BANK OF CANADA
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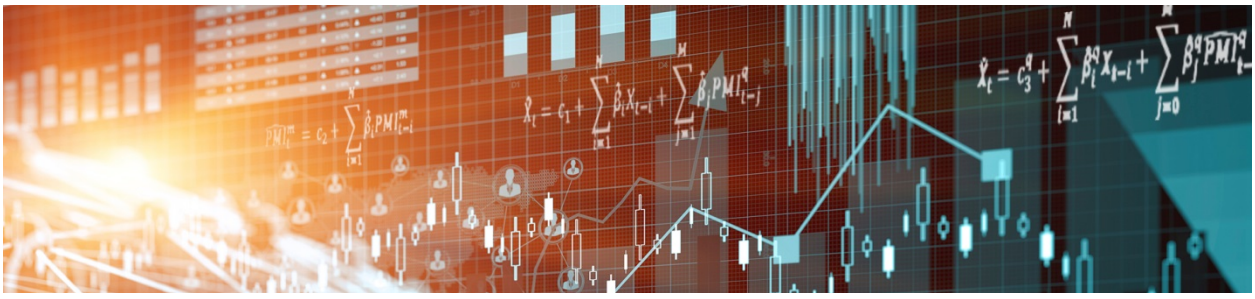
Staff Working Paper/Document de travail du personnel 2016-29

Financial Crisis Interventions



by Josef Schroth

Bank of Canada Staff Working Paper 2016-29

June 2016

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ISSN 1701-9397

Acknowledgements

I thank Jason Allen, Eva Carceles-Poveda, Matthieu Darracq Paries, Césaire Meh, Miguel Molico, Kevin Moran, Stephane Moyen, Patricia Palhau Mora, Victor Rios-Rull and Yasuo Terajima for helpful comments and suggestions.

Abstract

This paper develops a model of an economy where bank credit supports both productive investment and individual consumption smoothing in the face of idiosyncratic income risk. Bank credit is constrained by bank equity capital. When policy-makers inject equity capital during financial crises, they trade off stimulating credit supply immediately against long-term distortions related to funding equity injections. I calibrate my model and show that the bank equity capital injection that maximizes average utilitarian welfare redistributes from the poor to the wealthy. While wealthy savers benefit immediately from an increased supply of safe assets, less affluent borrowers and savers suffer from long-term distortions.

JEL classification: E13, E32, E44
Bank classification: Financial stability; Financial system regulation and policies; Lender of last resort; Credit and credit aggregates

Résumé

L'auteur élabore un modèle d'une économie où le crédit bancaire soutient à la fois l'investissement productif et le lissage de la consommation individuelle face à un risque idiosyncrasique pesant sur les revenus. Le crédit qu'une banque peut octroyer est limité par ses capitaux propres. Lorsque, durant une crise financière, les autorités monétaires injectent des liquidités à l'appui des fonds propres bancaires, elles effectuent un arbitrage entre l'effet stimulant immédiat de cette mesure sur l'offre de crédit et les distorsions à long terme qui en résultent. L'auteur étalonne son modèle et montre qu'une injection d'argent frais dans les banques qui maximise le bien-être utilitaire moyen entraîne une redistribution de la richesse des plus pauvres vers les plus riches. Alors que les épargnants aisés profitent immédiatement d'un apport accru d'actifs sûrs, les emprunteurs et les épargnants moins nantis souffrent des distorsions à long terme.

Classification JEL : E13, E32, E44
Classification de la Banque : Stabilité financière; Réglementation et politiques relatives au système financier; Prêteur de dernier ressort; Crédit et agrégats du crédit

Non-Technical Summary

Financial crises are rare events that have high social costs and often lead to policy interventions. Policy-makers are aware that policies aimed at preserving financial stability – much like monetary policy aimed at promoting price stability – may have distributive consequences. Specifically, financial crisis policy interventions that suddenly change the return and price of assets have the potential to redistribute wealth in economies where there is wealth inequality, such as Canada or the United States. However, while the redistributive effects of monetary policy changes have been broadly studied, little is known about how financial crisis policy interventions interact with existing wealth inequality. For example, while the provision of fresh equity capital or guarantees by policy-makers during systemic financial crises may bolster economic activity in the short run, the potential redistribution of income and wealth may leave some agents worse off on net. Regulatory changes following the 2007–2009 US financial crisis address such concerns by strengthening the role of resolution funds, as well as deposit insurance funds, that are financed by financial sector levies rather than by taxpayer funds.

This paper examines how bank equity capital injections that are funded by financial sector levies affect economic activity and analyzes their distributional consequences. I find that equity injections stabilize output and average welfare significantly but also redistribute from the poor to the wealthy. In particular, wealthy individuals benefit more from an increased supply of risk-free assets from the equity injection – banks use new equity to attract external funds – while poorer individuals are especially hurt by lower long-run wages. Policies that have the potential to correct these adverse distributional consequences, such as policies that attribute losses to bank creditors, might therefore be complementary to equity injections.

1 Introduction

Financial crises are rare events that have high social costs and often lead to policy interventions (Laeven and Valencia, 2013). Financial crisis policy interventions that suddenly change the return and price of assets have the potential to redistribute wealth in economies where there is wealth inequality, such as the United States (Heathcote et al., 2010; Saez and Zucman, 2014). While the redistributive effects of surprise monetary policy changes have been broadly studied (Doepke and Schneider, 2006; Meh et al., 2010), little is known about how financial crisis policy interventions interact with existing wealth inequality. For example, while the provision of fresh equity capital or guarantees by policy-makers during systemic financial crises may bolster economic activity in the short run, the potential redistribution of income and wealth may leave some agents worse off on net.[1] Regulatory changes following the 2007–2009 US financial crisis address such concerns by strengthening the role of resolution funds, as well as deposit insurance funds, that are financed by financial sector levies rather than taxpayer funds.[2]

The aim of this paper is to study how financial crisis policy interventions that are funded by financial sector levies affect economic activity and to analyze their distributional consequences. To this end, I build a model where consumers can be en-

[1]The United States did in fact provide "consumer relief" in the wake of the 2007–2009 financial crisis (WSJ, 2016). The program was small relative to interventions that had supported the financial sector during the crisis but its existence points to policy-maker concern about unevenly distributed gains from interventions such as bank equity capital injections by policy-makers.

[2]For example, both the Dodd-Frank Act in the United States and the Bank Recovery and Resolution Directive in the European Union envision the use of a resolution fund financed by financial sector industry levies (Dodd-Frank, 2010; BRRD, 2014). These rules do not envision support for failed financial institutions, as this could create "too big to fail" moral hazard problems, but rather the use of an Orderly Liquidation Fund or a Single Resolution Fund to support a resolution process (e.g., by providing funding to bridge banks). Financial system support may, for example, take the form of collecting assets of failed banks into bridge banks and providing (resolution) funding until the assets are sold at favourable prices to surviving banks. Ruling out moral hazard in this way, by amplifying the "last bank standing effect" (Perotti and Suarez, 2002), allows me to focus on the ex-post efficiency aspect of financial system support.

trepreneurs or workers, face uninsurable idiosyncratic risks and rely on financial intermediaries (banks) when borrowing. Bank creditors are concerned about potential bank moral hazard, such as possible risk shifting or neglect in servicing loans, and provide funding to banks only when banks have sufficient equity. A financial crisis in this economy is thus a bank balance-sheet crisis that causes a credit crunch leading to deteriorating entrepreneur balance sheets, a consumer balance-sheet recession and persistently low aggregate demand.

Specifically, in my model, when the economy experiences a financial crisis, then the supply of credit initially constrains economic activity. Banks rebuild equity through retained earnings by charging higher interest spreads. However, temporarily elevated lending spreads imply that borrower, and especially entrepreneur, balance sheets deteriorate, which results in weak demand for credit even after banks have rebuilt their equity.[3] Financial crises in the model are thus characterized by persistent declines in economic activity and warrant, if any, swift interventions.

I focus on policy interventions that mitigate a credit crunch by injecting equity capital into the banking sector during a financial crisis using future financial sector levies as a funding source. My focus on this particular class of policy instruments is motivated by recent regulatory changes: the Dodd-Frank Act in the United States and the Bank Recovery and Resolution Directive in the European Union. Both allow for support of the financial system by using funds backed by taxation of the financial sector in the future. In my model, both the financial crisis and the considered policy interventions are unanticipated from the viewpoint of agents in the model.[4]

[3]In the model of Bassetto et al. (2015), the erosion of entrepreneurial wealth also plays a role in shaping financial crises. However, they do not model financial intermediaries explicitly and do not focus on regulatory interventions during financial crises.

[4]Note that the type of ex-post financial system support considered in this model would not lead to ex-ante moral hazard by financial institutions (recall discussion in footnote 2). Recent increases in the scope and coverage of deposit insurance schemes potentially expand the set of policy tools that use financial sector levies as a funding source but may exacerbate moral hazard (Demirgüç-Kunt et al., 2015).

I calibrate my model to match moments of the US economy related to bank financing to small businesses and corporations, consumer debt, and wealth inequality. A financial crisis is generated by applying a sudden shock that reduces aggregate bank equity by 85 percent. I find that the optimal constant tax on bank lending is 15 basis points, or 0.15 percent, and funds an equity injection that reduces the utilitarian welfare loss of the financial crisis by 13 percent. When using the cumulative discounted gross domestic product loss relative to the initial equity loss as a proxy for the "systemic amplification" of the initial shock to bank equity, I find that the optimal equity injection reduces the utilitarian welfare loss of the financial crisis, *net* of losses due to the exogenous bank equity loss, by 87 percent. The first contribution of the paper is therefore to show that bank equity capital injections financed by bank levies are effective in reducing the utilitarian welfare cost of financial crises.

In the model, wealthier consumers tend to suffer relatively more from the financial crisis because of a sudden scarcity of available risk-free assets for the purpose of consumption smoothing. Most consumers are made better off by the optimal equity injection, but some poorer consumers are worse off. While wealthier consumers benefit more from an increased supply of risk-free assets following the equity injection – banks use new equity to attract external funds – poorer consumers are especially hurt by lower long-run wages. For example, when the optimal equity injection is applied, the wealthiest 5 percent of consumers are even made better off by the financial crisis. The equity injection that is optimal in the sense of minimizing the loss of aggregate utilitarian welfare thus leads to significant redistribution. The second contribution of the paper is therefore to show that optimal bank-levy-financed equity injections tend to benefit wealthier consumers more and may even hurt poorer ones. The main dif-

My analysis can nevertheless speak to ex-post efficiency considerations related to such tools.

ference when compared with redistributive monetary policy (Doepke and Schneider, 2006; Meh et al., 2010) is that equity injections redistribute by distorting flows rather than levels: equity injections increase the (lifetime) income of savers and reduce the (lifetime) income of workers, but do not affect the wealth of bank shareholders much since they – by relaxing balance-sheet constraints – also increase competition among banks.[5]

Recent regulations envision that resolution funding will come from taxing the financial sector and not from taxing consumers. I find that funding the optimal equity injection with a constant consumption tax instead of a constant tax on bank lending leads to lower long-run utilitarian welfare losses. However, taking into account the transition, I find that taxing consumption instead of bank lending lowers the welfare of all consumers. Funding an equity injection with a constant tax on consumption is useful because it increases aggregate utilitarian welfare, but less so than using a constant tax on bank lending as a funding source.

