Margin Regulation and Volatility*

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Abstract

An infinite-horizon asset-pricing model with heterogeneous agents and collateral constraints can explain why adjustments in stock market margins under US Regulation T had an economically insignificant impact on market volatility. In the model, raising the margin requirement for one asset class may barely affect its volatility if investors have access to another, unregulated class of collateralizable assets. Through spillovers, however, the volatility of the other asset class may substantially decrease. A very strong dampening effect on all assets' return volatilities can be achieved by a countercyclical regulation of all markets.

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JEL Classification Codes: D53, G01, G12, G18.

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1 Introduction

Under the mandate of the US Securities Exchange Act of 1934, the Federal Reserve Board (FRB) established Regulation T to set initial margin requirements for partially loan-financed transactions of stocks. From 1947 until 1974, the FRB frequently changed these margin requirements. Motivated by the "Great Crash" of 1929, a major objective of Regulation T was to reduce the volatility of stock markets. The frequent adjustment of margin requirements provided a natural experiment for testing whether Regulation T achieved this goal. The vast majority of a sizeable empirical literature, however, does not find substantial evidence that regulating margin requirements in stock markets had an economically significant impact on market volatility (see Fortune (2001) for a review).

This paper provides a model-based explanation of the inconclusive findings of the empirical literature on Regulation T. In order to do so, it analyzes the effects of margin regulation on asset return volatility within a calibrated, infinite-horizon asset-pricing model with heterogeneous agents and two classes of collateralizable assets. In this model, changes in the regulation of one class of collateralizable assets may have only small effects on these assets' return volatility if investors have access to another unregulated class of assets to enter leveraged positions. A detailed general equilibrium analysis uncovers the economic mechanisms driving asset market volatility.

In the economic model, financial securities are only traded if the promised payments associated with selling these securities are backed by collateral. Margin requirements dictate how much agents can borrow using risky assets as collateral: if the margin requirement for an asset is m, then agents can borrow a fraction $1-m$ of the value of this asset when using it as collateral. There are two different margin rules that may apply to different asset classes. In the first rule the margin requirements are determined in equilibrium by market forces: they are set to the lowest possible value that still ensures no default in the subsequent period. In addition to market-determined margin requirements, a (not further modeled) regulating agency has the power to set minimum margin requirements.

To generate collateralized borrowing in equilibrium we assume that there are two types of agents who differ in risk aversion. They have Epstein–Zin utility with identical elasticity of substitution (IES) parameters and identical time discount factors. The agent with the low risk aversion parameter (agent 1) is the natural buyer of risky assets and takes up leverage to finance these investments. The agent with the high risk aversion (agent 2) has a strong desire to insure against bad shocks and is thus a natural buyer of risk-free bonds. Growth rates in the economy reflect the possibility of disaster shocks as in Barro and Jin (2011). When the economy is hit by a bad shock, the leveraged agent 1 loses financial wealth. As a result, the collateral constraint forces her[1] to reduce consumption and to sell risky assets to the risk-averse agent. These actions trigger an additional decrease in asset prices, which further reduces the wealth of agent 1. In sum, the presence of margin requirements leads to endogenous changes in the wealth distribution which—in turn—strongly affect asset return volatility in the economic model. Therefore, changing margins has the potential to substantially affect asset market volatility.

[1]For simplicity, agent 1 is female and agent 2 is male throughout the paper.

The model-based general equilibrium analysis of Regulation T is based on an economy with two long-lived assets, where margin requirements are exogenously regulated for one long-lived asset (representing stocks) while the margin requirement for the second asset (representing housing and corporate bonds) is determined by market forces. There are two forms of margin regulation: constant margin requirements and countercyclical margin requirements. For constant margins, the same minimum margin requirement applies over the whole business cycle. For countercyclical margin regulation, minimum margin requirements are 50 percent and the regulator imposes additional margins (sometimes referred to as "macroprudential add-ons") in good times.

For constant margin requirements on stocks, higher margins do not imply significantly different stock return volatilities. The reason for this result is that an increase in the margin requirement has two opposing effects: First, the regulated asset becomes less attractive as collateral. Thus it is sold more frequently after bad shocks when agent 1 must de-leverage. This effect represents a "flight from high margins". As a result the price of the regulated asset must fall to induce agent 2 to buy it. Second, higher stock margins decrease the agents' ability to leverage. Therefore the amount of leverage decreases in equilibrium, leading to less de-leveraging after bad shocks. While the first effect increases the regulated asset's volatility, the second effect reduces it. In equilibrium, these two effects approximately offset each other and thus the return volatility of the regulated asset barely changes. In contrast, the two effects work in the same direction for the unregulated asset and therefore reduce its volatility.

Countercyclical margin regulation of the stock market has a slightly stronger impact on asset price volatility than does constant regulation. In good times, the former type of regulation dampens the buildup of leverage in the same way as it does so with time-constant margins. However, the withdrawal of the macroprudential add-ons in bad times decreases the de-leveraging pressure induced by binding collateral constraints. For this reason, volatility can be reduced through countercyclical margin regulation, yet the quantitative impact can hardly be interpreted as economically significant. To sum up, changes in the regulation of one class of collateralizable assets may have only small effects on these assets' return volatility if investors have access to another (unregulated) class of collateralizable assets to leverage their positions.

In light of these observations, it is natural to explore a setting in which all asset markets are subject to margin regulation. And indeed, the effects of countercyclical margin regulation can significantly reduce stock market volatility if this kind of regulation is applied to all collateralizable assets in the economy. Such a regulatory policy prohibits agents from excessively leveraging (in unregulated markets), which lowers aggregate asset price volatility. That is to say, setting countercyclical margins in all markets is a powerful tool for considerably reducing stock market volatility as well as aggregate volatility.

While the focus of the analysis in this paper is on the volatility effects of margin regulation, we also explore the welfare implications of changing margin requirements on stock markets. In general, tightening margins benefits the more risk-averse agent, agent 2, yet results in a utility loss for agent 1. However, replacing constant margins with countercyclical ones benefits both agents if one agent compensates the other financially. In some cases this regulatory change leads to a Pareto improvement even without compensation. The normative analysis therefore confirms that countercyclical regulation is preferable to constant regulation.

There is a growing literature on the effects of collateralized borrowing on asset market volatility; see, among many other papers, Geanakoplos (1997), Aiyagari and Gertler (1999), Coen-Pirani (2005), Fostel and Geanakoplos (2008), Brunnermeier and Pedersen (2009), Garleanu and Pedersen (2011), and Fostel and Geanakoplos (2013). Unlike the present study, these papers do not consider calibrated models and do not investigate the quantitative implications of margin regulation. More like the present study, Rytchkov (2014) and Chabakauri (2013) analyze the volatility implications of collateral constraints in models with heterogeneous agents and two assets; in continuous time however. Unlike the present study, but similar to Coen-Pirani (2005), Rytchkov (2014) and Chabakauri (2013) assume that all consumption stems from the dividend payments of the Lucas trees. This abundance of collateral is one reason why some of their results differ from ours. For instance, margin requirements typically lead to a reduction in stock market volatility in Rytchkov (2013).

The remainder of this paper is organized as follows. Section 2 discusses Regulation T and the related economics literature. Section 3 introduces the model and describe its calibration. Section 4 presents the key analysis of the effects of margin regulation. Section 5 concludes.

2 Regulation T

The stock market bubble of 1927–1929 and the subsequent "Great Crash" of 1929 were accompanied by an extraordinary growth and subsequent contraction of trading on margin, see Figure I.

[FIGURE I ABOUT HERE]

The Crash and the Great Depression led United States Congress to pass the Securities Exchange Act of 1934, which granted the Federal Reserve Board (FRB) the power to set initial margin requirements on national exchanges. The introduction of this law had three major purposes: the reduction of "excessive" credit in securities transactions, the protection of buyers from too much leverage, and the reduction of stock market volatility (see, for example, Kupiec (1998)). Under this mandate, the FRB established Regulation T to set minimum margins for partially loan-financed transactions of exchange-traded securities. Figure II shows Regulation T margin requirements between 1934 and 2014 and NBER recessions in the United States.

[FIGURE II ABOUT HERE]

While the initial margin has been held constant at 50 percent since 1974, the FRB frequently changed initial margin requirements in the range of 50 to 100 percent from 1947 until 1974.[2] During this time the Board viewed margin requirements as an important policy tool.[3] While the Board did

[2]While the Securities Exchange Act of 1934 also granted the Federal Reserve Board the power to set maintenance margins (see Kupiec (1998)), Regulation T governs initial margin requirements only. Maintenance margins are generally set by security exchanges and broker–dealers.

[3]For example, in his testimony before the US Senate in 1955, FRB chairman William McChesney summarized the Board's view on margin policy as follows (as quoted in Moore (1966)): "The task of the Board, as I see it, is to

not use a formal decision-making rule, there is evidence that it adjusted margins countercyclically. After analyzing annual reports of the Board of Governors and the Federal Reserve system, Hardouvelis (1990) concludes that the "Fed typically attributes its decision to increase margin requirements to a rapid increase in stock prices [. . .] and to a rapid expansion in stock market volatility. Sometimes high trading volumes, inflationary pressure, and an expanding economy were also given as reasons."

