Intangible Capital, Stock Markets and Investments: Implications for Macroeconomic Stability

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I link investments in total working capital to a forward-looking endogenous stock market mechanism in an otherwise standard New Keynesian financial frictions model with rational agents. The effects on macroeconomic stability are substantial. Impulse responses to shocks are on average three times more volatile than in a standard financial accelerator framework. Likewise, the fit of the extended model to post-2000 US data is considerably improved. Optimal monetary policy that includes explicit and timely reaction to stock market developments is strictly preferred in this economy.

Keywords: asset price cycles, financial frictions, rational expectations, asset price targeting

MOTIVATION

In the Financial Stability Report of November 2012, Bank of England observed that the price to book ratio of (bank) equity had dropped to its historical lowest at 0.5.[1] The ratio, which represents the wedge between the market value and the book value of capital, is frequently used to indicate the growth prospects and investment opportunities of a particular bank or firm. The report concluded that the sharp fall in the ratio over the period 2010-12 had mainly been generated by pessimistic investors, who seriously questioned banks ability to generate earnings sufficient to exceed the required return of investors.

But pessimistic market sentiment was not only isolated to the banking sector. Corporate markets on both sides of the Atlantic had equally been affected. Following a persistent appreciation in the US stock market of 87 per cent between 2002:II and 2007:II, in just two years (2007:II - 2009:III) the value of S&P500 had fallen by 40 per cent.[2] One of the key reasons behind the boom had been the prospect of higher productivity growth of US firms (Jermann and Quadrini, 2007), allowing firm earnings to persistently increase between 2002 and 2007. This consolidation in firm finances resulted in two things. First, it brought the loan default probability down to negligible levels, leading to an easing in firm external financing constraints (Jermann and Quadrini, 2007). Second, the investors' required earnings sharply declined since the growth in earnings and the relaxed financing constraints assured investors that firms would have enough finances to continue growing.[3] Moreover, the boom-bust cycle in corporate equity during the first decade of 2000's had been more accentuated and volatile than many previous ones, including the dot-com era.[4] One reason behind this is that the asset-side composition of the corporate sector had undergone a pro- found shift towards intangible capital (such as IT, know-how, patents, or human-and organizational capital), which holds a higher price volatility (Caggesse and Perez-Orive, 2016). Likewise, the dependence on physical capital for firms has, on aggregate, steadily decreased (Corrado and Hulten, 2010). In Japan, for instance, Tsutomu et al (2013) show that the ratio of intangible capital to total tangible assets reached just below 1 in early 2000 and has remained above 0.85 ever since. In the US, UK, Sweden, and Finland, as early as 2006, the aggregate investment share in intangible assets (as percentage of GDP) outpaced investment in tangibles. Moreover, in the first three countries, the share in intangible investment is twice that of tangibles (Andrew and De Serres, 2012). The dynamic effects is that firms with higher share of intangible assets (0.8 or above) start smaller, grow faster and have higher market value per unit of asset (Chen, 2014).

At the same time, intangible assets have increasingly been used as collateral in credit markets. During the period 1996-2005, 21 % of U.S.-originated secured syndicated loans had been collateralized using intangible capital. For firms using both tangible and intangible capital as collateral, the use of latter increased the loan size by, on average, 18% and loan pricing by 74 basis points (Loumioti, 2012). It has also been found that intangible assets support debt qualitatively and quantitatively similar to tangibles. This debt-support of intangibles grows as the intensity of tangible assets in a firm fall, such as in technology-intensive firms (Lim et al, 2015).

While there is strong empirical support for this shift in firm dynamics and value, its impact on business cycles and economic stability has received much less attention in the literature. In particular, it would be interesting to study its impact in a financial accelerator framework which effectively links the financial condition of firms to their capital purchases and asset-side com- position. In what follows, I proceed to amend the original framework of Bernanke, Gertler and Gilchrist (1999) (henceafter BGG) by introducing two prices of capital: *market* and *book* values. While books capture the value of tangible assets, market value contains information on both the tangible and intangible assets. Firm's optimal decisions, including their degree of access to (external) credit, are contingent on the (stock) market value of capital. A wedge between the two capital prices emerges and varies positively with projections about the future firm-and macroeconomic activity. In the second part of the paper, I proceed to investigate the role that monetary policy plays in taming the asset price cycle and to maintain economic stability. More importantly, I wish to corroborate the heavily debated claim that the post-2007 recession could have been avoided if alternative monetary policy rules had been adopted. To do so, I conduct a series of counterfactual experiments based on a loss function derived from consumers' welfare in the model.