In practice, resolution authorities have some discretion to allocate losses to bank creditors ex post. I analyze the case where, at the time of the negative shock to bank equity, a fraction of bank debt is immediately converted into bank equity in order to completely offset the loss of bank equity. In the model, not surprisingly, such a "surprise bail-in" makes wealthy consumers worse off compared with the laissez-faire case of no financial crisis intervention.

I find that a 50-50 combination of equity injection and "surprise bail-in" is slightly more effective in terms of average utilitarian welfare than the equity injection by itself and, more importantly, achieves a Pareto improvement. Thus, the third contribution of

[5]Savers in my model have high exposure to interest rates since they are assumed to be perfectly altruistic with respect to future generations. Auclert (2015) builds on the work by Doepke and Schneider (2006) and studies how monetary policy redistributes between individuals who differ in their interest rate exposure, especially borrowers and savers, but does not take into account redistribution between savers and workers via effects on capital accumulation.

the paper is to show a role for bank creditor expropriation in rectifying distributional concerns related to equity injections, even when those equity injections are financed by bank levies.[6] In summary, the analysis in this paper supports recent regulatory changes that envision obtaining resolution funding by both bailing in bank creditors and imposing bank levies (BRRD, 2014; Dodd-Frank, 2010).

There is a growing body of literature analyzing ex-post interventions aimed at mitigating the social costs of shocks to the financial sector. In Brunnermeier and Sannikov (2016), monetary policy can provide insurance to financial intermediaries who engage in maturity transformation by selling short-term assets and buying safe long-term assets during crisis times. If the valuation effect reducing the value of liabilities, for example, via inflation, is small enough relative to the positive valuation effect on the asset side of the balance sheet, then the monetary policy intervention on net would discourage ex-ante risk-taking. He and Krishnamurthy (2013) also emphasize the usefulness of interventions that support financial intermediary balance sheets.[7] In Schroth (2016), a regulator can reduce the amplification of shocks affecting the financial sector by granting long-term rents to financial intermediaries. Realized rents are proportional to intermediary capital such that the anticipation of rents would not cause financial intermediary moral hazard (see also Jeanne and Korinek, 2013). Kuncl (2014) develops a model where interventions in the form of asset purchases on secondary markets for securitized assets can be useful by alleviating adverse selection problems. These papers do not, however, consider the interaction of policy interventions with wealth inequality, which is the focus here.

[6]This motivation for an ex-post "surprise bail-in" could potentially be strengthened when it is anticipated ex ante, since bank creditor incentives to monitor banks may increase. An analysis of convertible debt is, however, beyond the scope of the model in this paper since it assumes a zero cost of bank capital.

[7]See also Gertler and Karadi (2011). Kühl (2014) finds, using a DSGE model calibrated to European data, that financial crisis interventions in the form of direct recapitalizations tend to be more effective than asset purchases.

This paper draws on the literature on occupational choice and entrepreneurship. While I assume for simplicity that occupations vary exogenously, modelling entrepreneurship explicitly allows me to capture a realistic degree of wealth inequality (Quadrini, 2000; Cagetti and De Nardi, 2006), and a persistent impact of short-lived changes in credit conditions (Bassetto et al., 2015) due to entrepreneur balance sheet effects. In addition, my focus on bank levies that imply a constant, rather than a progressive, tax on bank credit can be motivated by Meh (2005), who finds that, owing to entrepreneur balance-sheet effects, progressive taxation may not reduce wealth inequality.

This paper connects the literature on bank balance-sheet constraints (Holmstrom and Tirole, 1997; Meh and Moran, 2010; Gertler and Karadi, 2011) to the literature on financial shocks in heterogeneous-agent economies. The latter emphasizes the link between financing conditions and aggregate productivity, while my paper focuses on the distributional consequences of bank equity capital injections. For instance, Khan and Thomas (2013) introduce exogenous aggregate shocks affecting heterogeneous firms' access to credit into a business-cycle model. As in Bassetto et al. (2015), the recession triggered by tight borrowing conditions persists even after borrowing conditions return to normal. In these models, and in the model in this paper, tighter borrowing conditions reduce aggregate productivity endogenously. Shourideh and Zetlin-Jones (2012) explore the role of across-firms non-financial linkages in further strengthening this channel. Guerrieri and Lorenzoni (2011) uncover subtle general equilibrium effects through which tighter borrowing conditions, by reducing the return on savings, discourage the labour supply of temporarily productive agents.

Bassetto (2014) and Costinot et al. (2014) study how pecuniary externalities related to interest rates induce redistribution when agents differ in the steepness of their consumption paths. In my model, the optimal equity injection benefits savers relatively

more since it increases the risk-free interest rate.

The paper proceeds as follows. Section 2 presents the model, Section 3 discusses the calibration of the model parameters, Section 4 presents the model results, and Section 5 concludes.

2 Model

The model has an infinite number of periods $t = 0, 1, 2, \ldots$. There is a measure one of consumers and a measure one of identical financial intermediaries (banks). In addition, there is a measure one of identical firms labelled "corporate sector". There is a consumption good that can be costlessly exchanged into a capital good and vice versa. Each consumer is endowed with a unit of labour that they supply inelastically. labour productivity ξ is independent and identically distributed (i.i.d.) across consumers and its distribution is characterized by a two-state transition matrix P_ξ with support $\{\xi_L, \xi_H\}$. Consumers have access to a production technology that uses labour and capital to produce the consumption good. A consumer who invests $k \geq 0$ units of the capital good in period t and uses $n \geq 0$ units of labour in period $t+1$ can produce $y = z\left(k^\alpha n^{1-\alpha}\right)^\gamma + (1-\delta)k$ units of the consumption good in period $t+1$, where $\delta \in (0,1)$ is the capital good depreciation rate and α, $\gamma \in (0,1)$. $z > 0$ denotes the consumer's investment productivity, which is i.i.d. across consumers, and its distribution is characterized by a two-state transition matrix P_z with support $\{z_L, z_H\}$. Below, we will also refer to consumers with investment productivity z_H as entrepreneurs and to consumers with investment productivity z_L as workers. It is assumed that only entrepreneurs can produce.[8] A firm in the corporate sector that invests $\tilde{k} \geq 0$ units of

[8]Owing to decreasing returns in physical capital, workers would have an incentive to invest at least a small amount. However, I fix consumer occupations exogenously: only consumers with productivity z_H may produce. And since producing does not require them to forego labour income, they will produce

the capital good in period t and uses $\tilde{n} \geq 0$ units of labour in period $t+1$ can produce $\tilde{y} = \tilde{k}^{\alpha}\tilde{n}^{1-\alpha} + (1-\delta)\tilde{k}$ units of the consumption good in period $t+1$.

There are markets for labour, bonds, bank loans, and bank shares. Let w_t be the price of one efficiency unit of labour in period t. Let q_{t+1} be the price of one unit of the consumption good in t to be delivered in $t+1$ in the market for bonds. Let q^B_{t+1} denote the price of one unit of the consumption good in t to be delivered in $t+1$ in the market for bank loans, such that $1/q^B_{t+1}$ is the gross interest rate on bank loans. Finally, let p_t denote the bank share price.

Consumers

Consumers choose capital investment k, labour input n, bonds b, bank loans ℓ and bank shares s to maximize their lifetime utility as follows:

$$\max_{\{c_t,k_{t+1},n_t,b_{t+1},\ell_{t+1},s_{t+1}\}_{t=0,1,2,\ldots}} E_0 \sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\sigma}}{1-\sigma}, \tag{1}$$

where $\beta \in (0,1)$ is a subjective discount factor and $\sigma > 1$ denotes (constant) relative risk aversion, subject to budget constraints

$$\begin{aligned} &c_t + k_{t+1} + q_{t+1}b_{t+1} + \ell_t + p_t s_{t+1} + w_t n_t \\ &\quad \leq q^B_{t+1}\ell_{t+1} + z_t\left(k_t^{\alpha} n_t^{1-\alpha}\right)^{\gamma} + (1-\delta)k_t + w_t\xi_t + s_t p_t + d_t s_{t+1} + b_t, \quad t = 0,1,2,\ldots \end{aligned} \tag{2}$$

independently of their net worth. This particular modelling choice is motivated by the wish to keep the model parsimonious; in fact, Hurst and Lusardi (2004) report that "[a]lthough we find no relationship between wealth and business entry over most of the wealth distribution, we do find that very wealthy households are much more likely to start a business." In Cagetti and De Nardi (2006), consumers face a non-trivial choice of whether or not to produce, since producers forego labour income and therefore only produce when their net worth is sufficiently high. Bassetto et al. (2015) find that this occupational choice does not interact with aggregate financing conditions in a quantitatively important way. As in those papers, I assume that labour and investment productivities are independent of each other. I motivate this assumption with the finding in Hamilton (2000) that "[t]he wage distribution of would-be entrepreneurs does not appear to be significantly different from that of paid employment stayers, except perhaps at the upper end."

and collateral constraints

$$\ell_{t+1} \leq \psi w_{t+1} + \eta k_{t+1}, \quad t = 0, 1, 2, \ldots \tag{3}$$

with $c_t, b_{t+1}, \ell_{t+1}, s_{t+1} \geq 0$, $n_t, k_{t+1} \geq 0$ if $z_t = z_H$ and zero else, and $k_0, b_0, \ell_0, s_0 \geq 0$ given.[9] E_t denotes a consumer's expectations over future idiosyncratic labour and investment productivity shocks given the consumer's realized idiosyncratic shocks at time $t = 0, 1, 2, \ldots$. Consumers take dividends $\{d_t\}_{t=1,2,\ldots}$ as given. The parameters $\psi > 0$ and $\eta > 0$ determine the extent to which consumers can obtain bank financing by pledging future labour income as well as physical capital investment.

