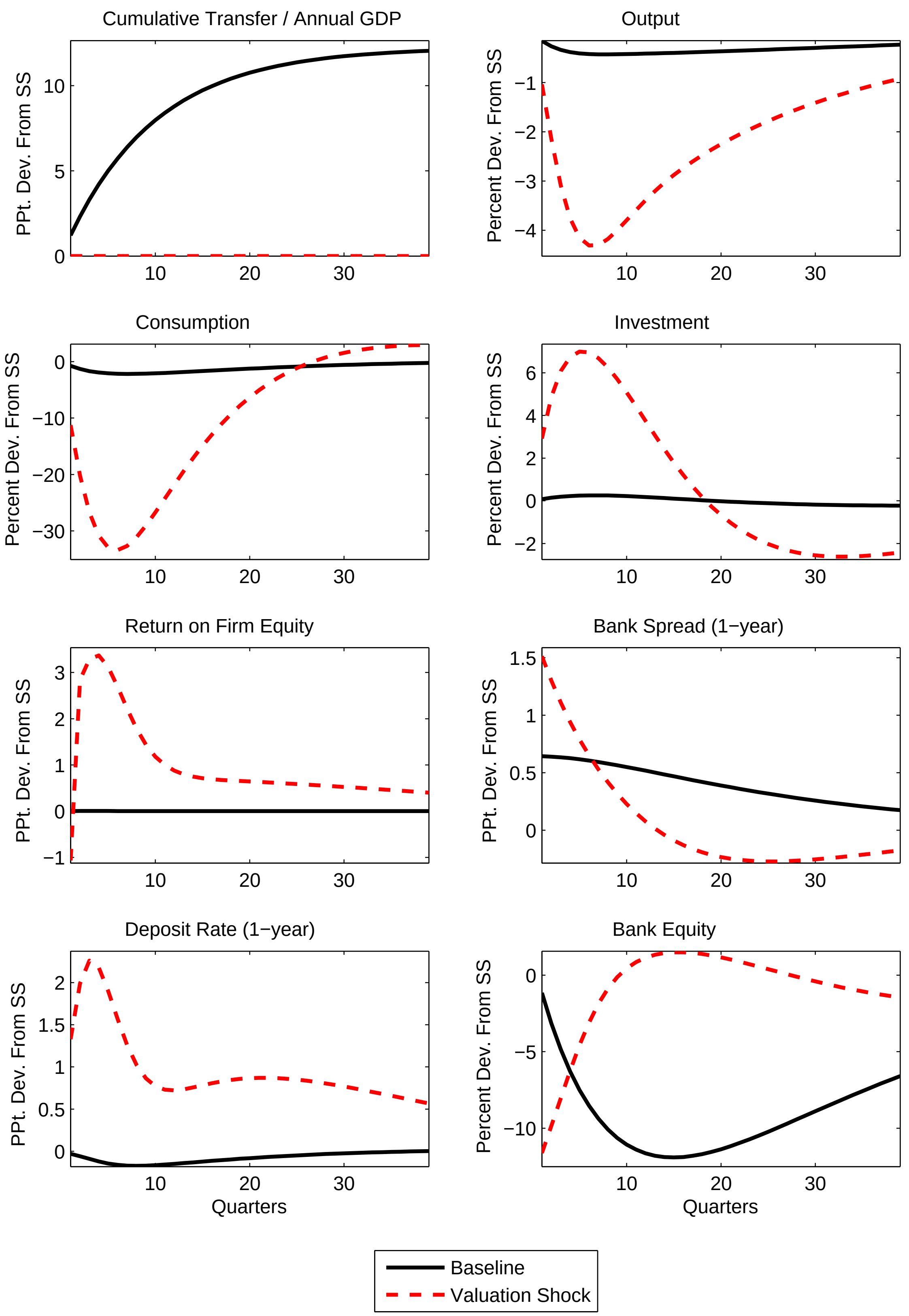