The introduction and frequent adjustment of the initial margin prompted the development of a sizable literature on the effects of Regulation T. Moore (1966), in an early contribution, claims that the establishment of margin requirements had failed to satisfy any of the regulation's objectives. He argues that a major reason for the regulation's failure was that investors could avoid its impact by substituting other forms of borrowing for margin loans. Kupiec (1998) provides a comprehensive review of the empirical literature; in particular, he extends the scope of his analysis to account for margin constraints on equity derivative markets. He finds that "there is no substantial body of scientific evidence that supports the hypothesis that margin requirements can be systematically altered to manage the volatility in stock markets. The empirical evidence shows that, while high Reg T margin requirements may reduce the volume of securities credit lending and high futures margins do appear to reduce the open interest in futures markets, neither of these measurable effects appears to be systematically associated with lower stock return volatility."Kupiec (1998), furthermore, quotes from an internal 1984 FRB study that states that "margin requirements were ineffective as selective credit controls, inappropriate as rules for investor protection, and were unlikely to be useful in controlling stock price volatility."Similarly, Fortune (2001) argues that even though some studies suggest that the effect of margin loans on stock return volatility is statistically significant, such effects are much too small to be of economic significance. He also reiterates Moore's (1966) conjecture that investors substitute between margin loans and other debt.

The empirical analysis of Regulation T in Hardouvelis and Theodossiou (2002) and in Hardouvelis (1990) provides an exception to mainstream opinion, finding that increasing margin requirements in normal and bull periods significantly lowers stock market volatility but that no relationship can be established during bear periods. The authors' policy recommendation is to set margin requirements in a countercyclical fashion as to stabilize stock markets.

While there is a large empirical literature on Regulation T, the theoretical literature on the effect of margin requirements on stock prices is much smaller. Kupiec and Sharpe (1991) adopt a model with two overlapping generations in which risk-aversion is heterogeneous within and changing across generations showing that, depending on how risk aversion changes, introducing margin requirements may either reduce or increase stock price volatility. Rytchkov (2014) finds that margin requirements may decrease volatility. Wang (2013) develops a two-period model and shows that margin requirements may increase volatility even if they restrict borrowing. The present paper differs from these

formulate regulations with two principal objectives. One is to permit adequate access to credit facilities for securities markets to perform the basic economic functions. The other is to prevent the use of stock market credit from becoming excessive. The latter helps to minimize the danger of pyramiding credit in a rising market and also reduces the danger of forced sales of securities from undermargined accounts in a falling market."

studies in that a second asset, which is collateralizable but not regulated, plays an essential role in explaining the effects of Regulation T.

3 The Model

This section introduces an infinite-horizon exchange economy with two infinitely lived heterogeneous agents, and two long-lived assets that can be traded on margin. The respective margin requirements determine the collateral constraints on short-term borrowing and thus restrict leverage.

3.1 The Physical Economy

Time is indexed by $t = 0, 1, 2, \ldots$. Exogenous shocks (s_t) follow a Markov chain with support $\mathcal{S} = \{1, \ldots, S\}$ and transition matrix π. The evolution of time and shocks in the economy is represented by an infinite event tree Σ. Each node of the tree, $\sigma \in \Sigma$, describes a finite history of shocks $\sigma = s^t = (s_0, s_1, \ldots, s_t)$ and is also called a date–event. The symbols σ and s^t are used interchangeably. To indicate that $s^{t'}$ is a successor of s^t (or is s^t itself), write $s^{t'} \succeq s^t$. The expression s^{-1} refers to the initial conditions of the economy prior to $t = 0$.

At each date–event $\sigma \in \Sigma$, there is a single perishable consumption good. The economy is populated by $H = 2$ agents, $h \in \mathcal{H} = \{1, 2\}$. Agent h receives an individual endowment in the consumption good, $e^h(\sigma) > 0$, at each node. In addition, there are two different long-lived assets ("Lucas trees"), $a \in \mathcal{A} = \{1, 2\}$. At the beginning of period 0, each agent h owns initial holdings $\theta_a^h(s^{-1}) \geq 0$ of asset a. Aggregate holdings in each long-lived asset sum to one, that is, $\sum_{h\in\mathcal{H}} \theta_a^h(s^{-1}) = 1$ for all $a \in \mathcal{A}$. At date–event σ, agent h's (end-of-period) holding of asset a is denoted by $\theta_a^h(\sigma)$ and the entire portfolio of asset holdings by the A-vector $\theta^h(\sigma)$. The long-lived assets pay positive dividends $d_a(\sigma)$ in units of the consumption good at all date–events. The aggregate endowments in the economy is then

$$\bar{e}(\sigma) = \sum_{h\in\mathcal{H}} e^h(\sigma) + \sum_{a\in\mathcal{A}} d_a(\sigma).$$

Agent h has preferences over consumption streams $c^h = \left(c^h(s^t)\right)_{s^t\in\Sigma}$ representable by the following recursive utility function (see Epstein and Zin (1989)),

$$U^h\left(c^h, s^t\right) = \left\{ \left[c^h(s^t)\right]^{\rho^h} + \beta \left[\sum_{s_{t+1}} \pi(s_{t+1}|s_t) \left(U^h(c^h, s^{t+1})\right)^{\alpha^h}\right]^{\frac{\rho^h}{\alpha^h}} \right\}^{\frac{1}{\rho^h}},$$

where $\frac{1}{1-\rho^h}$ represents the intertemporal elasticity of substitution (IES) and $1 - \alpha^h$ the relative risk aversion of the agent.

3.2 Financial Markets and Collateral

At each date–event, agents can engage in security trading. Agent h can buy $\theta_a^h(\sigma) \geq 0$ shares of asset a at node σ for a price $q_a(\sigma)$. Agents cannot assume short positions of the long-lived assets.

Therefore, the agents make no promises of future payments when they trade shares of long-lived assets and thus there is no possibility of default when it comes to such positions.

In addition to the long-lived assets, there are one-period bonds available for trade; they are in zero net supply and their face value is one unit of the consumption good in the subsequent period. Agents can take up debt by shorting these bonds. They can default on such short positions at any time without any utility penalties or loss of reputation. The bonds are therefore only traded if the promised payments are backed by collateral. For each long-lived asset a, there is a one-period bond, also indexed by a, that can be used for borrowing against this asset. Agent h's (end-of-period) portfolio of bonds at date–event σ is denoted by the vector $\phi^h(\sigma) \in \mathbb{R}^2$, and the price of bond a at this date–event by $p_a(\sigma)$. If an agent borrows by short selling a bond, $\phi_a^h(s^t) < 0$, then that agent is required to hold a sufficient amount of collateral in the corresponding long-lived asset a. The difference between the value of the collateral holding in the long-lived asset a, $q_a(s^t)\theta_a^h(s^t) > 0$, and the current value of the loan, $-p_a(s^t)\phi_a^h(s^t)$, is the amount of capital the agent puts up to obtain the loan. A margin requirement $m_a(s^t)$, as defined by US Regulation T, enforces a lower bound on the value of this capital relative to the value of the collateral,

$$m_a(s^t) \left(q_a(s^t)\theta_a^h(s^t) \right) \le q_a(s^t)\theta_a^h(s^t) + p_a(s^t)\phi_a^h(s^t). \tag{1}$$

Since there are no penalties for default, an agent who sold bond a at date–event s^t defaults on his or her promise at a successor node s^{t+1} whenever the initial promise exceeds the current value of the collateral–that is, whenever

$$-\phi_a^h(s^t) > \theta^h(s^t) \left(q_a(s^{t+1}) + d_a(s^{t+1}) \right).$$

In this paper, margin requirements are sufficiently large so that no default occurs in equilibrium. There are two different rules for the determination of such requirements.

3.2.1 Market-Determined Margin Requirements

In the economy, market-determined margin requirements $m_a(s^t)$ are the lowest possible margins that still ensure no default in the subsequent period,

$$m_a(s^t) = 1 - \frac{p_a(s^t) \cdot \min_{s_{t+1}} \left\{ q_a(s^{t+1}) + d_a(s^{t+1}) \right\}}{q_a(s^t)}.$$

Substituting this margin requirement into inequality (1) leads to the inequality

$$-\phi_a^h(s^t) \le \theta^h(s^t) \min_{s_{t+1}} \left\{ q_a(s^{t+1}) + d_a(s^{t+1}) \right\}.$$

This margin requirement makes the bond risk-free by ensuring that a short-seller will never default on his or her promise. In this paper, defaultable bonds are not traded. In Brumm et al. (2015) this restriction is an equilibrium outcome: following Geanakoplos (1997) and Geanakoplos and Zame (2002), Brumm et al. (2015) assume that, in principle, bonds with any margin requirement may be traded in equilibrium, yet show that with moderate default costs only risk-free bonds are traded.

3.2.2 Regulated Margin Requirements

According to the second rule, a (not further modeled) regulating agency requires debtors to have a certain minimal amount of capital relative to the value of the collateral they hold. Put differently, the regulator imposes a floor on margin requirements so that the margin requirement for regulated assets traded is always the larger of this required minimal level $m_a(\sigma)$ and the market-determined margin level. If the minimal level is one, $m_a(\sigma) = 1$, then the asset cannot be used as collateral at all.

3.2.3 Financial Markets Equilibrium with Collateral

We are now in the position to formally define a financial markets equilibrium. Equilibrium values of a variable x are denoted by $\bar{x}$.