Bank share price

Recall from (2) that the current bank share price includes the current dividend. A consumer who chooses a strictly positive level of bank shares, $s_{t+1} > 0$, has the following Euler equation for bank shares:

$$p_t = d_t + \beta E_t \left(\left(\frac{c_{t+1}}{c_t} \right)^{-\sigma} p_{t+1} \right) = d_t + \beta E_t \left(\frac{c_{t+1}}{c_t} \right)^{-\sigma} p_{t+1}.$$

But then this consumer also has an Euler equation for bonds that is given as follows:

$$q_{t+1} = \beta E_t \left(\frac{c_{t+1}}{c_t} \right)^{-\sigma}.$$

The bank share price then satisfies

$$p_t = d_t + q_{t+1} p_{t+1} = \sum_{t'=t}^{\infty} Q_{t',t} d_{t'} \tag{4}$$

[9] Recall that only entrepreneurs, i.e., consumers with high investment productivity, are assumed to have the ability to manage factor inputs and produce. Also note that entrepreneurs cannot supply labour to themselves. Since there is no friction assumed in the labour market, this is merely a normalization and without loss of generality.

for all $t = 0, 1, 2, \ldots$, where $Q_{t',t} = \Pi_{k=t+1}^{t'} q_k$ is the period t price of a unit of the consumption good to be delivered in period $t' \geq t$. Define the discount factors $Q_t \equiv Q_{0,t}$ for $t = 1, 2, \ldots$.

Banks

Banks choose dividends d, bonds $\mathcal{B}$ and bank loans $\mathcal{L}$ to maximize shareholder value as follows:

$$\max_{\{d_t, \mathcal{B}_{t+1}, \mathcal{L}_{t+1}\}_{t=0,1,2,\ldots}} V_0 = \sum_{t=0}^{\infty} Q_t d_t \tag{5}$$

subject to a budget constraint

$$d_t + \mathcal{B}_{t+1} q_{t+1} + \mathcal{L}_{t+1} q_{t+1}^B \leq \mathcal{B}_t + \mathcal{L}_t, \tag{6}$$

an individual rationality constraint

$$V_t = \sum_{s=t}^{\infty} Q_{s,t} d_s \geq \theta \mathcal{L}_t, \tag{7}$$

and dividend non-negativity $d_t \geq 0$, with $\mathcal{L}_0, \mathcal{B}_0$ given. The parameter $\theta \in [0, 1]$ represents payments per unit of outstanding loans that the bank can extract from its creditors by defaulting.[10] The constraint (7) ensures that a bank's shareholder value is at least as high as the payment it could extract by defaulting. It is assumed that a defaulting bank is being shut down (after it transferred the default payment to its shareholders). The constraint (7) then allows the highest possible level of bank leverage that is consistent with the shareholder-value-maximizing bank not defaulting (the constraint is not too tight in the sense of Kehoe and Levine, 1993 and Alvarez and Jermann, 2000). We will refer below to (7) as an endogenous equity requirement.

[10] These payments can be thought of as resulting from holding up creditors (as in Diamond and Rajan, 2000) or from a benefit of not monitoring (as in Holmstrom and Tirole, 1997).

To see more easily how (7) defines an endogenous equity requirement, note that bank shareholder value, using (6), can be written as

$$V_t = \mathcal{L}_t + \mathcal{B}_t + \sum_{s=t+1}^{\infty} Q_{s,t+1} \left(1 - \frac{q_s^B}{q_s}\right) \mathcal{L}_s = A_t + \Pi_t, \tag{8}$$

where $A_t \equiv \mathcal{L}_t + \mathcal{B}_t$ is bank equity and Π_t is the present discounted value of the bank's profits. We say a bank issues bonds, or debt, when $\mathcal{B}_t < 0$. Condition (7) can be written as an explicit constraint on bank equity

$$A_t \geq \theta \mathcal{L}_t - \Pi_t. \tag{9}$$

When $\Pi_t > 0$, then banks can issue debt to raise their leverage in terms of equity beyond $1/\theta$. Banks thus face more accommodating funding conditions when they are expected to be profitable in the future. Condition (7) is exactly the same as in Schroth (2016) and similar to the equity constraint in Gertler and Karadi (2011). Since future prices enter into the condition via bank budget constraints, a competitive equilibrium is not constrained efficient, in the sense of Greenwald and Stiglitz (1986). It is shown analytically in Schroth (2016), within the context of a representative-agent economy, that a tax on bank lending that is constant over time can yield a Pareto improvement and restore constrained efficiency in a financial crisis when bank equity requirements bind. Taxes on bank lending – levies on banks that depend on the size and riskiness of bank balance sheets – are important policy tools in practice, for example, for the financing of deposit insurance schemes and financial crisis resolution funds. This paper investigates the redistributional implications of such policy tools.

Corporate sector

Firms in the corporate sector can issue equity to finance physical capital investment. In

contrast, consumers cannot issue equity. One way to motivate this assumption is that entrepreneurs' funding needs may lack the scale to be of interest to the equity market. Firms in the corporate sector must, however, finance at least fraction $\chi \in (0,1)$ of their physical capital investment with bank loans. The motivation behind this assumption is the possible division of ownership and control in the corporate sector such that (outside) equity holders rely on the monitoring role that banks are playing (Holmstrom and Tirole, 1997). I assume that firms do not choose more than fraction χ of bank finance, even when they are indifferent between equity and intermediated finance. Owing to their constant-returns technology, firms in the corporate sector are left with no internal funds after paying equity holders their required return $1/q$.

Competitive equilibrium

Define the following aggregates

$$B_{t+1} \equiv \int_0^1 b_{t+1}(i)di, \qquad L_{t+1} \equiv \int_0^1 \ell_{t+1}(i)di, \qquad \tilde{K}_{t+1} \equiv \int_0^1 \tilde{k}_{t+1}(j)dj,$$
$$N_t \equiv \int_0^1 n_t(i)di, \qquad \tilde{N}_t \equiv \int_0^1 \tilde{n}_t(j)dj, \qquad S_{t+1} \equiv \int_0^1 s_{t+1}(i)di,$$

where i denotes an individual consumer and j denotes an individual firm in the corporate sector. Since consumer labour productivity is determined by the same exogenous process in each period and since banks do not issue equity, I normalize effective labour supply to unity, $\int_0^1 \xi_t(i)di = 1$, and the supply of bank shares to unity as well.

In a competitive equilibrium, the allocation that solves the problems of consumers, of banks and of firms in the corporate sector also clears the markets for labour, bank

shares, bonds and bank loans in each period:

$$N_t + \tilde{N}_t = 1, \qquad S_{t+1} = 1,$$
$$B_{t+1} + \mathcal{B}_{t+1} = \frac{1-\chi}{q_{t+1}}\tilde{K}_{t+1}, \qquad L_{t+1} + \frac{\chi}{q^B_{t+1}}\tilde{K}_{t+1} = \mathcal{L}_{t+1}.$$

Note that the equilibrium bank share price is given by bank shareholder value such that $p_t = V_t$.

3 Calibrating the Model

The model has 15 parameters. Seven parameters can be chosen by following the literature closely as follows. For the coefficient of relative risk aversion, σ, I choose 2, which is within the range of values used in the literature. The capital share α is set to 0.35, and the depreciation rate is set to $\delta = 0.067$. The long-run bank equity requirement θ is set to 0.10, which yields a bank common equity to asset ratio of 0.10 in a steady state (see Federal Reserve Board data release Z1 H8).[11] The transition matrix for labour productivity is symmetric, where productivity levels and the probability of remaining in the same state are chosen such that the natural logarithms of productivity levels have an autocorrelation of 0.90 and a standard deviation of 0.30, which is close to estimates in Storesletten et al. (2004). Normalizing the unconditional mean of idiosyncratic labour productivity to one yields $\xi_L = 0.71$ and $\xi_H = 1.29$, as well as a probability of remaining in the same state of 0.95.

Choosing the remaining eight model parameters requires solving for the steady state of the economy. The transition matrix for investment productivity P_z is cho-

[11] I assume that the bank equity requirement (7) binds weakly in a steady state, for example, because of an arbitrarily small agency cost related to bank equity.

sen such that the fraction of entrepreneurs is 7.5 percent and the probability of entrepreneurs ceasing to be productive is 23 percent. The productivity realizations z are chosen such that the corporate sector output share is 54 percent (see SBA, 2012), where I normalize the lower realization to zero. The model generates wealth inequality through entrepreneurship as in Quadrini (2000) or Cagetti and De Nardi (2006). I therefore set the degrees to scale of the entrepreneurial technology γ such that the net worth of the wealthiest one percent of consumers equals 34.1 percent of total consumer net worth. The borrowing limit ψ is chosen to target wealth of -0.7 percent held by the bottom quintile. The data on wealth inequality are from the 2010 Survey of Consumer Finances (see for example Díaz-Giménez and Pijoan-Mas, 2011). I set the collateral parameter ν such that the ratio of small business debt to gross domestic product (GDP) is 0.2524. Similarly, I set the parameter χ to obtain a ratio of corporate sector debt to GDP of 0.4417. The data on business debt are from the Federal Reserve Board (data release Z.1 section D.3).[12]

The model calibration is summarized in Table 1. With these parameters, the model generates a risk-free interest rate of 1.83 percent in steady state. Bank assets are 73 percent of GDP, consumer net assets are 3.26 times GDP, corporate sector assets are 2.22 times GDP and corporate sector capital is 71 percent of total capital in the model steady state. Consumers have a fixed propensity of 1.9 percent to become an entrepreneur. Table 2 shows that the model roughly generates the distribution of wealth observed in the data.

[12]Entrepreneurs in the model run small businesses and generate receipts up to $24 million. In the data, such small businesses may actually be incorporated. Since I use non-incorporated business debt as a proxy for small business debt, the model likely underestimates the importance of bank loans for entrepreneurs.

Also note that I use debt securities, which include bonds, as a proxy for corporate sector reliance on intermediated finance. The reason is that an increase in the cost of bank credit may reduce bank credit, weaken bank/firm relationships and increase yields that firms must offer on the bond market. See Diamond (1991) for a theory and Datta et al. (1999) for empirical evidence on the cross-monitoring benefits of bank debt.

Parameter	Explanation	Value	Target
σ	CRRA coefficient	2	within range of literature
δ	depreciation rate	0.067	replacement investment
α	capital share	0.35	average capital income share
θ	long-run equity-asset ratio	0.10	long-run leverage of ten
P_ξ	labour productivity process	$\left(\begin{smallmatrix} 0.95 & 0.05 \\ 0.05 & 0.95 \end{smallmatrix}\right)$	autocorrelation log earnings
ξ	values labour shock	$\left(\begin{smallmatrix} 0.71 & 1.29 \end{smallmatrix}\right)$	Std deviation log earnings
P_z	investment productivity process	$\left(\begin{smallmatrix} 0.98 & 0.23 \\ 0.02 & 0.77 \end{smallmatrix}\right)$	overall fraction and exit rate of entrepreneurs
z	values investment shock	$\left(\begin{smallmatrix} 0 & 1.85 \end{smallmatrix}\right)$	corporate sector output share
γ	entrepreneur returns to scale	0.938	wealth of top 1 percent
β	discount factor	0.948	capital output ratio of 3.1
χ	bank finance corporate sector	0.199	corporate sector loans to GDP
η	collateral physical capital	0.286	small business loans to GDP
ψ	borrowing limit	0.186	wealth of bottom quintile

Table 1: Calibration of model parameters.