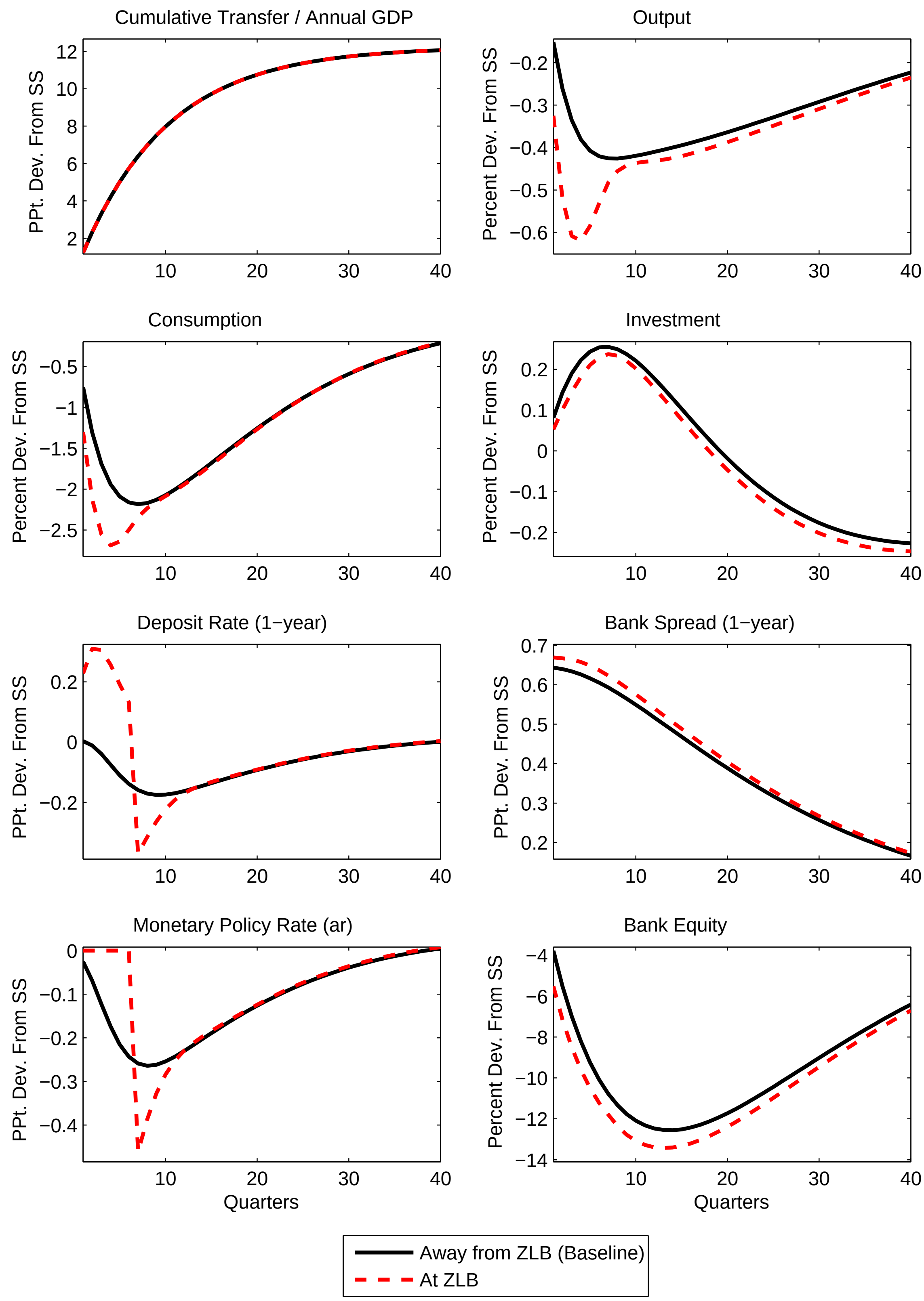