DEFINITION 1 *A financial markets equilibrium for an economy with regulated minimum margins* $\left((m_a(\sigma))_{a\in\mathcal{A}}\right)_{\sigma\in\Sigma}$*, initial shock* s_0*, and initial asset holdings* $(\theta^h(s^{-1}))_{h\in\mathcal{H}}$ *is a collection of agents' portfolio holdings and consumption allocations as well as security prices and margin requirements,* $\Big(\big(\bar{\theta}^h(\sigma), \bar{\phi}^h(\sigma), \bar{c}^h(\sigma)\big)_{h\in\mathcal{H}}; (\bar{q}_a(\sigma))_{a\in\mathcal{A}}, (\bar{p}_a(\sigma))_{a\in$ *satisfying the following conditions:*

(1) Markets clear:

$$\sum_{h\in\mathcal{H}} \bar{\theta}^h(\sigma) = 1 \quad \text{and} \quad \sum_{h\in\mathcal{H}} \bar{\phi}^h(\sigma) = 0 \quad \text{for all } \sigma \in \Sigma.$$

(2) For each agent h*, the choices* $\big(\bar{\theta}^h(\sigma), \bar{\phi}^h(\sigma), \bar{c}^h(\sigma)\big)$ *solve the agent's utility maximization problem,*

$$\begin{aligned} \max_{\theta\geq 0,\phi,c\geq 0} U_h(c) \quad &\text{s.t.} \quad \text{for all } s^t \in \Sigma \\ c(s^t) &= e^h(s^t) + \sum_{a\in\mathcal{A}} \phi_a(s^{t-1}) + \theta^h(s^{t-1}) \cdot \big(\bar{q}(s^t) + d(s^t)\big) \\ &\quad - \theta^h(s^t) \cdot \bar{q}(s^t) - \phi^h(s^t) \cdot \bar{p}(s^t) \\ \bar{m}_a(s^t)\bar{q}_a(s^t)\theta^h_a(s^t) &\leq \bar{q}_a(s^t)\theta^h_a(s^t) + \bar{p}_a(s^t)\phi^h_a(s^t) \quad \text{for all } a \in \mathcal{A}. \end{aligned}$$

(3) For all s^t*, and for each* $a \in \mathcal{A}$*, the margin requirement satisfies*

$$\bar{m}_a(s^t) = \max\left\{ m_a(s^t), 1 - \frac{\bar{p}_a(s^t) \cdot \min_{s_{t+1}} \left\{\bar{q}_a(s^{t+1}) + d_a(s^{t+1}\right\}}{\bar{q}_a(s^t)} \right\}.$$

Note that an asset a is called unregulated if the regulated minimum margin requirement, $m_a(\sigma)$, is equal to zero for all date–events $\sigma \in \Sigma$.

3.3 The Calibration

This section briefly describes the two different calibrations for the economic analysis in this paper, while the supplementary material provides a detailed discussion of the parameter choices. The model is calibrated to yearly US data. The aggregate endowment grows at the stochastic rate

$g(s_{t+1}) = \bar{e}(s^{t+1})/\bar{e}(s^t)$, which only depends on the new shock $s_{t+1} \in \mathcal{S}$. There are $S = 6$ exogenous shocks. The first three of them, $s = 1, 2, 3$, are rare disasters, which match the first three moments of the continuous distribution of consumption disasters estimated by Barro and Jin (2011). Also following Barro and Jin (2011), the transition probabilities are such that the six exogenous shocks are i.i.d. The non-disaster shocks, $s = 4, 5, 6$, are then calibrated such that their standard deviation is 2 percent (matching normal business cycle fluctuations) and the overall average growth rate is 2 percent. The resulting growth rates $(g(s))_{s=1,\dots,6}$ and probabilities $(\pi(s))_{s=1,\dots,6}$ for the six exogenous shocks to the economy are $g = (0.565, 0.717, 0.867, 0.968, 1.028, 1.088)$ and $\pi = (0.005, 0.005, 0.024, 0.0533, 0.8594, 0.0533)$, respectively.

In the baseline calibration, *calibration A*, the dividend streams of the long-lived assets have stochastic characteristics that are identical to those of aggregate consumption: for $a = 1, 2$, dividends satisfy $d_a(s^t) = \delta_a \bar{e}(s^t)$, where δ_a measures the magnitude of the asset dividends (the alternative calibration, *calibration B*, below, relaxes this assumption). The size of the dividend streams is based on Table 1.2 of the National Income and Product Accounts (NIPA), see Chien and Lustig (2010). Also following Chien and Lustig (2010), the collateralizable income is the sum of "rental income of persons with capital consumption adjustment", "net dividends", and "net interest". Between 1947 and 2010, the average share of this narrowly defined collateralizable income was about 11 percent, thus $\sum_a \delta_a = 0.11$. The total amount of tradeable assets is divided into two parts and modeled as two long-lived assets that differ in how their margins are determined. The first asset represents the stock market with $\delta_1 = 4\%$. The margins of this asset are regulated, since the FRB sets initial margin requirements for stocks under Regulation T. To simplify the analysis, net interest and net rental income are aggregated into the dividends of a second long-lived asset representing corporate bonds and housing and are $\delta_2 = 7\%$ accordingly. Since margins on (non-convertible) corporate bonds and mortgage-related securities as well as down payment requirements for housing have been largely unregulated, margins on the second long-lived asset are market-determined in equilibrium.

Each agent h receives a fixed share of aggregate endowments as individual endowments–that is, $e^h(s^t) = \eta^h \bar{e}(s^t)$. The first agent, $h = 1$, is much less risk-averse than the second one, with relative risk aversion parameters of $1 - \alpha^1 = 0.5$ and $1 - \alpha^2 = 7$. As a result, agent 1 holds the two risky long-lived assets most of the time. This fact guides the choice of endowment shares η^1 and η^2. With the objective of analyzing margin regulation, the endowment share η^1 of agent 1 should ideally correspond to the labor income share of investors with a margin account. Unfortunately, data on that rather specific share appears to be unavailable. Guided by data on active stock market participation (see, e.g., Vissing-Jørgensen and Attanasio (2003) and Poterba et al. (1995)), agent 1 receives 10 percent of all individual endowments, and agent 2 receives the remaining 90 percent in the baseline economy. Since $\sum_a \delta_a = 0.11$, it holds that $\eta^1 = 0.089$ and $\eta^2 = 0.801$. The majority of the population is thus quite risk-averse, while 10 percent of households have low risk aversion. Due to her relatively higher risk tolerance, agent 1 has an average wealth share of about two-thirds along the simulations of the baseline economy. This is consistent with the fact that in the US a large proportion of net wealth is held by stockholders (see Guvenen (2009)). While the two agents have different risk-aversion parameters, they have identical IES of 2–that is, $\rho^1 = \rho^2 = 1/2$. Finally, set $\beta^h = 0.942$ for both $h = 1, 2$, because it matches an annual risk-free rate of 1 percent in an economy with a regulated margin of 60 percent on stocks.

This completes the description of the baseline calibration, *calibration A*. In the alternative calibration, *calibration B*, the dividends of the two long-lived assets are no longer constant shares of aggregate endowments; instead the dividend shares match the volatility and persistence of their counterparts in NIPA data.

4 Regulation of Margin Requirements

The objective of this paper is to analyze the effects of margin regulation in general equilibrium and to compare the model's predictions to the empirical findings on Regulation T. As explained in the discussion of Regulation T in Section 2 above, for three decades the FRB viewed margin regulation as an active policy tool and frequently adjusted margins in response to economic conditions. Since the Board did not have an explicitly formalized decision-making rule as to when and by how much to adjust margins, this section considers two regulatory policies as benchmark cases. The first policy imposes a constant margin level at all times. The second policy imposes a countercyclical rule for margins, which are 50 percent in the negative-growth states 1–4 and are set to a higher level in states 5 and 6.

4.1 Margin Regulation of the Stock Market

This section analyzes the effects of the two benchmark policies in an economic model in which a regulating agency sets exogenous margin requirements for the stock market (asset 1), while not regulating collateralized borrowing of other assets (asset 2, such as real estate, corporate bonds, etc.) Margins on asset 2 are market-determined as explained in Section 3.2 above. The numerical results uncover intuitive economic reasons why the regulation of margins on stocks might have no or little effect on stock-market volatility, thereby shedding light on the empirical observations regarding Regulation T. In particular, endogenous equilibrium behavior supports the conjecture of Moore (1966) and Fortune (2001) that margin regulation has little impact if investors have access to other forms of debt.

Figure III shows the volatility of both assets' returns as a function of the margin requirement m_1 for the regulated asset. The figure shows return volatilities both for constant (upper graph) and for countercyclical (lower graph) margin regulation.

[FIGURE III ABOUT HERE]

First, consider the case of constant regulation in the upper graph. Over the entire range of values for the regulated margin requirement, the volatility of the regulated asset is rather flat. It initially increases slightly from 8.4 percent (for $m_1 = 0.5$) to 8.8 percent (for $m_1 = 0.8$) and then decreases slightly to about 8.5 percent (for $m_1 = 1$). Thus, changes in the margin requirement of the regulated market have a non-monotone and rather small effect on its own volatility. In contrast, such changes have a spillover effect on the unregulated asset, the volatility of which decreases monotonically. Second, with countercyclical regulation observe that adjustments of the margin level (in good times) in the range of 50 percent to 80 percent again have a negligible impact on the return volatility of the regulated asset. Only once this margin is set to 90 percent or higher does the return volatility decrease somewhat. For example, margin levels (in good times) of 90 percent lead to a return volatility of 8.0 percent as compared to 8.4 percent when margins are always equal to 50 percent. The return volatility of 8.0 percent with countercyclical margins is lower than the 8.7 percent in the upper graph for a constant margin of 90 percent (in all six states) but the overall effect of margin regulation on stock-return volatility is rather modest.