		Quintile					Top Percentile		
Economy	Gini	First	Second	Third	Fourth	Fifth	90th-95th	95th-99th	99th-100th
United States	0.82	-0.7	0.7	3.3	10.0	86.7	13.5	26.8	34.1
Model	0.84	-0.7	0.99	4.7	8.6	86.4	12.8	29.3	34.2

Table 2: Wealth inequality in steady state

The model is solved by iterating over the consumer value function and over prices for risk-free debt q and bank credit q^B. I assume that consumers weakly prefer bank deposits to corporate sector firm equity – both offer the same risk-free return $1/q$ – such that the bank equity requirement given by condition (7) binds at least weakly at all times. Note, however, that whether a consumer's borrowing constraint (3) binds depends on the consumer's net worth and the realization of the consumer's idiosyncratic shocks.

4 Quantitative Analysis

Suppose the economy is in steady state when an unexpected shock in period $t = 0$ leads to a sudden drop in bank equity. My motivation for generating a financial crisis in this way is the fact that financial crises are rare and largely unanticipated events. For example, in the case of the 2007–2009 US financial crisis, regulators realized the severity of the crisis only as it unfolded (Swagel, 2015).[13] I specifically assume that the shock causes $\mathcal{L}_0 + \mathcal{B}_0$ to be 85 percent below steady-state bank equity, which corresponds to a bank balance-sheet loss equivalent to 6.2 percent of GDP. Note that I do not assume any losses in other parts of the economy. The motivation behind this assumption is that financial intermediaries provide insurance against rare events.[14]

This section numerically analyzes the laissez-faire case of no intervention and also studies three particular interventions: an equity capital injection, a "surprise bail-in," and a combination of the two.

4.1 Laissez-faire

Figure 1 shows that it takes banks five years to rebuild their equity following the initial shock. During that time, bank lending is severely constrained owing to low bank shareholder value. Recall that bank shareholder value is proportional to bank lending by the bank equity requirement (7). Note, however, that the relative decline in bank lending is far below the decline in bank equity. The reason is that banks enjoy strictly

[13]The early-warning tools developed in the wake of the Latin American and Asian financial crises of the 1990s (Kaminsky et al., 1998) did not induce US regulators to act sooner, in areas where they had the powers to do so, possibly because these crises were different from the 2007–2009 US financial crisis.

[14]For instance, prior to the 2007–2009 financial crisis in the United States, banks implicitly insured some households, those that took out mortgages with very high loan-to-value ratios, against the risk of a slowdown in house price growth (see Zame (1993) for a formal discussion of the insurance aspect of default). Insurance companies such as AIG explicitly provided insurance against natural disasters as well as a slowdown in house price growth.

positive profits $\Pi_t > 0$ temporarily, which reduces their equity requirement (see (9)). Once banks have rebuilt their equity, they are again able to compete away the spread between the loan rate and funding rate. However, economic activity has barely recovered by that time, as indicated by the still-low levels for wages, GDP and installed physical capital.

Result 1. *By the time banks have rebuilt their equity, the economy is still in a deep recession.*

Figure 2 reveals some of the economic forces behind Result 1. Consumer net worth is lowest at the time when banks have recovered from the initial shock to their equity. When the interest rate reaches its highest point, consumers start rebuilding their net worth. Temporarily elevated interest rate spreads enabled banks to rebuild their equity but hurt entrepreneur balance sheets, thus making the crisis more persistent.[15] The credit crunch, during which economic activity is depressed by low supply of bank loans, lasts four periods (years) and is followed by many years of below-steady-state demand for bank loans.

In addition, Figure 2 reveals how the dynamics of worker net worth make the recovery even more sluggish. The reason is that the credit crunch not only erodes entrepreneurs' net worth but also leads to a prolonged savings squeeze for workers. Workers do not have access to a production technology, and therefore they take longer than entrepreneurs to recover from an initial episode of high borrowing costs, low wages and low savings returns. As a result, interest rates will be elevated for many years, reducing economic activity in the corporate sector. The reason is that the corporate sector is more interest rate sensitive, compared with entrepreneurs, owing to its lower financing frictions. Figure 3 shows how the corporate sector can soften the economic blow of the credit crunch initially since it benefits from depressed wages and

[15]Bassetto et al. (2015) also document this persistent entrepreneurs' balance-sheet effect when they exogenously increase the cost of credit temporarily in their model.

relies on bank financing significantly less than do entrepreneurs. However, the figure also shows how entrepreneurial economic activity recovers faster, while corporate sector economic activity is somewhat depressed for many years.

Result 2. *The fall in worker net worth is even more persistent than the fall in entrepreneur net worth and further increases the persistence of the economic crisis that follows the initial credit crunch.*

4.1.1 Welfare analysis

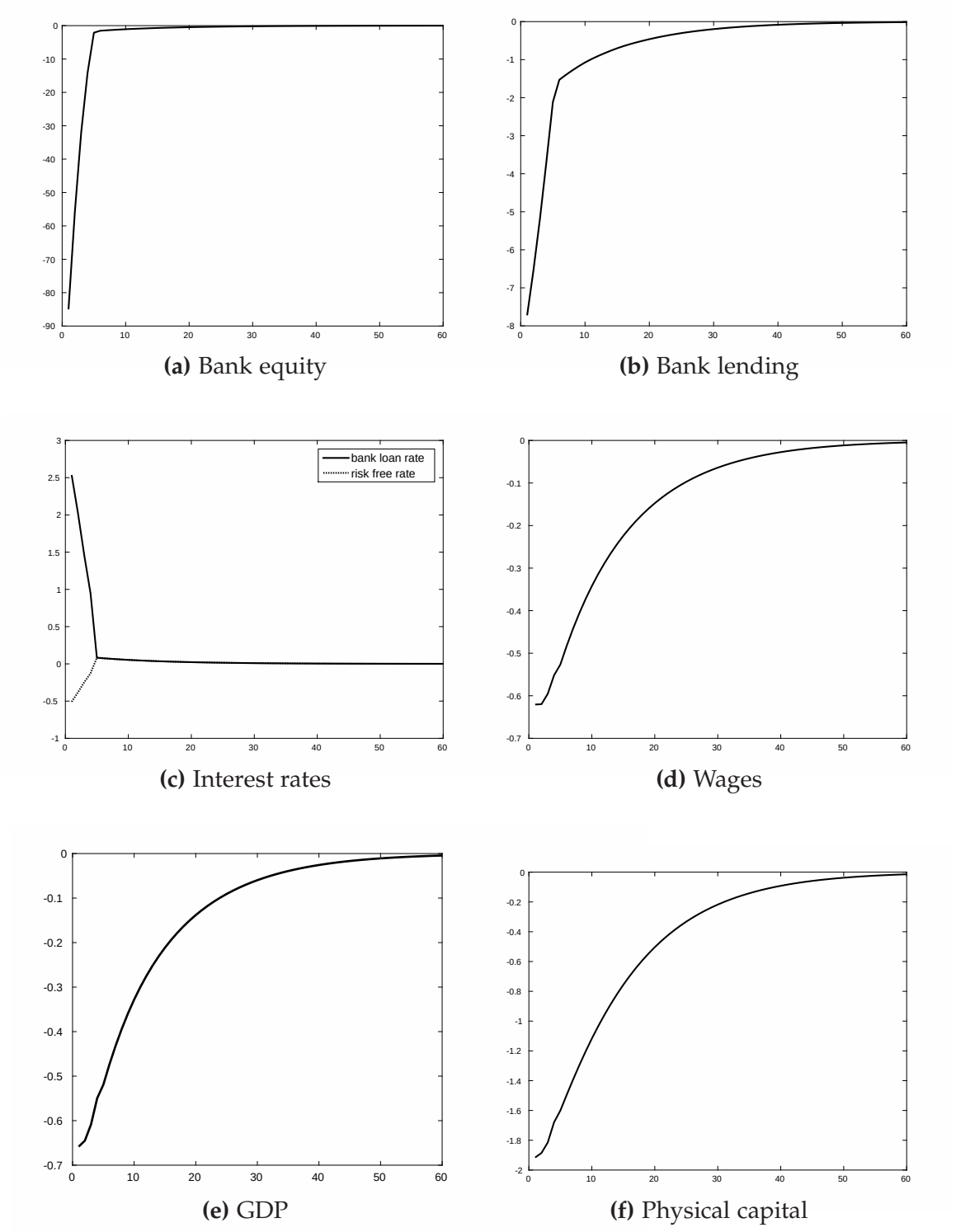
The welfare criterion is given by equation (1). Figure 4 shows that wealthier consumers tend to suffer more from the financial crisis. For each level of net worth, the figure shows equivalent consumption variation averaged over consumers' idiosyncratic states. Wealthy workers suffer from a reduced supply of safe assets, because of decreased intermediation by banks, which reduces their ability to smooth consumption over time.[16]

Result 3. *Wealthy consumers tend to be more negatively affected by the financial crisis.*

4.2 Equity injection funded with tax on bank lending

I find that the equity injection that yields the highest average utilitarian welfare taxes bank lending by 15 basis points in every period and is announced in the first period, immediately after the shock to bank equity. The timing of equity injection payments to banks funded by these taxes does not matter since a bank's access to funding depends only on the present value of these payments by the equity requirement (7).

[16]Wealthy consumers also suffer through lower bank dividends. However, this direct effect is weak relative to the indirect effect through lower risk-free interest rates.



(a) Bank equity

(b) Bank lending

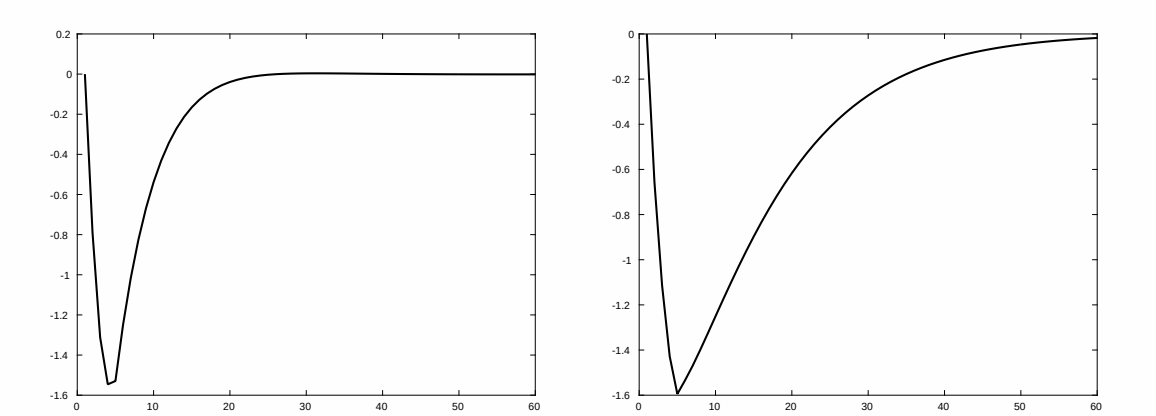
(c) Interest rates

(d) Wages

(e) GDP

(f) Physical capital

Figure 1: Economy after initial shock to bank equity (in years). All quantities and prices are in terms of percentage deviations from steady state except interest rates, which are in percentage-point deviations.