Figure 18: Transfer Shock at the Zero Lower Bound in the Guerrieri/Jahan-Parvar Model



References

Aiyagari, R. (1994). Uninsured idiosyncratic risk and aggregate saving. *Quarterly Journal of Economics 109*, 659–684. [11]

Albuquerque, R., M. Eichenbaum, and S. Rebelo (2012). Valuation risk and asset pricing. Working Paper. [26]

Angeletos, G.-M. (2007). Idiosyncratic investment risk and aggregate savings. *Review of Economic Dynamics 10*, 1–30. [12]

Bassett, W. and F. Covas (2013). A new look at the relationship between capital constraints and bank lending. Mimeo. [30]

BCBS (2010). An assessment of the long-term economic impact of stronger capital and liquidity requirements. Technical report, Basel Committee on Banking Supervision, Bank for International Settlements. [5, 8]

Bernanke, B. and M. Gertler (1989). Agency costs, net worth, and business fluctuations. *The American Economic Review 79*(1), 14–31. [19]

Bodenstein, M., C. J. Erceg, and L. Guerrieri (2009). The effects of foreign shocks when interest rates are at zero. International Finance Discussion Papers 983, Board of Governors of the Federal Reserve System. [27, 28]

Bodenstein, M., L. Guerrieri, and C. J. Gust (2013). Oil shocks and the zero bound on nominal interest rates. *Journal of International Money and Finance 32*(C), 941–967. [28]

Boldrin, M., L. J. Christiano, and J. D. M. Fisher (2001). Habit persistence, asset returns and the business cycle. *American Economic Review 91*(1), 149–166. [24]

Brunnermeier, M. K. and Y. Sannikov (2013). A macroeconomic model with a financial sector. *American Economic Review*. [16, 17]

Calomiris, C. and C. Kahn (1991). The role of demandable debt in structuring banking arrangements. *American Economic Review* (81), 497–513. [21]

Coeurdacier, R., H. Rey, and P. Winant (2011). The risky steady state. Technical report, London Business School. [22]

Coleman, W. J. (1990). Solving the stochastic growth model by policy-function iteration. *Journal of Business and Economic Statistics 8*, 27–29. [13]

Covas, F. (2006). Unisured idiosyncratic production risk with borrowing constraints. *Journal of Economic Dynamics and Control 30*, 2167–2190. [12]

Covas, F. and J. D. Driscoll (2013). The macroeconomic impact of adding liquidity regulations to bank capital regulations. Mimeo. [11]

De Nicolò, G., A. Gamba, and M. Lucchetta (2013, March). Capital regulation and liquidity requirements in a dynamic model of banking. Mimeo. [12]

Gertler, M. and P. Karadi (2011, January). A model of unconventional monetary policy. *Journal of Monetary Economics 58*(1), 17–34. [16, 19, 24]

Gertler, M. and N. Kiyotaki (2010). Financial intermediation and credit policy in business cycle analysis. Volume 3 of *Handbook of Monetary Economics*, pp. 547 – 599. Elsevier. [16, 19]

Gertler, M., N. Kiyotaki, and A. Queralto (2012). Financial crises, bank risk exposure and government financial policy. *Journal of Monetary Economics 59*(S), S17–S34. [19, 20, 22]

Gorton, G., S. Lewellen, and A. Metrick (2012). The safe-asset share. *American Economic Review: Papers & Proceedings 102*, 101–106. [30]

Greenwood, J., Z. Hercowitz, and G. W. Huffman (1988). Investment, capacity utilization, and the real business cycle. *American Economic Review 78*(3), 402–17. [20]

Guerrieri, L. and M. Iacoviello (2013). Occbin: A toolbox for solving dynamic models with occasionally binding constraints easily. Technical report. Mimeo, Federal Reserve Board. [27]

He, Z. and A. Krishnamurthy (2012, October). A macroeconomic framework for quantifying systemic risk. Working Paper Research 233, National Bank of Belgium. [16]

Iacoviello, M. (2005, June). House prices, borrowing constraints, and monetary policy in the business cycle. *American Economic Review 95*(3), 739–764. [8]

Iacoviello, M. (2013). Financial business cycles. *Unpublished manuscript, Federal Reserve Board*. [8]

Kiyotaki, N. and J. Moore (1997). Credit cycles. *The Journal of Political Economy 105*(2), pp. 211–248. [19]

Miao, J. and P. Wang (2010). Credit risk and business cycles. Technical report, Boston University. [20]

Myers, S. C. and N. S. Majluf (1984). Corporate financing and investment decisions when firms have information that investors do not have. *Journal of Financial Economics 13*(2), 187 – 221. [16]

Smets, F. and R. Wouters (2007). Shocks and frictions in us business cycles: A bayesian dsge approach. *The American Economic Review 97*(3), 586–606. [16]