To obtain an understanding of the underlying economic effects, it is helpful to focus first on a particular case of constant regulation. Even for an extreme margin requirement of 100 percent–that is, when the regulation enforces stocks to be non-marginable, the stock market volatility is higher than for the case of very loose regulation, $m_1 = 0.5$. On the contrary, the volatility of the unregulated asset is significantly lower for such a policy. Why is it that margin regulation completely fails to fulfill its purpose? Figure IV shows the time series of six key variables in a simulation of a margin policy of $m_1 = 1$ for a time window of 200 periods. Recall that the economic model is a stochastic growth economy. Therefore, all reported prices are normalized asset prices–that is, equilibrium asset prices divided by aggregate consumption.

[FIGURE IV ABOUT HERE]

When a bad shock occurs, both the current dividend and the expected net present value of all future dividends decrease. As a result, asset prices drop, but in the absence of further effects the normalized prices should remain the same since the shocks to the growth rate are i.i.d. Figure IV, however, indicates that additional effects occur because the normalized price for the two long-lived assets declines. First, note that agent 1 is always leveraged–that is, her bond position is always negative. When a bad shock occurs, her beginning-of-period financial wealth falls relative to the financial wealth of agent 2 due to prices declining for the long-lived assets. The fact that collateral is scarce in the economy now implies that these changes in the wealth distribution strongly affect equilibrium portfolios and prices. In "normal times" agent 1 has a wealth share of about two-thirds and holds both long-lived assets. After a bad shock, agent 1's financial wealth drops and she has to sell some of these assets. In equilibrium, therefore, the price has to be sufficiently low to induce the much more risk-averse agent 2 to buy a (substantial) portion of the assets.

In addition to the described within-period effect, there is also a dynamic effect at work. As agent 1 is poorer today due to the bad shock, she will also be poorer tomorrow implying that asset prices tomorrow are also depressed. This effect further reduces the price that agent 2 is willing to pay for the assets today. Clearly, this dynamic effect is present not only for one but for several periods ahead, which is illustrated in Figure IV by the slow recovery of the normalized asset prices after bad shocks. Figure IV shows that the total impact of the two described effects is very strong for shock 1 but also large for shock 2. Recall once more that the depicted asset prices are normalized prices, so the drop in the actual asset prices is much larger than that displayed in the two figures. In disaster shock

1, agent 1's wealth share falls below four-tenths and she is forced to sell the entire regulated asset; as a result, this asset's normalized price drops by almost 25 percent while the actual price drops by approximately 55 percent. Agent 1 is also forced to sell part of the unregulated asset. In shock 2, she sells much less than half of her total asset holdings but the price effect is still substantial. Even in shock 3, the price effect is still clearly visible, although agent 1 has to sell only very little.

The described effects result in important differences in the price and the return dynamics of the two assets. First, the volatility of the regulated asset 1 is larger than that of the unregulated asset 2. Second, agent 1 holds the unregulated asset 2 in almost all periods but frequently sells the regulated asset. When faced with financial difficulties–that is to say, a declining wealth share after a bad shock, agent 1 holds on to the unregulated asset as long as possible, because this asset allows her to hold a short position in the bond. So, after suffering a reduction in financial wealth, agent 1 first sells the regulated asset. In fact, as her wealth share decreases, agent 1 sells a portion of the unregulated asset only after she has sold the entire regulated asset. So, one key factor contributing to the different volatility levels of the two assets is that the regulated asset is traded much more often and in larger quantities than the unregulated one. Over very long simulations, the average trading volume of the unregulated asset is tiny (0.0027). By comparison, the average trading volume of the regulated asset is about ten times larger (0.0298).

In light of the economic effects for the case $m_1 = 1$, we can provide an explanation for the observation that adjusting constant margins on the stock market has only little effect on its volatility. An increase in the margin requirement for stocks has two effects. As the margin requirement increases, the regulated asset becomes less attractive as collateral and at the same time the agents' ability to leverage decreases. These two effects both influence (the much less risk-averse) agent 1's portfolio decisions after a bad shock, yet they work against each other. First, when agent 1 must de-leverage her position, she always sells the regulated asset first, as it is a worse type of collateral due to its higher margins. Initially this effect leads to an increase in the return volatility of the regulated asset. However, the second effect of higher margins, a reduced ability to leverage, makes de-leveraging episodes less severe. This second effect decreases the return volatility of all assets. In the model's specification, the two effects roughly offset each other and therefore a change in the margin requirement has almost no observable effect on the volatility of the regulated asset.

Table I presents agent 1's average portfolio positions and the asset trading volume along long simulations for five different margin levels.

[TABLE I ABOUT HERE]

The two aforementioned effects also roughly offset each other with respect to both the average positions and the trading volume of the regulated asset; both averages barely change in response to changes in the regulated margin level m_1. Contrary to the mild effect of changes in the margin requirement m_1 on the regulated asset, a strong spillover effect on the unregulated asset is apparent. A tightening of the margin requirements on the regulated asset has two effects on the unregulated asset. First, the unregulated asset becomes more attractive as collateral relative to the regulated asset. Second, de-leveraging episodes become less severe. Both of these effects act in the same direction and so the less risk-averse agent 1 holds, on average, more units of the unregulated asset and the trading volume of that asset decreases. Table I reports that, for $m_1 = 0.9$, the average trading volume of the unregulated asset is less than half as large as for a margin level of $m_1 = 0.6$. The two effects also influence the return volatility of the unregulated asset. The dashed line in the upper graph of Figure III shows that the return volatility of the unregulated asset declines monotonically in the margin level of the other, regulated, asset.

Finally, return to the lower graph in Figure III, which depicts return volatilities for the second benchmark policy, that of countercyclical regulation. The implications of this second policy are qualitatively identical to those of the first policy. Countercyclical margin policy also has only small effects on stock market volatility while again the spillover effects on the second, unregulated, asset market are much stronger. However, with countercyclical regulation volatility is slightly lower than for constant regulation. In particular, contrary to the case of constant regulation, stock market volatility is smaller for very high than for low margins. The supplemental material in the online appendix provides the analogue of Table I for the second policy.

In sum, the numerical results of the general equilibrium analysis of margin regulation support the conclusions of Fortune (2001) based on the empirical literature on Regulation T (see Section 2). Changes in (constant or countercyclical) margin levels have a small and ambiguous effect on stock market volatility. However, the amount of borrowing decreases as margins are increased, just as Kupiec (1998) concluded from empirical studies—"high Reg T margin requirements may reduce the volume of securities credit lending". The main economic message of this analysis is clear as well. A tightening of constant or countercyclical margin requirements on a regulated asset market may have little or almost no effect on the asset's return volatility if agents have access to another asset class that is not subject to margin regulation. Instead, an adjustment of margin requirements in the regulated market may have stronger effects on the unregulated asset than on the regulated asset itself. This effect is similar to the "flight to collateral" in Fostel and Geanakoplos (2008), and so we call it the "flight from high margins". This general equilibrium effect supports the claims of Moore (1966) and Fortune (2001) that Regulation T has little impact on market volatility since investors have access to other forms of debt.

4.2 Countercyclical Margin Regulation of all Markets

The above analysis has demonstrated that the effects of regulatory margin policies on the return volatility of a regulated asset are considerably dampened by the presence of an unregulated asset. Clearly, this observation raises the question of whether extending margin regulation to all assets in the economy can lead to stronger effects on asset return volatility. Put differently, would Regulation T have been more successful in reducing market volatility if it somehow had been applied to all collateralizable assets? This question motivates the next part of the analysis.

For simplicity, assume that both assets are regulated in the same way. Since the two assets have collinear dividend processes, identical margin levels imply that both assets have the same return volatility. Therefore, it suffices to report the return volatility of the overall asset market (see Figure V). The graph shows the market return volatility as a function of the countercyclical[4] margin requirement in the growth states 5 and 6; as before, the margin requirement is fixed at 0.5 in the negative-growth states 1 to 4.

[FIGURE V ABOUT HERE]

Applying countercyclical regulation to all assets reduces return volatility much more than does regulation of the stock market alone. For example, countercyclical margins of 90 percent on all markets lead to a return volatility below 5.4 percent, which is much lower than the aggregate volatility of above 7.1 percent and a stock market volatility of 8.0 percent when regulation is applied to the stock market only (see Figure III). Table II reports agent 1's average portfolio holdings and the asset trading volume under countercyclical regulation of all assets.

[TABLE II ABOUT HERE]

Observe that an increase in margin requirements has somewhat different effects on holdings and trading volume than in the case of stock market regulation (of asset 1) only. An increase in the margin m, leads to a more pronounced increase in the average holdings of the two long-lived assets and a much more reduced average leverage for agent 1; the average trading volume in the (two) regulated assets decreases while in the stock market regulation the trading volume of the regulated stock (asset 1) stays almost constant. Naturally, the question arises as to why the volatility and portfolio effects of total-market regulation are different, particularly for large values of m. In order to answer this question, Table III reports the average asset price and agent 1's portfolio holdings conditional on the exogenous shock s for countercyclical margin regulation of all assets.

[TABLE III ABOUT HERE]

The results in Table III reveal several patterns. First, for margin levels $m \in \{0.8, 0.9\}$ the average, conditional, normalized price of the aggregated long-lived asset does not increase from (the recession) state 4 to (the normal growth) state 5 but instead decreases. Second, for each margin level m, agent 1's average holding of the long-lived asset in state 4 is larger than her average holding in the growth states 5 and 6. Moreover, for $m \in \{0.8, 0.9\}$ agent 1's average holding of the long-lived asset in all four negative-growth states exceeds her average holding in the normal-growth state 5. Third, for each margin level m, agent 1's average short position in the bond in state 4 is larger than in states 5 and 6. In fact, for $m \in \{0.7, 0.8, 0.9\}$, agent 1's average short position in states 2, 3, and 4 exceeds those in states 5 and 6. These three patterns reveal the critical impact of countercyclical margins on all markets in the economy.