(a) Net worth: entrepreneurs **(b)** Net worth: workers

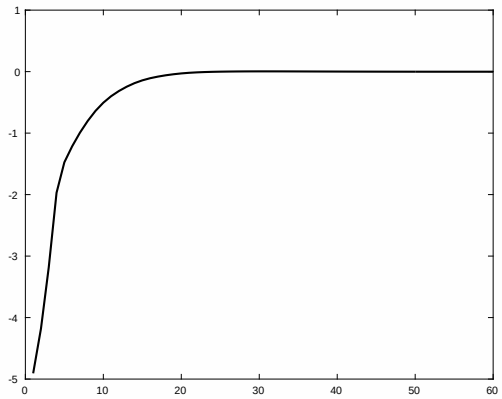
Figure 2: Economy after initial shock to bank equity (in years). Consumer net worth in terms of percentage deviations from steady state.

Figure 5 shows that the equity injection prevents a sharp initial drop in bank lending, and also stabilizes GDP and wages somewhat, at the cost of distorting bank lending downward in the future. The cost of bank lending is smoothed out over time and the drop in the risk-free rate is prevented.

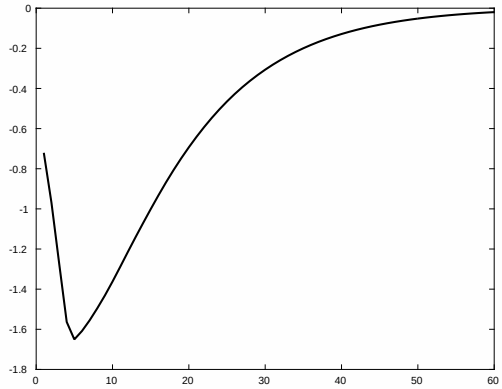
Result 4. *The equity injection has a stronger stabilizing effect on asset prices, such as the price of risk-free assets, than on economic activity.*

Short-run stabilization comes at the cost of long-run distortions. Specifically, depressed wages lead to higher entrepreneurial net worth and also, via eventual retirement from business, to higher worker net worth as shown in Figure 6. Figure 7 reveals how the equity injection shifts economic activity from the corporate sector to entrepreneurs. Owing to its high interest rate sensitivity, the corporate sector suffers not only from higher risk-free rates early on but also from higher bank lending rates later.

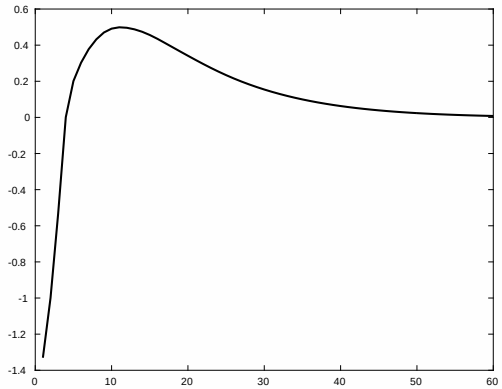
Some long-term costs are already evident in the data because of recent regulatory changes. For example, Germany introduced bank levies in 2011 to fund restructuring



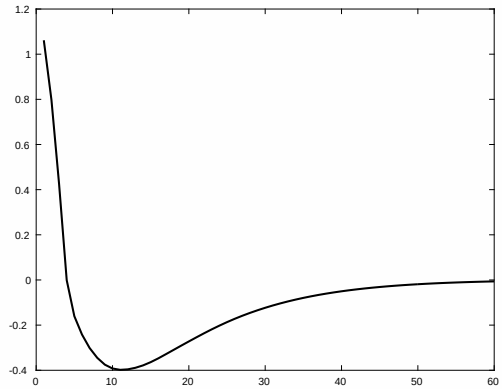
(a) Physical capital: entrepreneurs



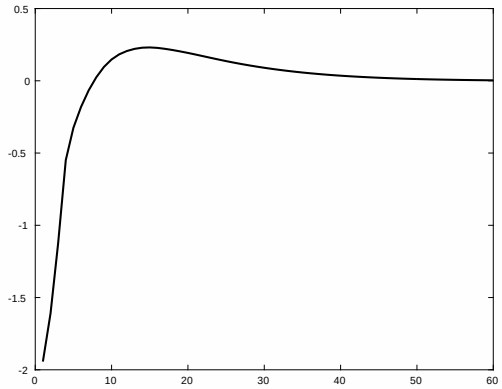
(b) Physical capital: corporate sector



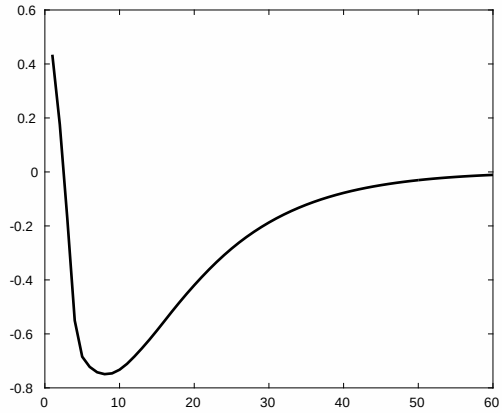
(c) Hours worked at entrepreneurs



(d) Hours worked: corporate sector



(e) GDP: entrepreneurs



(f) GDP: corporate sector

Figure 3: Economy after initial shock to bank equity (in years). All quantities are in terms of percentage deviations from steady state.

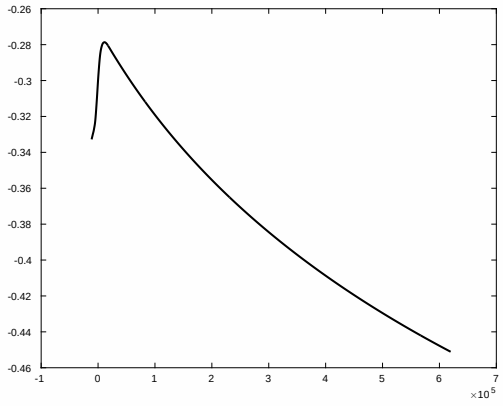


Figure 4: Welfare change in terms of equivalent consumption variation due to shock to bank equity as a function of net worth.

efforts. Buch et al. (2014) find that banks that bear the levy reduce lending, as well as deposits, and increase lending rates. These are also the long-term effects of an equity injection financed by the bank lending tax predicted by my model. Note that I do not consider shocks to banks that are large enough to lead to a bank's default, and to losses to its creditors, such that any equity injection does not affect bank creditors directly.[17] When bank creditors benefit directly from an equity injection, then bank funding rates may be inefficiently low (Jeske et al., 2013; Dam and Koetter, 2012; Gropp et al., 2013; Molyneux et al., 2014).

4.2.1 Welfare analysis

Figure 8 shows that wealthier consumers tend to benefit more from the equity injection. Wealthy workers benefit from an increased supply of safe assets, owing to increased intermediation by banks, which allows them to smooth consumption better over time.[18] On the other hand, consumers with low net worth may even be negatively affected. Such consumers had low past incomes and are thus typically workers. In general, a

[17] I consider the case of a "surprise bail-in" in the following section but do not model potential ex-ante effects.

[18] Wealthy consumers also benefit through higher bank dividends. However, this direct effect is weak relative to the indirect effect through higher risk-free interest rates.

worker with low wealth has an incentive to borrow against future wages. However, a reduction in the cost of borrowing that is accompanied by a reduction in future wages does not help such workers much and may even harm them on net.

Result 5. *Wealthy consumers tend to benefit more from the equity injection. Some less-wealthy consumers are, however, negatively affected.*

Figure 9 illustrates that the top 5 percent of consumers, in terms of net worth, enjoy a disproportionate share of the welfare gains of the equity injection. Despite its undesirable redistributive properties, the equity injection reduces the social cost of the financial crisis, in terms of losses in average utilitarian welfare, by 13 percent. No equity injection, however, can undo the initial adverse shock to bank equity. We could take discounted cumulative GDP losses, relative to the initial bank equity loss, as an indicator for the part of the financial crisis social cost that stems from amplification alone, i.e., net of losses due to the drop in initial bank equity. Adopting this metric, the equity injection is able to reduce the social cost of the financial crisis, net of the initial equity loss, by 87 percent.

4.2.2 Consumption tax as alternative funding source

Banks pass on the tax on bank lending because of competitive pressure. The equity injection in the previous section was therefore financed by a value-added tax on financial services. In this section, I instead consider a value-added tax on consumption to pay for the same equity injection. I find that using a value-added tax on consumption does not improve the distributive properties of the equity injection and does not improve its effectiveness in terms of avoiding a decrease in utilitarian welfare.

4.2.3 Relationship to US 2007–2009 financial crisis

Policy interventions during the recent US financial crisis have been focusing on equity injections rather than a "surprise bail-in," possibly because of a very short average duration of bank liabilities.[19] Resolution was achieved with equity injections by the Treasury (TARP), liquidity support by the Federal Reserve (TALF), and bank debt guarantees by the Federal Deposit Insurance Corporation (TLGP). While institutional constraints (Swagel, 2015) may have prevented these interventions from achieving an optimal equity injection, as described in this paper, there have nevertheless been financial sector "taxes" in the form of special dividends on Treasury equity injections or FDIC contributions.