Our analysis uncovers three facts. First, in an economy where firm value-and investment opportunities are determined by its (stock) market value, the macro-financial cycles are amplified, and there are more risks to economic stability stemming from this shift in firm dynamics. The impulse responses to exogenous disturbances are on average two to three times more volatile than in the canonical BGG model. Possibly more interesting is that the model is capable of generating an endogenous asset price wedge without the necessity to directly employ a shock to the wedge. Second, our extension improves the fit of the financial accelerator model to the post-2000 US financial data. Apart from data on capital and firm balance sheet, the model is capable to replicate other financial indicators such as the policy rate and the rate of return on capital. Further, our model is capable of reproducing the stylized fact that output, on average, takes longer time to recover after a stock market boom than after any other type of expansion. Third, I find that the role of monetary policy in an asset price boom is crucial. Counterfactual experiments show that consumers are, on average 10 percent better off in terms of foregone consumption with a monetary policy that explicitly targets stock market prices compared to a standard policy that only targets inflation and output. Finally, I wish to draw attention to the fact that the model is capable of generating these intensified macro-financial cycles without the necessity to recur to imperfect beliefs or other types of frictions or non-linearities.

EMPIRICAL EVIDENCE

The growing importance of intangible capital for firms since 1990's has profoundly changed the ways firms invest, are valued on the market, and externally finance themselves. A handful of studies have attempted to quantify the size and scope of this transformation. For instance, on in- vestment and firm capital structure, Nakamura (2001, 2003) found that already by the millennium shift, the annual investment rate in intangible had become practically equal to that of tangibles, at around 1 trillion US dollars each in 2001. The same study showed moreover that around the same time, a third of the value of U.S. corporate assets were intangibles. This share has continued to grow as the new millennium progressed.[5]

At the same time, a collection of studies has found that stock markets are most effective in pricing intangible capital when valuing firms. Along these lines, Chen (2014) find that the market value per unit of physical assets in the U.S. is significantly higher among firms with large shares of intangible assets. Intangible capital is therefore a crucial factor for explaining heterogeneity in the market value of old firms. However, the same study notes that modifications to the standard Q theory of investment are necessary to accommodate for a fair valuation of intangibles if one aims to explain these empirical regularities.

Intangibles have also been largely used as collateral to support credit and debt. Loumioti (2012) and Lim et al (2015) both showed that intangible assets support debt in similar ways to tangibles. There are both demand and supply-side reasons for this phenomenon. On the demand end, many younger firms have a higher share of intangible capital that they wish to capitalise in order to extract credit. At the same time, Loumioti (2012) showed that using intangibles as collateral does not significantly deteriorate lenders' credit profile. On the supply-side, banks use intangibles to reduce their estimates of expected losses upon borrowers' default and to contribute towards their capital requirements. Recognising the role of intangibles as collateral is important since it helps explain why U.S. corporate debt increased so much during 2000's. Traditional macroeconomic studies fail to analyse the general equilibrium effects from these new developments in the corporate (finance) sector since they assume that *only* tangible capital can be used as collateral, and that new investments are only in physical capital. However, these assumptions are not valid anymore, and are the reasons behind the divergence in (general equilibrium) results from their and our model.