In response to larger margin requirements in the good states, agent 1 must reduce her leverage. For this purpose, she must even sell a small portion of the long-lived assets; selling the risky asset to the risk-averse agent 2 dampens the increase in the conditional price that naturally occurs when agent 1's relative wealth increases in response to good shocks 5 or 6. In fact, for margin levels $m \in \{0.8, 0.9\}$ the normalized price in state 5 is even lower than in state 4. This dampening effect

[4]Since the previous results indicate that countercyclical regulation is (slightly) more effective in reducing volatility, only this type of regulation is considered here.

on the asset price in the positive-growth states reduces the asset return volatility. Conversely, in response to smaller margin requirements in negative-growth states, agent 1 can actually increase her leverage compared to good states. In particular for $m \in \{0.8, 0.9\}$, both agent 1's average holding of the aggregated long-lived asset and her short position in the bond are larger in the four negative-growth states than in the two positive-growth states. So, on average, agent 1 buys the long-lived asset in response to a bad shock. As a result, the normalized asset price does not decrease as much as it would have otherwise because agent 1's relative wealth decreases in response to a bad shock $s = 1, 2, 3, 4$. This buffer effect on the asset price in the negative-growth states also reduces the asset return volatility. And so, the dampening effect in the good states and the buffer effect in the bad states together lead to the significant decrease in the asset return volatility.

In sum, equilibrium portfolios and prices exhibit qualitatively different features in an economy with countercyclical margins on all assets than those exhibited in an economy with both a regulated and an unregulated asset. For sufficiently large margin requirements in the positive-growth states, the much less risk-averse agent 1 reduces leverage in positive-growth states and increases leverage in negative-growth states. These changes in leverage dampen or even reverse those movements in the conditional price that lead to large excess volatility in the presence of an unregulated asset.

4.3 Results for the Alternative Calibration

So far the general equilibrium analysis in this paper has revealed several different effects of margin regulation. For the detection of these effects it has been helpful to rely on a simple calibration of the model. *Calibration A* (see Section 3.3) assumed that the two long-lived assets have collinear dividends. While this assumption guaranteed that the different statistics of the two assets were (apart from their different sizes) only driven by their different margins, it is, of course, not supported by the data. Therefore, consider now *calibration B* (see Section 3.3), which reflects the data more closely in terms of the volatility and persistence of the dividend shares. For this alternative calibration, Figure VI presents return volatilities for a constant regulation of the stock market, a countercyclical regulation of the stock market, and for a countercyclical regulation of all asset markets.

[FIGURE VI ABOUT HERE]

All three graphs are qualitatively similar to the corresponding graphs for the baseline calibration, *calibration A*. Generally, the return volatilities are now a little higher, since the volatility of the two dividend shares leads to higher price volatility even in absence of collateralized borrowing. The first two graphs in the figure illustrate that the main economic effect–namely the flight from high margins, is robust with respect to the exact specification of dividends. Just as in *calibration A*, the effect of regulating margins on the stock is rather small, both for constant and countercyclical regulation. For the alternative calibration, *calibration B*, volatility is slightly higher for a 100 percent than for a 50 percent requirement — even under countercyclical regulation. The difference between countercyclical and uniform regulation is smaller for intermediate values of margin requirements. As before, the spillover effect on the return volatility of the unregulated asset 2 is considerably stronger than that on the regulated asset itself. In sum, while the exact specification of the dividend processes matters quantitatively, the qualitative effects and the economic mechanism appear to be robust.

4.4 Welfare

Up to now, the focus of this paper has been on the effect of margin regulation on volatility. This is motivated by the question of whether Regulation T enabled the FRB to reach the aforementioned third goal of the Securities and Exchange Act of 1934–namely the reduction of stock market volatility. This final part of the analysis presents some quantitative welfare implications of margin regulation.[5]

To compare a constant margin regulation of stock markets to a countercyclical regulation, conduct the following policy experiment: assume that the economy is in a constant regulation regime when the regulating agency announces a shift to countercyclical regulation with the same margin level for the good states. Given the yearly calibration of the economic model, assume that before and after the change in regulation, agents can trade in asset markets while the economy resides in the same exogenous state. The welfare impact of this policy change depends critically on the distribution of wealth at the time of the regulatory adjustment. It is, therefore, necessary to evaluate the policy change for a wide range of wealth levels.

We find that countercyclical stock market regulation dominates constant regulation for a wide range of margin levels, a large portion of the endogenous state space, and the most relevant exogenous states. Figure VII shows, for a margin level of 80 percent, that both agents can be made better-off by the introduction of countercyclical regulation.[6]

[FIGURE VII ABOUT HERE]

For the median of the conditional wealth distribution, agent 2 experiences (after the compensation of agent 1) a welfare increase that is approximately equivalent to a 0.07 percent increase in his consumption level.[7] For the part of the endogenous state space where the economy resides almost all the time, the change in regulation improves the welfare of agent 2 but may make agent 1 worse off. However, compensating agent 1 for her welfare loss (i.e., shifting the wealth distribution in agent 1's favor so that she is indifferent between the two regulation regimes) can be achieved without making agent 2 worse off than before the change in regulation. For a small portion of the endogenous state space even a Pareto-improving change in regulation is achievable without compensation.

In sum, the analysis shows that a policy maker could achieve welfare improvements when moving from constant to countercyclical regulation. This result is similar in spirit to the results regarding volatility where countercyclical margins yield lower volatility than constant margins. The normative analysis therefore confirms that countercyclical regulation is preferable to constant regulation.

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[5] All reported results are for *calibration B*. Since the welfare results are very similar for both calibrations, only results for *calibration B* are reported as it reflects the data more closely.

[6] Figure VII is based on the business-cycle-sized shock 5. However, the results are very similar for all business-cycle-sized exogenous shocks. By comparison, for the median of the wealth distribution conditional on the small probability disaster shocks, agent 1 may be better-off, whereas agent 2 may be worse-off.

[7] A table in the Supplementary Material provides further results for other margin levels.

In addition to the comparison of countercyclical to constant regulation, consider the welfare implications of changing the margin level for a given type of regulation. For both countercyclical and constant stock market regulation, increasing the margin requirement by 10 percent from a given level generally benefits the more risk-averse agent 2, whereas agent 1 is generally worse-off. However, after compensating agent 1 for her welfare loss, now agent 2 is generally worse-off. For example, when increasing the countercyclical margin from 60 to 70 percent, agent 2 gains 0.33 percent in consumption equivalents, whereas agent 1 loses 1.1 percent. After compensation of agent 1, agent 2 is worse off by 0.02 percent.[8]

Finally, the countercyclical regulation of all markets turns out to be less favorable in welfare terms than it is for reducing volatility. Moving from a constant or countercyclical regulation of stock markets to a countercyclical regulation of all markets does in general either reduce the welfare of both agents or reduce the welfare of agent 1 so much that she cannot be compensated for this loss without making agent 2 worse off. Thus, while such a policy change reduces volatility, it comes at the cost of reducing trading opportunities so much that even by including compensations it cannot be made a Pareto improvement.

The above welfare analysis shows that changes in regulation may modestly affect agents' welfare. To obtain stronger results (e.g., Pareto-improving changes in margin regulation for the whole ergodic distribution), we believe that features such as production or costly default would need to be introduced into the model. In such settings, regulation may be even more important for overcoming externalities stemming from leverage and excess volatility.

5 Conclusion

An infinite-horizon asset-pricing model with heterogeneous agents and collateral constraints can explain the empirical findings on the regulation of margins in US stock markets: adjustments in margins under Regulation T had an economically insignificant impact on market volatility. Changes in the regulation of one class of assets may have only small effects on these assets' return volatility if investors have access to another (unregulated) class of collateralizable assets to take up leverage. This result even holds for countercyclical margin regulation, which outperforms constant regulation in welfare terms. The volatility implications of the general equilibrium model are in consonance with the findings of the empirical literature on US Regulation T. A margin regulation has a much stronger impact on asset return volatility if all long-lived assets in the economy are regulated. In such an economy, countercyclical regulation that imposes sufficiently large macroprudential add-ons on margin levels in high-growth states can lead to significant reductions in asset return volatility.

While this paper analyzes stock market margin regulation (like Regulation T), the findings are also relevant to the current debate on the regulation of margin requirements, or "haircuts"[9], for

[8] The Supplementary Material contains two tables presenting the results for both countercyclical and constant stock market regulation at various margin levels.

[9] In the current policy debate, instead of "margin requirement" the term "haircut" is often used.

securities lending and repo markets. The Financial Stability Board (FSB) is currently considering a policy framework for addressing risks in these markets, which includes a proposal to introduce minimum haircuts on collateral (see FSB (2012) and FSB (2013)). It aims "to set a floor on the cost of secured borrowing against risky assets in order to limit the buildup of excessive leverage"(FSB (2012), p.12). Since the analysis shows that countercyclical stock market regulation is preferable to constant regulation, with respect to both volatility and welfare, the policy framework should ideally allow regulators to set countercyclical margins. The analysis in this paper further shows that only a comprehensive regulation of collateralized borrowing reduces asset market volatility considerably. This observation suggests that the FSB policy framework should have a broad scope if it is to have a significant impact on asset market volatility.