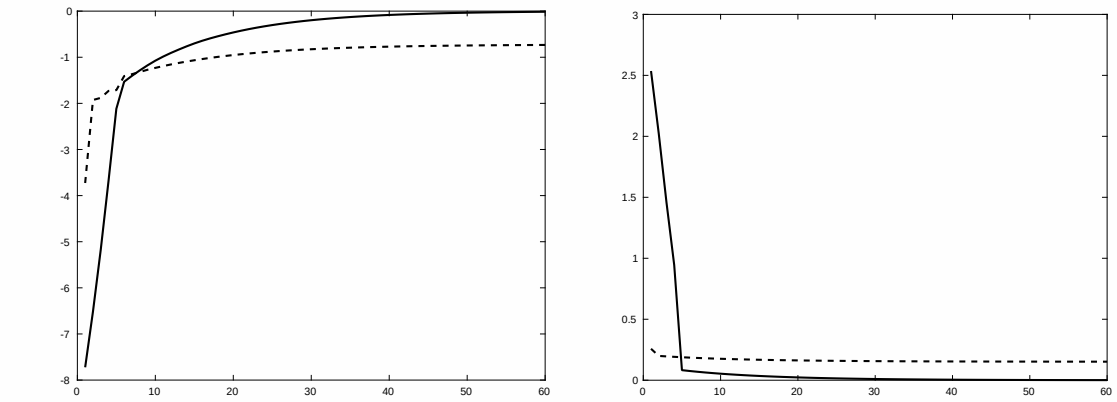
4.3 "Surprise bail-in" (equity injection funded with tax on savers)

Suppose the shock is to bank creditors rather than to banks. One way to motivate this exercise is to assume that a fraction of outstanding bank debt is converted into bank equity when the shock occurs in a way that leaves the level of bank equity unchanged.[20]

When the shock is to bank creditors rather than to banks, then the shock is not being amplified by a binding bank equity requirement (7). The decline in economic activity is now due to consumption smoothing by bank creditors. Specifically, an increase in the risk-free rate lowers economic activity in the corporate sector. However, there is no erosion of entrepreneurial net worth. Figures 10 to 12 compare the allocation with the "surprise bail-in" to the laissez-faire allocation.

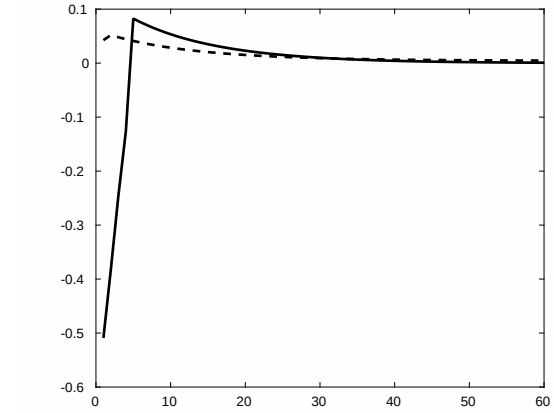
[19] Ensuring that banks hold sufficient levels of "bail-in-able" debt is one concern of Basel III (BIS, 2010).

[20] The exercise goes beyond "bail-ins" envisioned by the recent regulatory changes, which require bank creditors to absorb only part of bank equity losses (see analysis in section 4.3.2).

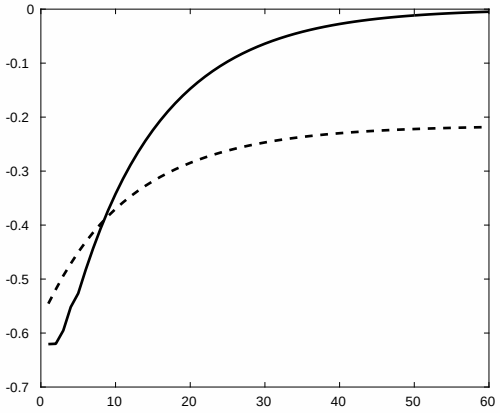


(a) Bank lending

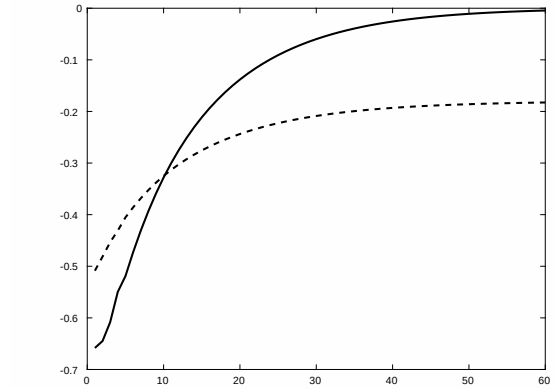
(b) Bank lending rate



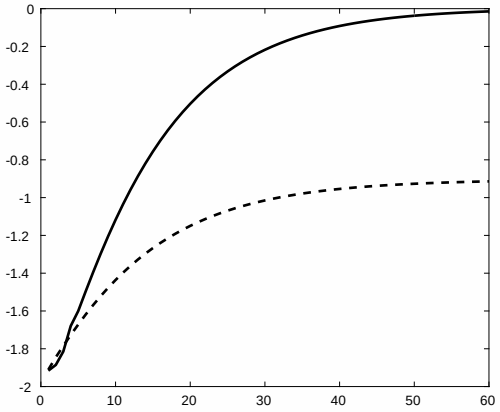
(c) Risk-free rate



(d) Wages

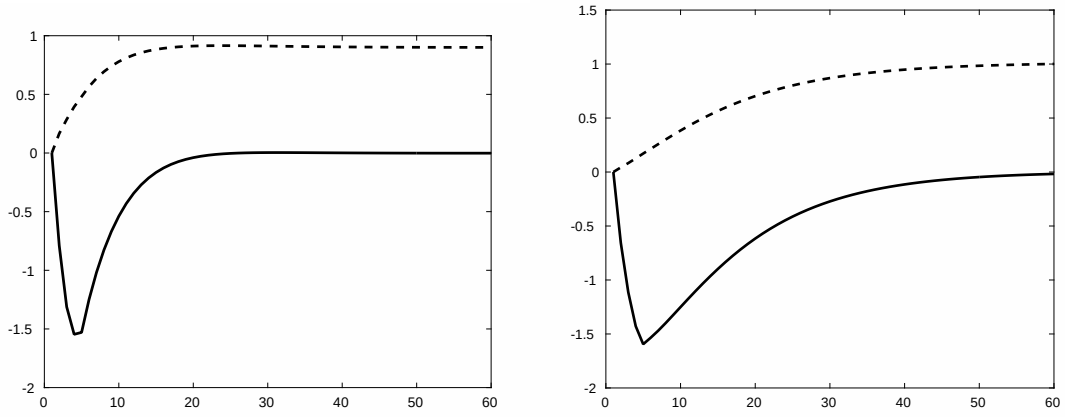


(e) GDP



(f) Physical capital

Figure 5: Comparison between laissez-faire (solid line) and equity injection (dashed line) following the initial shock to bank equity (in years). All quantities and prices are in terms of percentage deviations from steady state except interest rates, which are in percentage-point deviations.



(a) Net worth: entrepreneurs **(b)** Net worth: workers

Figure 6: Comparison between laissez-faire (solid line) and equity injection (dashed line) following the initial shock to bank equity (in years). Consumer net worth in terms of percentage deviations from steady state.

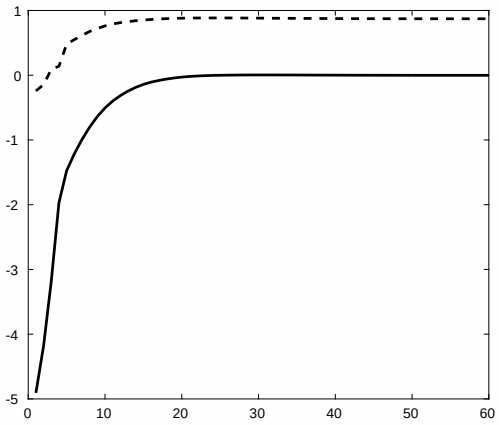
4.3.1 Welfare analysis

Figures 13 and 14 show that less-wealthy consumers tend to benefit more from a "surprise bail-in". Specifically, less-wealthy workers benefit from higher wages, while wealthy workers of course suffer from losing a fraction of their risk-free assets. Consumers with net worth below $75,000 are, on average, better off when there is a "surprise bail-in" compared with the laissez-faire case of no intervention. The "surprise bail-in" achieves utilitarian welfare that is higher than under the equity injection.

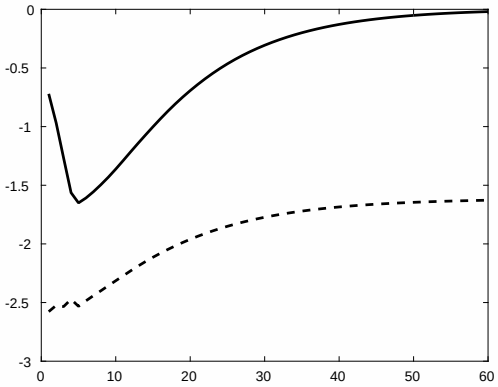
Result 6. *The "surprise bail-in" benefits consumers with low net worth and hurts consumers with high net worth. Its effect on average utilitarian welfare is higher than that of the bank-tax-financed equity injection.*

4.3.2 Combined intervention: "surprise bail-in" and equity injection (50-50)

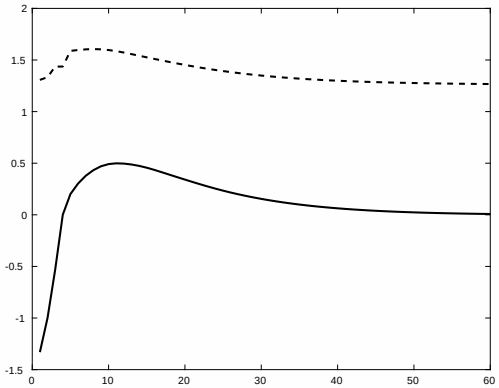
In this section, I consider the case where one-half of lost bank equity is replaced with funds from a "surprise bail-in," while the other half is replaced with a bank-



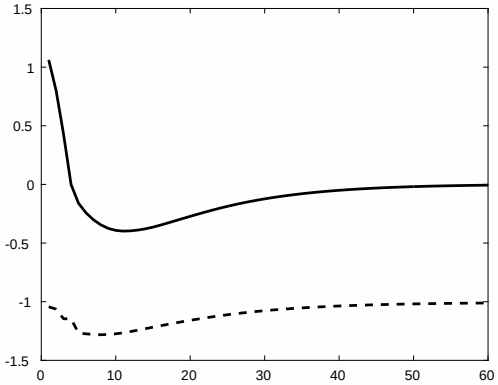
(a) Physical capital: entrepreneurs



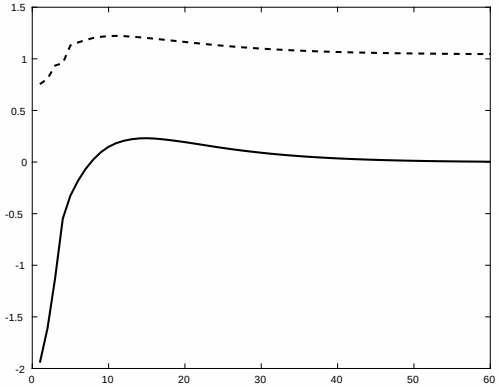
(b) Physical capital: corporate sector



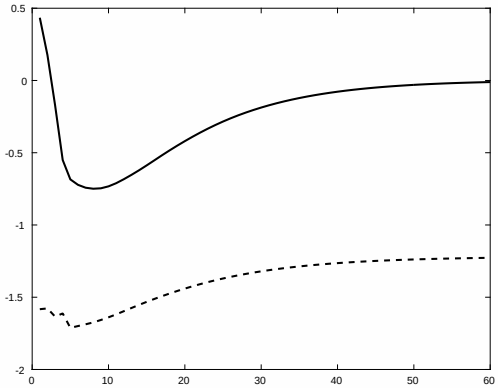
(c) Hours worked at entrepreneurs



(d) Hours worked: corporate sector



(e) GDP: entrepreneurs



(f) GDP: corporate sector

Figure 7: Comparison between laissez-faire (solid line) and equity injection (dashed line) following the initial shock to bank equity (in years). All quantities are in terms of percentage deviations from steady state.