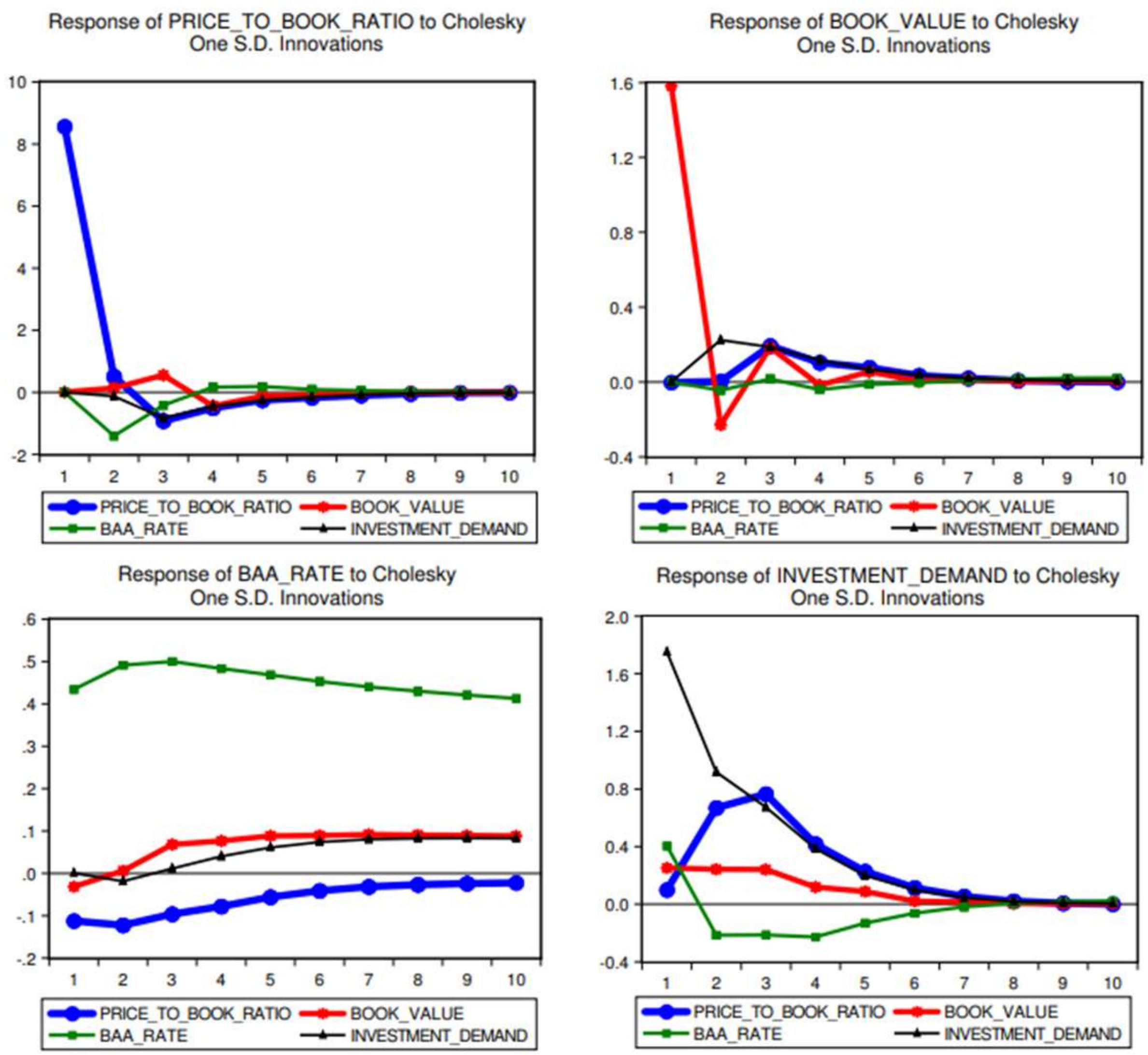
While valid and relevant for the purpose of this paper, most of the studies above have a corporate finance or *microeconomic* focus. To corroborate our claim of a deep link between an asset price wedge (which captures the value of intangibles), firms' ability to borrow on external credit market, and investment on the *macroeconomic* level, I will cast this relationship in a structural VAR(2) model using aggregate data. The particular hypothesis I wish to test is that the wedge between the two capital prices (*market* and *book* value) contains (on its own) information about prospective firm borrowing capacity and investment returns, and therefore determines today's investment demand. In this respect, I expect to find a statistically significant and positive coefficient of the wedge in the investment equation. I also expect the wedge and the corporate lending rate to have a negative bidirectional relationship, or the coefficient of wedge in corporate lending equation to be negative and the coefficient of corporate lending rate to be negative in the wedge equation. This is because probability of default on loans increases as the value of intangibles (and thus the wedge) decreases at the same time as the growth possibilities in the wedge are reduced as the bor- rowing costs rise, and firms become more credit constrained (by limiting investments in intangible capital). Our VAR model can be represented by this general form:

$$y_t = c + A_1 y_{t-1} + A_2 y_{t-2} + e_t \quad (1)$$

where y_t is a $4x1$ vector containing the four variables, and A_1 and A_2 are $4x4$ matrices of two lags for the four variables. c is a 4x1 vector of constants, and e_t is a $4x1$ vector of error terms (one for each equation).[6] The variables enter the model in the following order: the wedge, book value, corporate bond rate, and investment demand. The VAR model is expressed in first difference (except the interest rate), since the unit root tests confirmed the variables to be I(1).[7] In order to separate movements in the wedge caused by movements in the book value, I include book value in our VAR models and position it after the wedge.