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Table I: Average holdings and trading volume under constant stock market regulation

Margin of Asset 1	Agent 1 Holding of			Trading Volume of	
	Asset 1	Asset 2	Bonds	Asset 1	Asset 2
0.6	0.9462	0.9875	-1.277	0.0265	0.0084
0.7	0.9462	0.9922	-1.236	0.0292	0.0063
0.8	0.9490	0.9955	-1.184	0.0284	0.0044
0.9	0.9466	0.9967	-1.144	0.0291	0.0034
1.0	0.9425	0.9974	-1.111	0.0298	0.0027

The table reports average holdings of agent 1 and the trading volume for the two long-lived assets under a constant margin regulation for asset 1 and market-determined margins on asset 2. On average, agent 1 holds most of the two long-lived assets and a substantial short position in the one-period bond. The average trading volume in the unregulated asset 2 is much smaller than in the regulated asset 1 and is sharply decreasing as the margin requirement for asset 1 increases.

Table II: Average holdings of agent 1 and trading volume under countercyclical regulation

Margin of both Assets	Agent 1 Holding of both Assets	Agent 1 Holding of Bonds	Trading Volume of both Assets
0.6	0.9650	-1.2188	0.0138
0.7	0.9827	-0.9685	0.0128
0.8	0.9899	-0.6051	0.0111
0.9	0.9900	-0.2593	0.0057

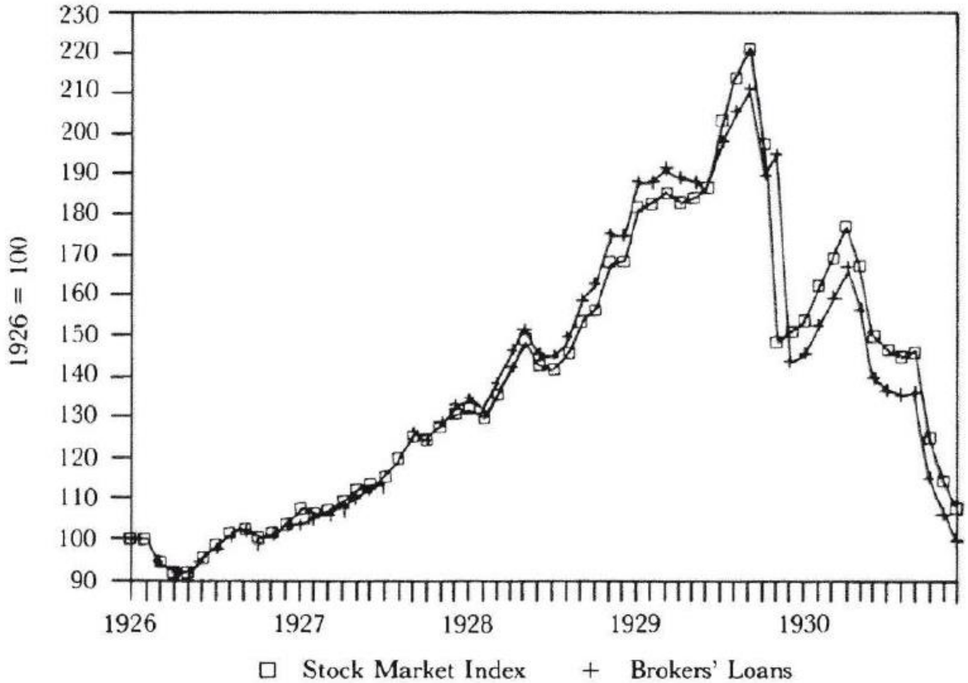
The table reports average holdings of agent 1 and the aggregate asset trading volume for an economy with identical countercyclical margin regulation of both long-lived assets. The regulated margin level on both assets is 0.5 in states 1–4 and equal to the levels given in the table in the growth states 5 and 6. As the countercyclical margin requirement increases, agent 1 increases her average holding of the two long-lived assets and substantially decreases her short position in the bond. Also, the trading volume of the long-lived assets decreases.

Table III: Asset price and portfolio holdings under countercyclical regulation

margin	state →	1	2	3	4	5	6
0.6	asset price	2.1616	2.5554	2.9403	3.2043	3.3798	3.4584
	asset holding	0.0970	0.7115	0.9235	0.9757	0.9716	0.9728
	bond holding	-0.1019	-0.8877	-1.1765	-1.2434	-1.2287	-1.1941
0.7	asset price	2.2876	2.6280	3.0601	3.2283	3.2810	3.4068
	asset holding	0.5972	0.9604	0.9944	0.9962	0.9836	0.9873
	bond holding	-0.6662	-1.1664	-1.1241	-1.0494	-0.9605	-0.9582
0.8	asset price	2.7285	2.8737	2.9971	3.0842	3.0563	3.1735
	asset holding	0.9943	0.9990	0.9999	0.9999	0.9886	0.9935
	bond holding	-1.0325	-0.8473	-0.7298	-0.6755	-0.5931	-0.6076
0.9	asset price	2.7045	2.7338	2.7569	2.7716	2.6208	2.6935
	asset holding	1.0000	1.0000	1.0000	1.0000	0.9888	0.9919
	bond holding	-0.4965	-0.4113	-0.3546	-0.3275	-0.2501	-0.2607

The table reports, for each state, the average asset price and the average holdings of agent 1 for an economy with identical countercyclical margin regulation of both long-lived assets. The regulated margin level on both assets is 0.5 in states 1–4 and equal to the levels given in the table in the growth states 5 and 6.

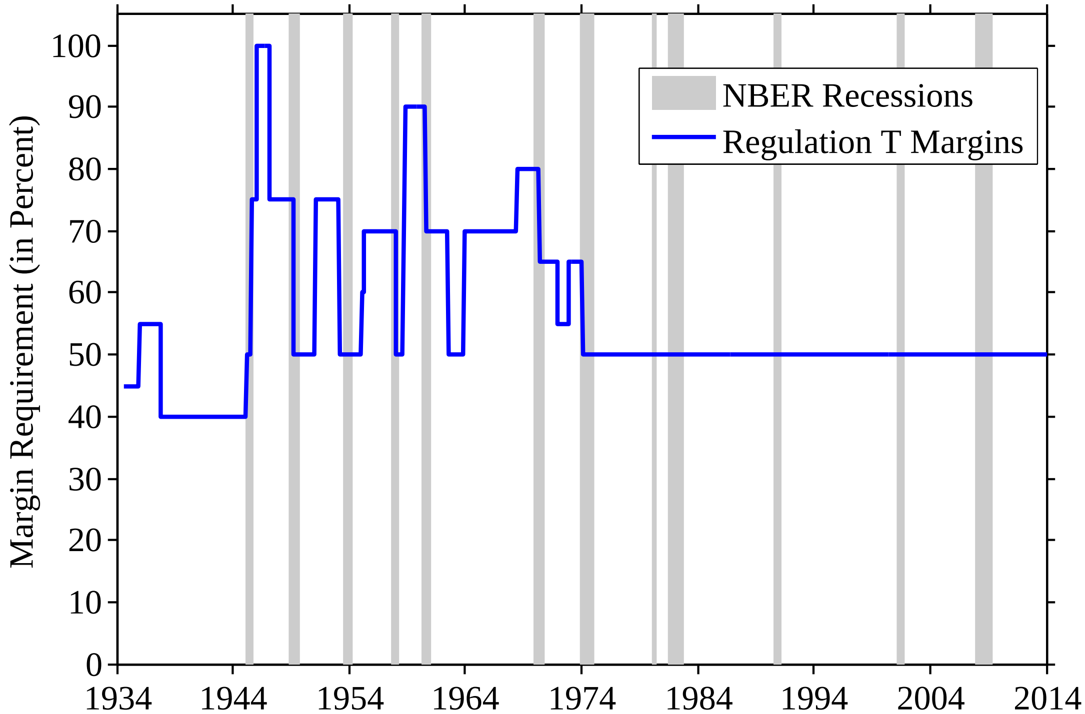
Figure I: Stock prices and brokers' loans for US stocks 1926–1931



Source: Board of Governors of the Federal Reserve system (1943) and the New York Stock Exchange *Year Book* (1931).

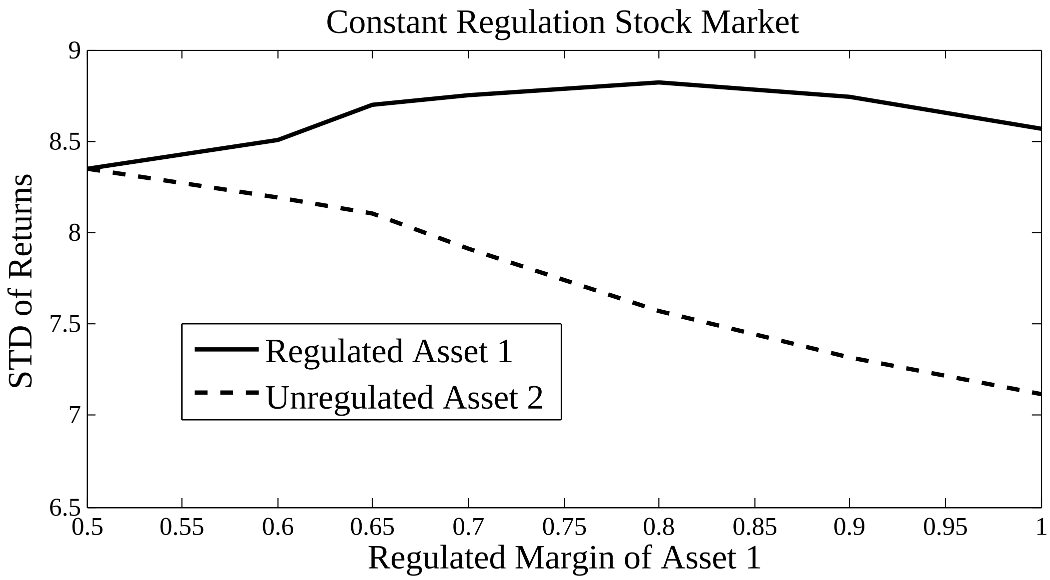
This figure shows both an index of the New York Stock Exchange's brokers' loans and an index of stock prices. It is a reproduction of Figure 4 in White (1990). Note the extraordinary tight co-movement of the two time-series.