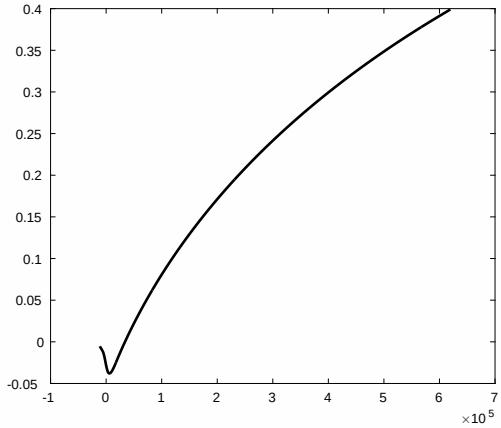
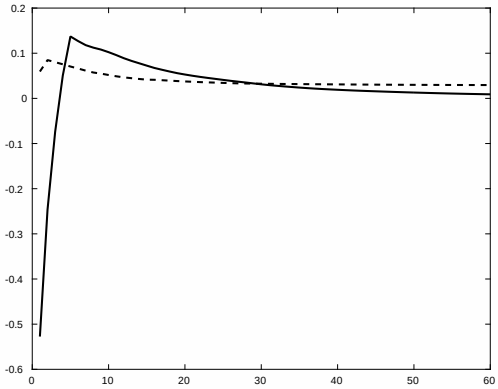
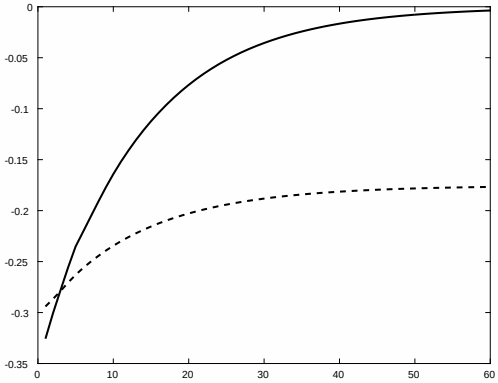


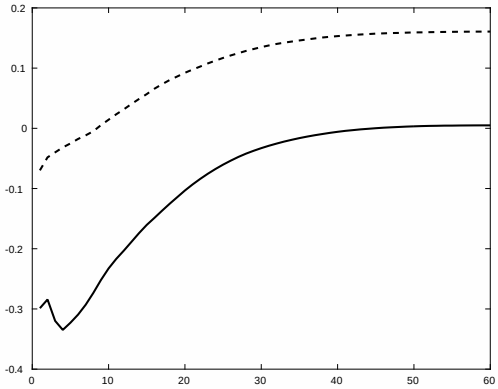
Figure 8: Welfare change due to equity injection, relative to laissez-faire, in terms of equivalent consumption variation as a function of net worth.



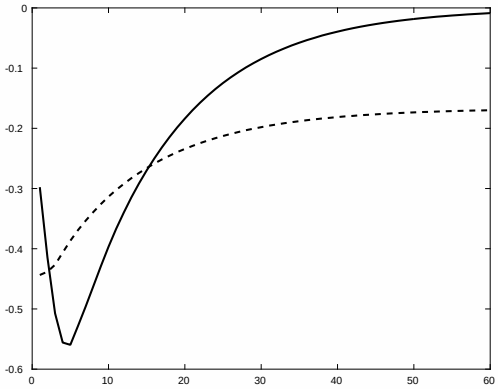
(a) Welfare of wealthiest 5 percent



(b) Welfare of poorest 95 percent

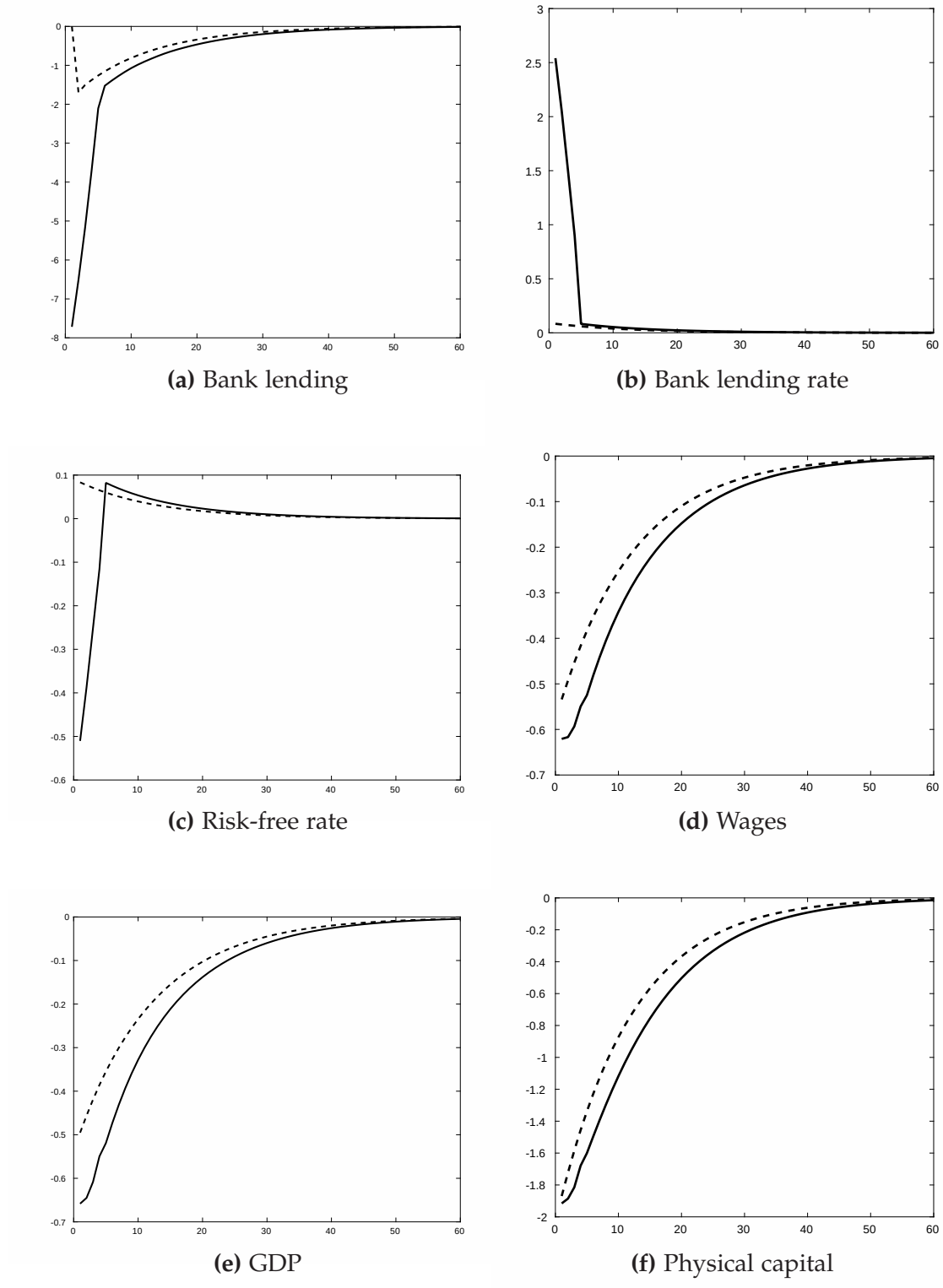


(c) Consumption of wealthiest 5 percent



(d) Consumption of poorest 95 percent

Figure 9: Comparison between laissez-faire (solid line) and equity injection (dashed line) following the initial shock to bank equity (in years). All quantities are in terms of percentage deviations from steady state.



(a) Bank lending

(b) Bank lending rate

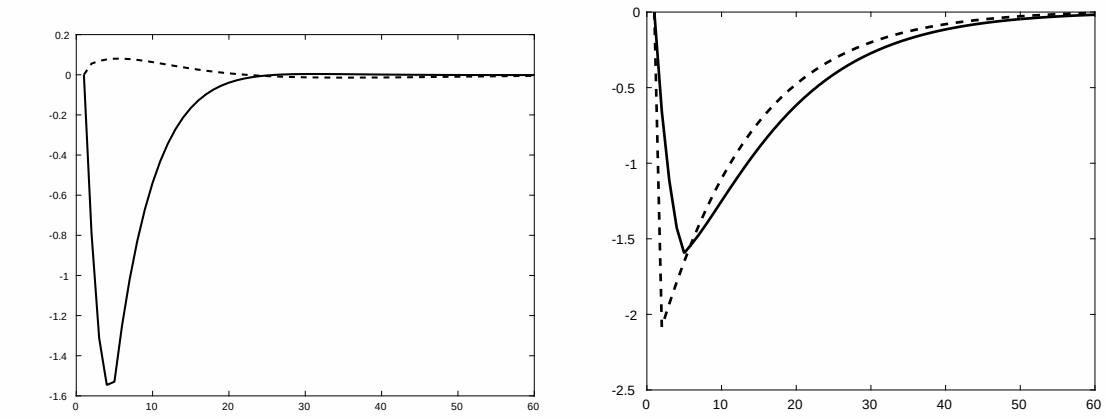
(c) Risk-free rate

(d) Wages

(e) GDP

(f) Physical capital

Figure 10: Comparison between laissez-faire (solid line) and "surprise bail-in" (dashed line) following the initial shock to bank equity (in years). All quantities and prices are in terms of percentage deviations from steady state except interest rates, which are in percentage-point deviations.



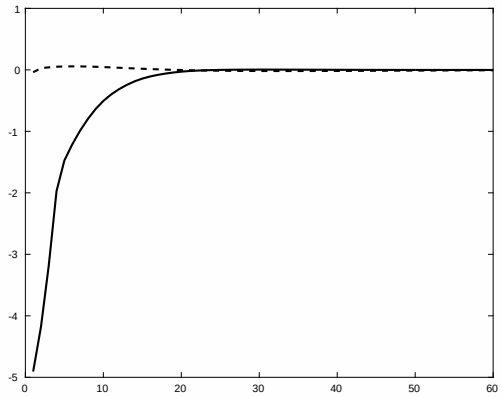
(a) Net worth: entrepreneurs **(b)** Net worth: workers

Figure 11: Comparison between laissez-faire (solid line) and "surprise bail-in" (dashed line) following the initial shock to bank equity (in years). Consumer net worth in terms of percentage deviations from steady state.