Further, I define market value as the *(stock) market value of shareholder equity of non-farm and non-financial corporate businesses*. For book value and investment demand, I have used data *on replacement cost of capital and private non-residential real fixed investment* of non-farm and non-financial corporate business, respectively. These are the closest empirical counterparts to the theoretical definitions given in BGG. The wedge between the two capital prices is therefore the differences between stockholders' equity and the replacement cost of capital. I use Moody's 30- year BAA rate as a measure for the costs in corporate borrowing. This measure is broad enough to include riskier corporate long-term borrowing. The data set has quarterly frequency, covering the period 1953:I to 2012:II and accessible from the Federal System Economic Database (FRED).[8]

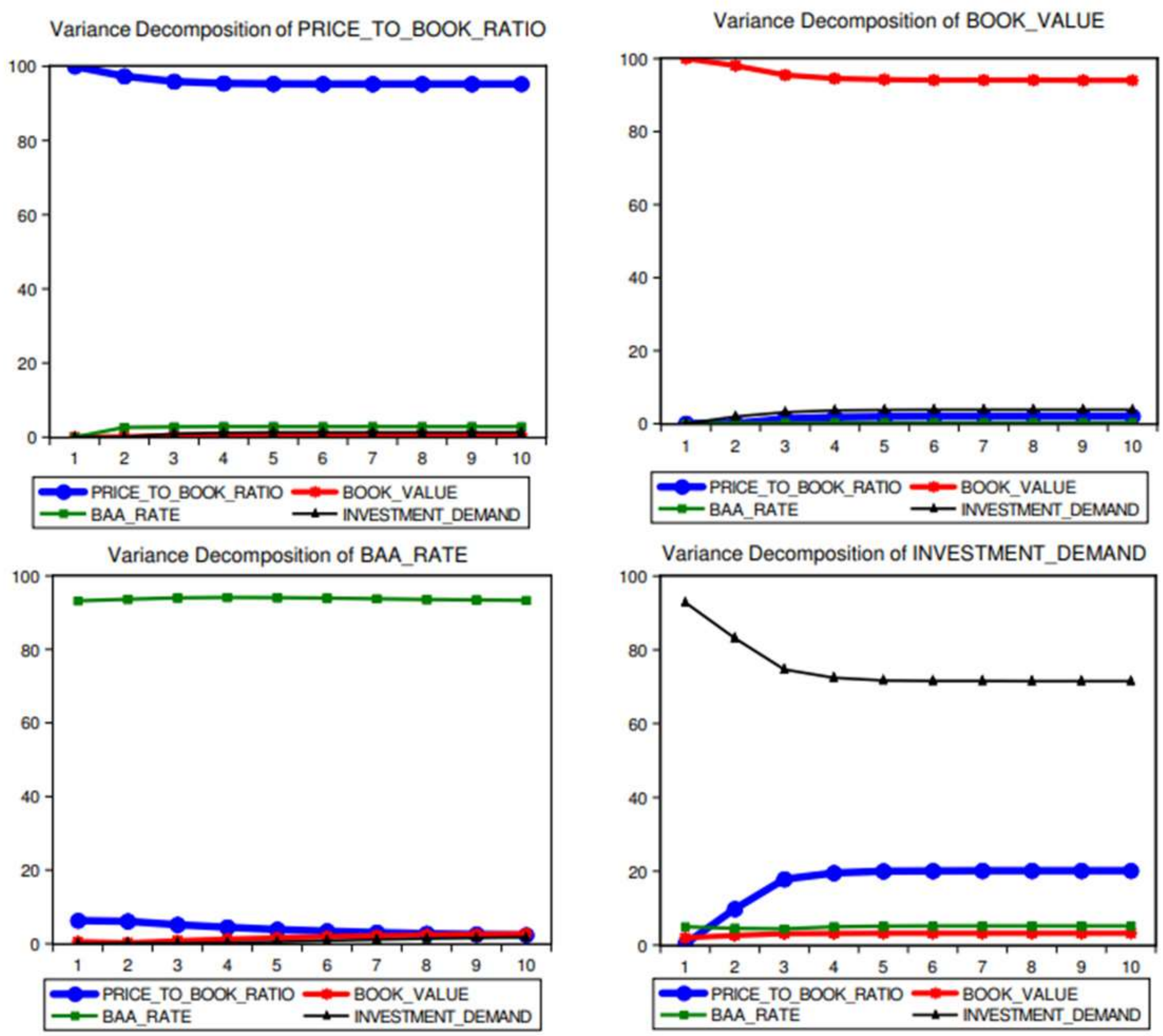
FIGURE 1
VAR(2)-FD-IMPULSE RESPONSES



Notes: The impulse responses to the four shocks (market-to-book, book value, corporate bond rate, and investment demand) using Cholesky decomposition are reported. Investment demand is excluding residential investment and the BAA-rate is the corporate bond rate used. The VAR was estimated on the first difference of the original series, except for the interest rate.

I calculate the impulse responses to innovations in each of the four variables using Cholesky decomposition and the innovations are normalized. The relevant responses are reported in Figure 1 and the variance decompositions in Figure 2.[9] Let us start with investment demand. One percent increase in the wedge leads to a 0.8 percent rise in investment and a 0.11 percent fall in the cost of borrowing. Only the investment shock causes a greater response of investment of 1.70 percent. The wedge explains also around 20 percent of the variation in investment demand and 10 percent of variation in the cost of external finances. In contrast, a 1 percent rise in the book value decreases the cost of external finances by 0.03 percent and increases investment demand by 0.3 percent. In other words, the effect of book value on investment demand is around 3 times smaller. Equally, the shock in book value does not explain variations in any of the variables.