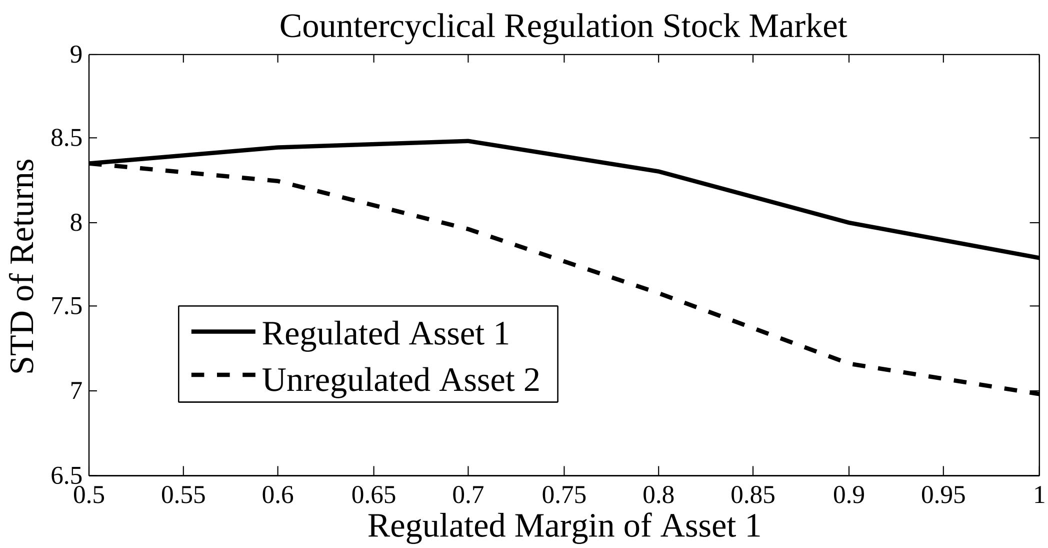
Figure II: Historical levels of margin requirements and US recessions



The solid line shows the initial margin requirement on stocks according to Regulation T between 1934 and 2014. The shaded vertical areas indicate the occurrence of NBER recessions in the United States. The initial margin has been held constant at 50 percent since 1974. In contrast, the FRB frequently changed initial margin requirements in the range of 50 to 100 percent from 1947 until 1974. While the FRB did not use a formal decision-making rule, the coincidence of margin decreases and recessions suggests that margins were, at least to some extent, set countercyclically during that period.

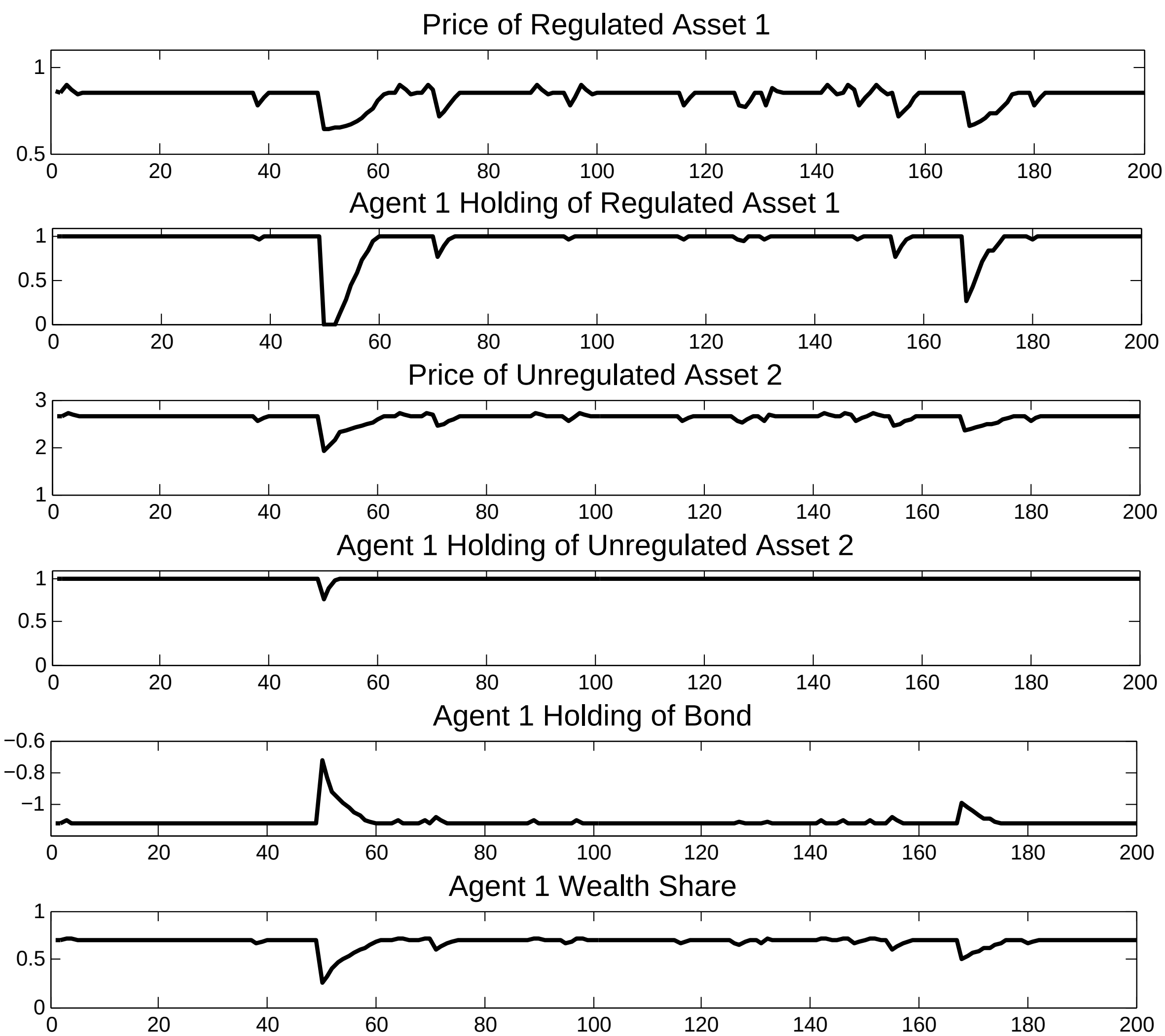
Figure III: Margin regulation of the stock market





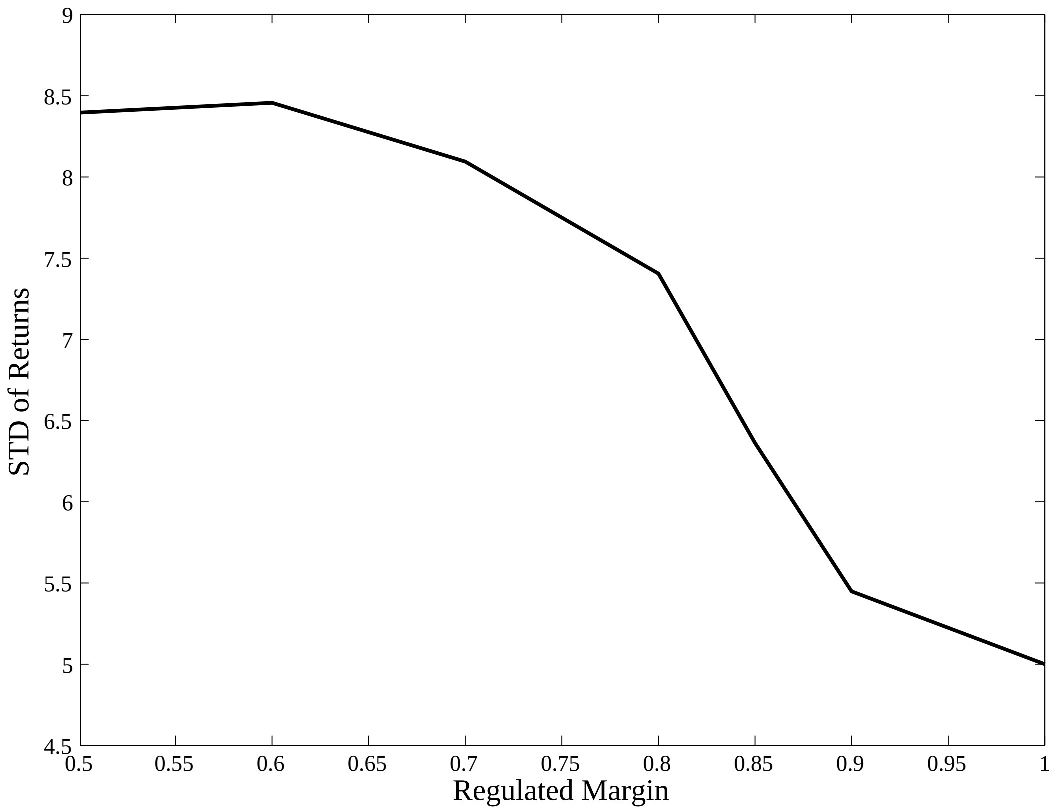
The upper graph displays the standard deviations of asset returns (in percent) as a function of the constant margin requirement m_1 on the regulated asset, which corresponds to the stock market in the calibration. The lower graph shows the standard deviations of asset returns (in percent) as a function of the countercyclical margin level in states 5 and 6. The margin requirement in states 1–4 is 0.5. The solid lines show the return volatility of the regulated asset and the dashed lines that of the unregulated asset.