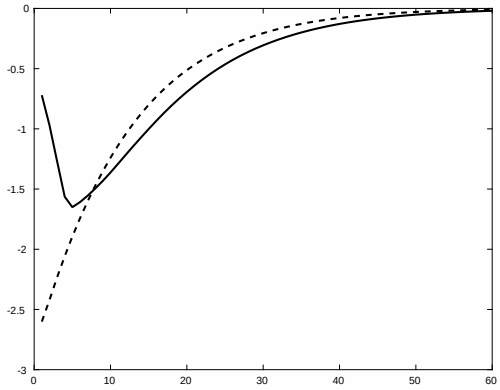
tax-financed equity injection. Specifically, a lump-sum tax, worth around 3 percent of GDP, is imposed on bank creditors, while a permanent 7-basis-point tax is imposed on bank lending. This combined intervention does better than the equity injection, and worse than the "surprise bail-in," in stabilizing average utilitarian welfare and is also able to achieve a Pareto improvement as Figure 15 shows.

Result 7. *A combination of a "surprise bail-in" and an equity injection can stabilize utilitarian welfare in a similar fashion as the "surprise bail-in" or equity injection while also achieving a Pareto improvement.*

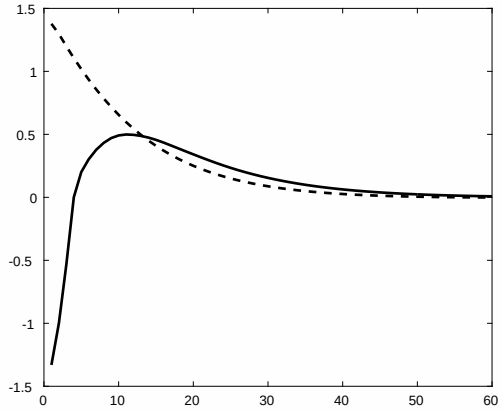
Result 7 is directly related to recent regulatory changes. In the case of a systemic financial crisis, both the Dodd-Frank Act in the United States (Dodd-Frank, 2010) and the Bank Recovery and Resolution Directive in the European Union (BRRD, 2014) prescribe a combination of bank creditor contributions and financial sector levies – financing the Orderly Liquidation Fund and the Single Resolution Fund, respectively – to support crisis resolution. Specifically, the analysis in this paper suggests that a combination of creditor "surprise bail-in" and financial sector levies is effective in resolving a financial



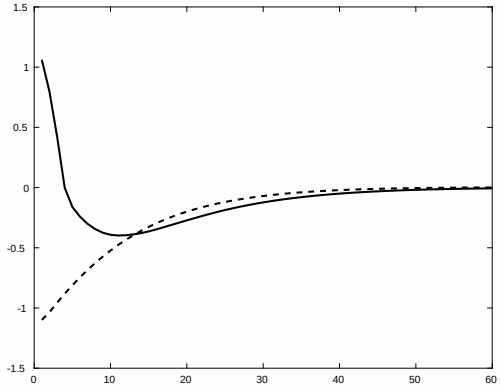
(a) Physical capital: entrepreneurs



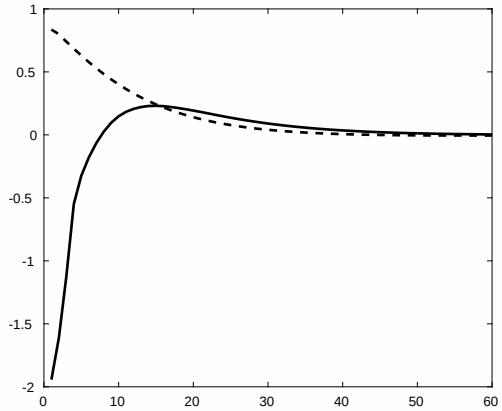
(b) Physical capital: corporate sector



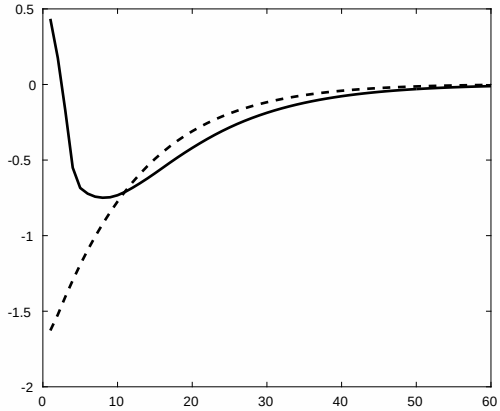
(c) Hours worked at entrepreneurs



(d) Hours worked: corporate sector



(e) GDP: entrepreneurs



(f) GDP: corporate sector

Figure 12: Comparison between laissez-faire (solid line) and "surprise bail-in" (dashed line) following the initial shock to bank equity (in years). All quantities are in terms of percentage deviations from steady state.

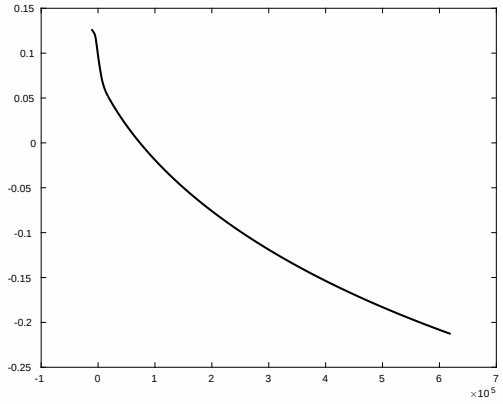
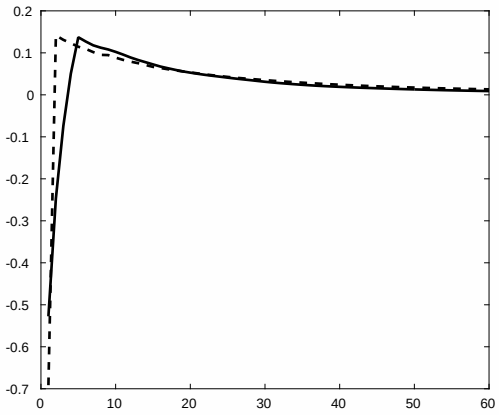
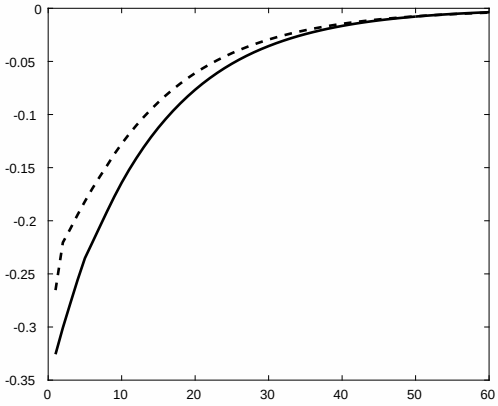


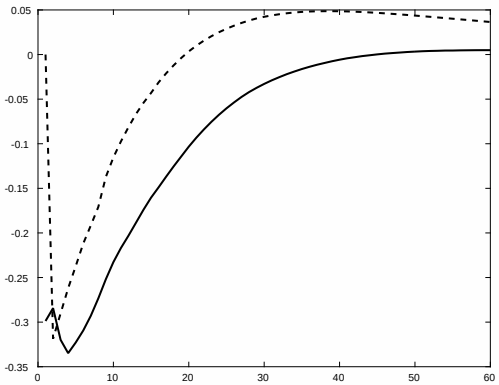
Figure 13: Welfare change due to "surprise bail-in," relative to laissez-faire, in terms of equivalent consumption variation as a function of net worth.



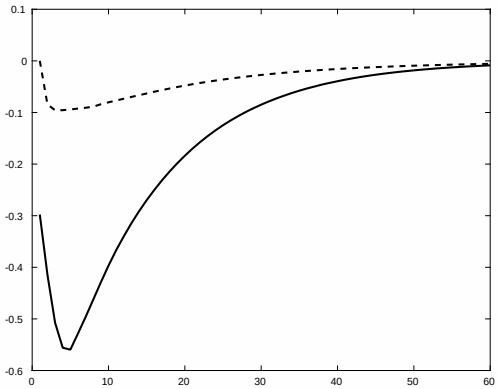
(a) Welfare of wealthiest 5 percent



(b) Welfare of poorest 95 percent



(c) Consumption of wealthiest 5 percent



(d) Consumption of poorest 95 percent

Figure 14: Comparison between laissez-faire (solid line) and "surprise bail-in" (dashed line) following the initial shock to bank equity (in years). All quantities are in terms of percentage deviations from steady state.

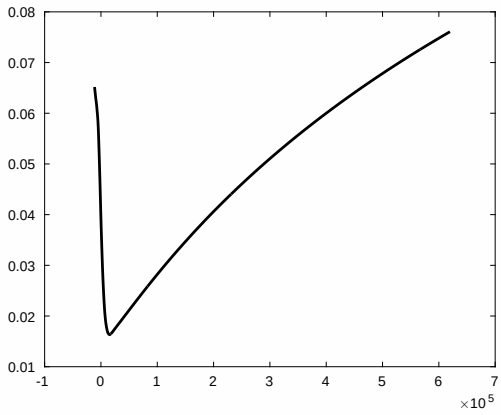


Figure 15: Welfare change due to 50-50 combination of "surprise bail-in" and equity injection relative to laissez-faire, in terms of equivalent consumption variation as a function of net worth.

crisis while at the same time avoiding potentially undesirable redistributional consequences. Owing to the unanticipated nature of the "surprise bail-in," its distributive implications are similar to those of monetary policy surprises (Doepke and Schneider, 2006; Meh et al., 2010) such as the "monetization" of bank debt during financial crises.

5 Conclusion

This paper studies the resolution of systemic financial crises via bank equity capital injections by policy-makers. In my model, a financial crisis hurts both borrowers and savers directly via higher borrowing rates and lower savings rates. I study the effectiveness of equity injections that are funded by financial industry levies in reducing the average welfare loss from a financial crisis and also study their distributive properties. I find that such equity injections are effective but redistribute wealth from the poor to the wealthy, even though no taxpayer funds, such as labour income taxes revenue, are used. I also consider support for the financial system that is funded by taxing financial intermediary creditors ("bail-in"). I find that such a bail-in is effective but redistributes from savers to borrowers. Third, I consider a combination of bank levies and bail-in

and find that it is effective and yields a Pareto improvement.

In the case of a systemic financial crisis, both the Dodd-Frank Act in the United States and the Bank Recovery and Resolution Directive in the European Union prescribe a combination of bank creditor contributions and financial sector levies to support crisis resolution. The results in this paper speak directly to these recent regulatory changes. Specifically, my model suggests that a combination of creditor bail-in and financial sector levies is effective in resolving a financial crisis and avoids undesirable redistributional consequences.

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