FIGURE 2
VAR(2)-FD-VARIANCE DECOMPOSITION

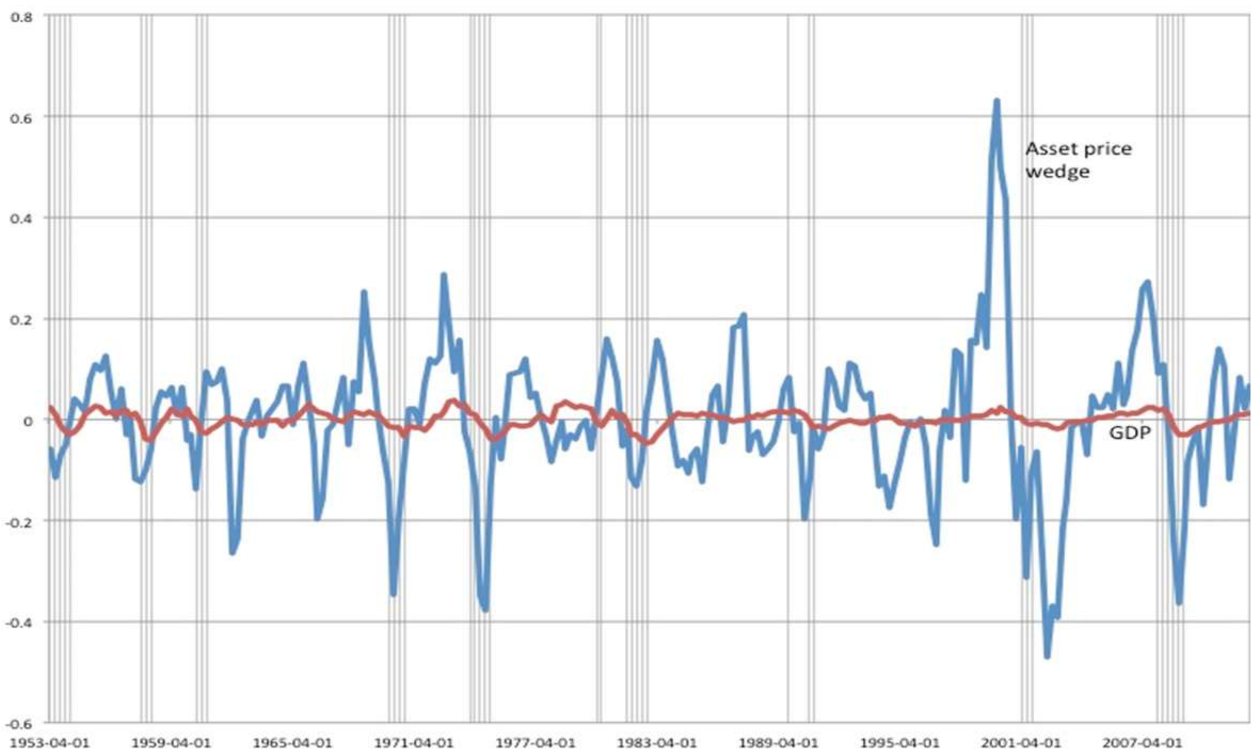


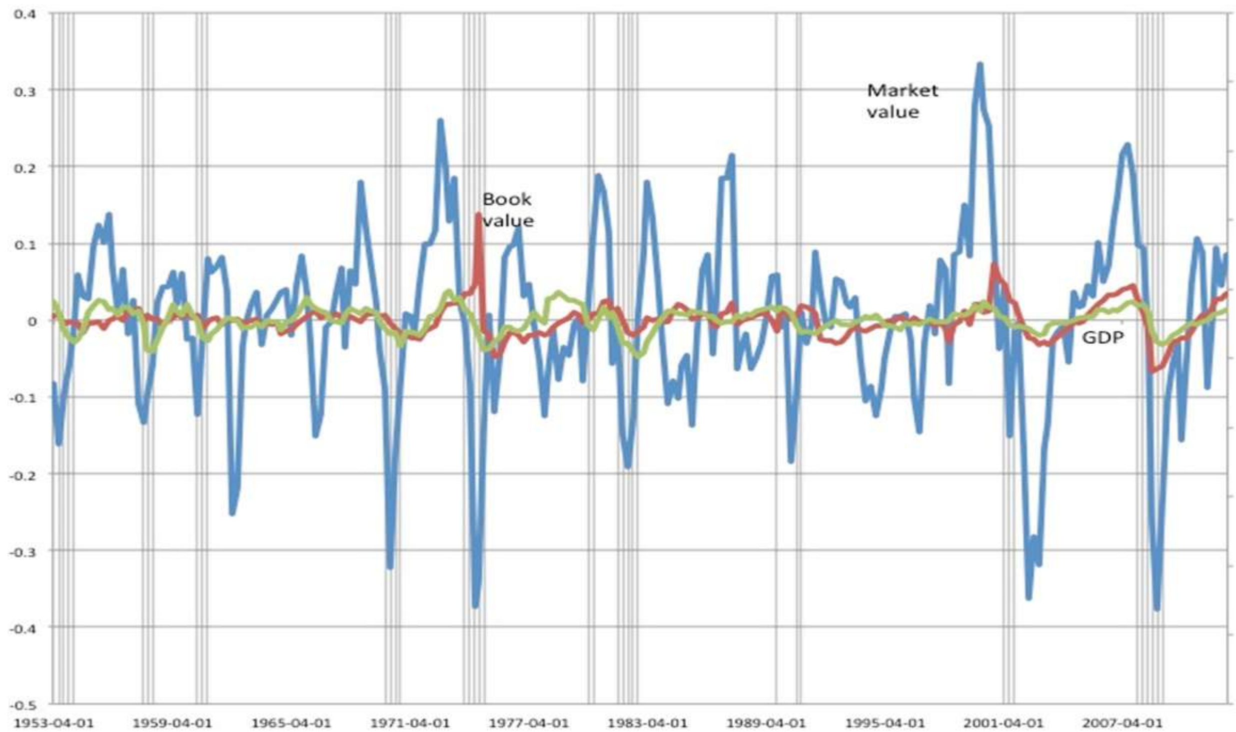
Notes: The variance decomposition of the four variables (market-to-book, book value, corporate bond rate, and investment demand) are reported. Investment demand is excluding residential investment and the BAA-rate is the corporate bond rate used. The VAR was estimated on the first difference of the original series, except for the interest rate.