Figure IV: Simulation path for constant regulation with $m_1 = 1$



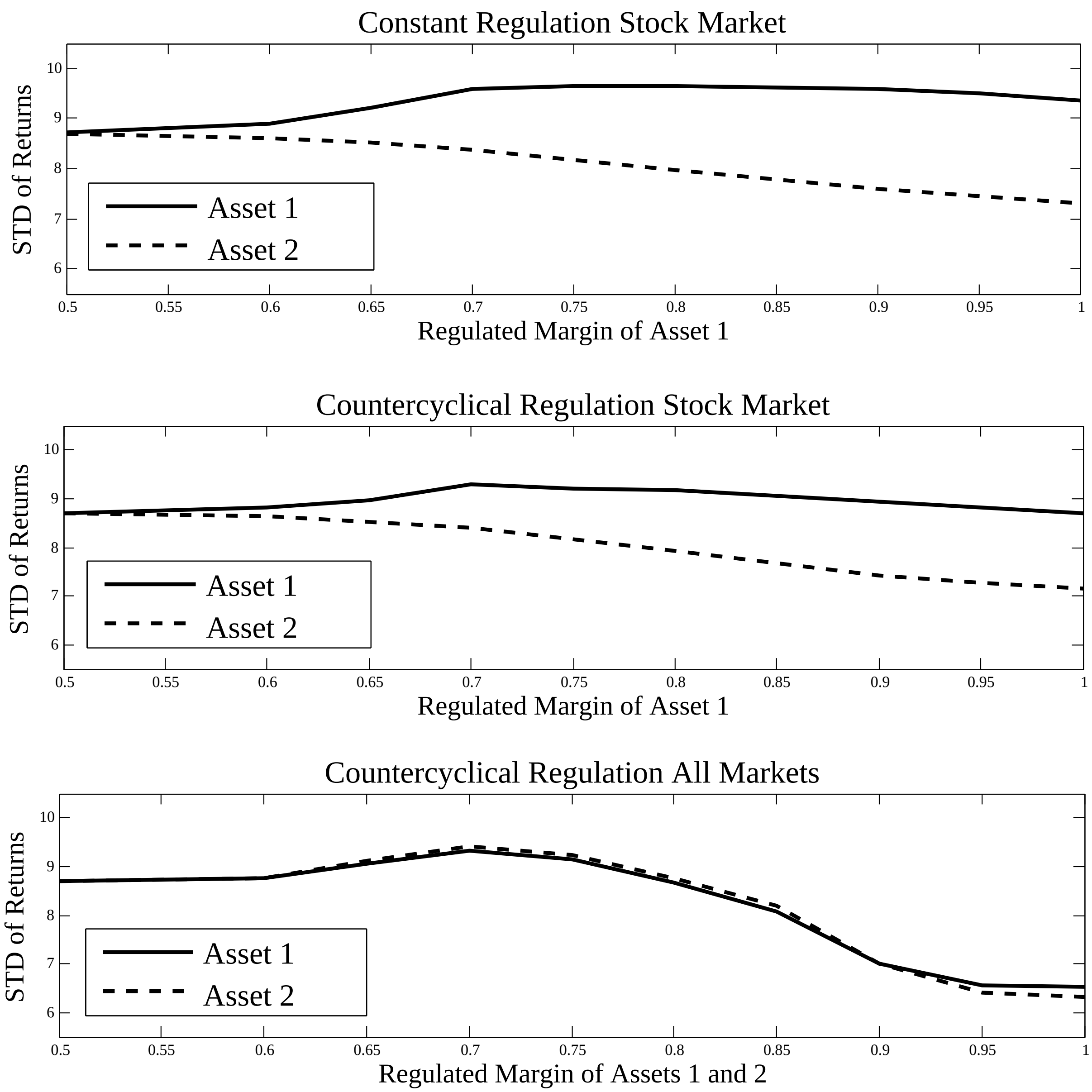
The figure shows a snapshot from a long simulation of an economy in which the regulated asset is not marginable–that is, the margin requirement is 100%. The first graph shows the normalized price of asset 1, the regulated asset. The second graph displays agent 1's holding of this asset. The next two graphs show the price and agent 1's holding of the unregulated asset 2, respectively. The last two graphs show agent 1's bond position and share of financial wealth, respectively. In the displayed sample, shock $s = 3$ occurs in periods 71 and 155, while shock 2 occurs in period 168, and the worst disaster shock 1 hits the economy in period 50.

Figure V: Countercyclical regulation of all markets



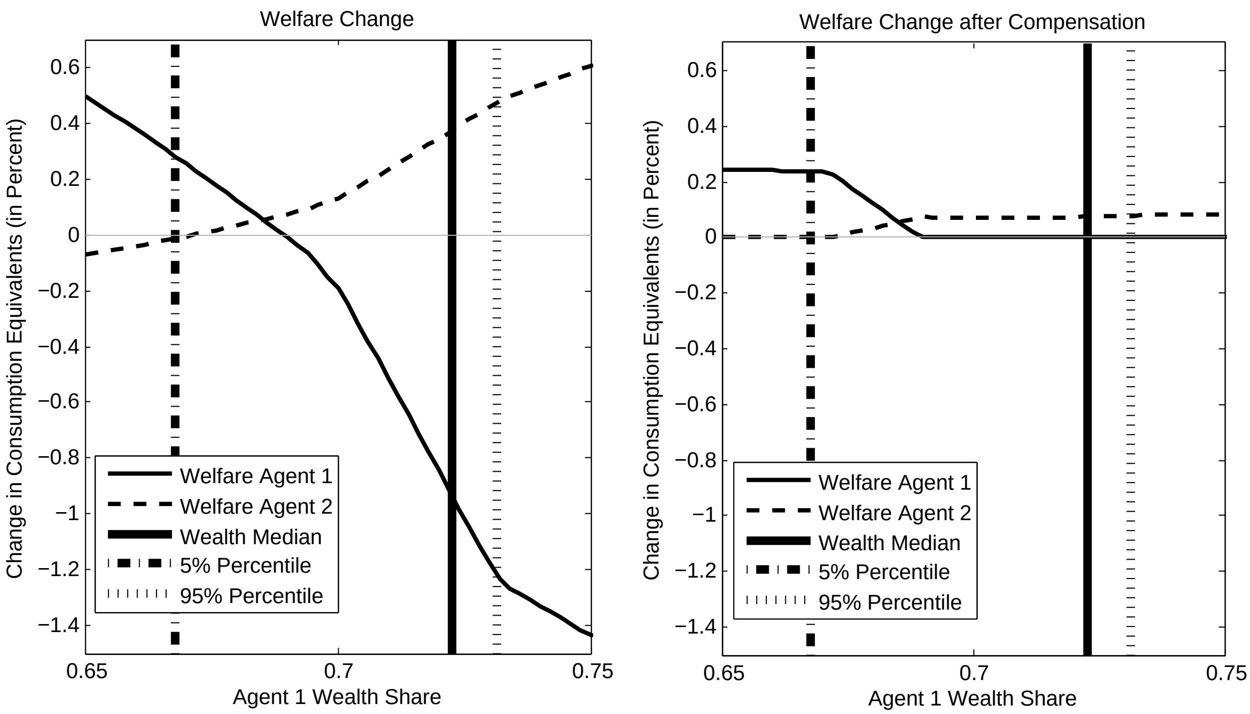
The graph shows the return volatility (in percent) of the two long-lived assets as a function of the margin on both assets. Due to their collinear dividends and their identical margins, the two assets have the same volatility in this policy experiment. The margin requirement is 0.5 in states 1–4 and equal to the value on the horizontal axis for the positive-growth states 5 and 6.

Figure VI: Results for the alternative calibration, *Calibration B*



The upper graph displays the return volatilities (in percent) of the two long-lived assets as a function of the constant margin requirement on the regulated asset. The second graph displays the return volatilities for countercyclical margins on the regulated asset. The last graph displays the return volatilities for identical countercyclical margin requirements on both assets. The solid lines show the return volatilities for asset 1 (regulated in the first two graphs); the dashed lines show the return volatilities for asset 2 (the unregulated asset in the first two graphs). For the case of countercyclical regulation, the margin requirement is 0.5 in states 1–4 and equal to the value on the horizontal axis for the positive-growth states 5 and 6.

Figure VII: Welfare Implications of a Change in Regulation



The left hand graph displays the changes in welfare for both agents after a change from constant to countercyclical stock market regulation. The change in welfare is plotted in as relative changes (in percent) in terms of consumption equivalents. The right hand graph displays the welfare changes for the same experiment after the compensation of worse-off agents. Note that for a small part of the wealth space both agents are better off and no compensation is necessary. The vertical solid line indicates the median of the wealth distribution, conditional on the economy residing in state 5. The dashed vertical lines indicate the 5 percent and the 95 percent percentiles of this conditional wealth distribution, respectively.