Also, along our hypothesis, I find that an increase in firm borrowing costs has a significantly negative impact on wedge and investment. A 1 percent rise in the cost results in a 1.70 percent fall in the wedge and a 0.20 percent fall in investment demand. In contrast, the effect on book value is negligible. Conversely, a 1 percent rise in the wedge reduces the borrowing costs by 0.12 percent. In contrast, book value has a negligible (or even slightly positive) effect on borrowing costs. Hence, I find a strong and independent role for intangible capital and the wedge in driving the borrowing costs for firms and for investment demand. Our model should therefore replicate this tight structural relation. To do so, I first need to establish a set of stylized facts for these variables that I want our model of the asset price wedge to be consistent with. For that purpose, I report the relevant correlations and relative standard deviations of the cyclical components of the data in Table 1.[10] The graphs are reported in Figure 3. Again I use the same sample period of 1953: I to 2012:II.

All capital prices are procyclical. However, the rate at which synchronicity of prices with the overall business cycle has largely varied over time, with the wedge transforming the most. Wedge has become 113 percent more procyclical since 1990's compared to the entire post-war period. Market value is very similar at 118 percent. On the other hand, the synchronicity of book value with the business cycle has only increased by 82.5 percent during the same period. By the turn of the century, the procyclicality of book value and the wedge had almost become equal. Likewise, I see a similar increase in volatility since 1990's. Compared to the entire sample, the volatility of wedge (in relation to the business cycle) was 79 percent higher in the 1991:I-2012:II subsample. For book value, this increase was lower at 63 percent. In other words, while the wedge was 15 times more volatile than output, book value was only 2 times more volatile.

FIGURE 3
EVOLUTION OF CAPITAL PRICES OVER THE CYCLE





Notes: The first figure is the HP-filtered asset price wedge (blue) and the GDP (red) in the US from 1953:1-2012:III. The second figure contains the HP-filtered series of the capital market value (blue), capital book value (red), and the GDP (green) in the US from 1953:I-2012:III. The grey vertical lines represent the NBER recession dates.

Taken together, the higher volatility of the wedge will affect firm dynamics and I should expect to see higher volatility in firm variables and the aggregate economy over time. At the same time, measures of firm value have become highly contingent on the overall swings in the business cycle. However, there is not sufficient evidence to suggest that this is due to irrational pricing (or non- rational swings in market sentiment) since the procyclical nature of the wedge is very similar to the one observed for the book value, a fundamental measure of a firm value. I need to construct a financial frictions model that accommodates these facts: an endogenous and highly procyclical asset price wedge coupled with a market value that is significantly more volatile than the book value. This wedge should *per se* influence borrowing cost of firms and the level of firm investment demand. Once these stylized facts have been captured, I can proceed to investigate the effects on firm optimization, credit supply, production and investment, debt and equity stocks of firms, and more generally, the impact on the overall stability of the economy.

TABLE 1
CORRELATIONS AND VARIANCES

Correlation (Relative Standard Deviation)	Output 1953:I-2012:II	Output 1991:II-2012:II	Output 2001:IV-2012:II
Wedge	0.30	0.64	0.76
	(8.77)	(15.72)	(12.42)
Market value	0.34	0.74	0.83
	(7.22)	(11.1)	(10.33)
Book value	0.40	0.73	0.90
	(1.31)	(2.14)	(2.02)

BEYOND THE Q THEORY OF INVESTMENT

In order to capture these divergent dynamics between the two capital prices, I need to go beyond the standard Q theory of investment used in most financial friction models, and individually model the underlying dynamics of the two prices separately.[11] In what follows, the book value of capital will capture the value of tangible assets of the firm. Market value will, in addition, include the value of intangible assets. The market value is derived from a forward-looking mechanism where investors on the stock market determine the expected cash-flow or value that the firm will generate, using firm-specific and future macroeconomic information. In addition, firms can use their total value, instead of only the value of tangibles, to collateralise their credit. The additional funds from collateralised credit coupled with the forward-looking market valuation of firm performance will allow to increase the firm's investment possibilities, since I assume that all retained earnings are re-invested in the firm. Compared to standard financial friction models, this will allow firms to expand their investment projects considerably. Therefore, I make investment demand contingent on the stock market value of the firm *only*.[12] There is plenty of empirical studies supporting this causality between stock market prices and investment demand, such as Chaney, Sraer and Thesmar (2010), Dupor (2005), and Bond and Cummins (2001).

In regard to the forward-looking pricing mechanism I introduce here, empirical studies have found that stock market prices fluctuate largely endogenously depending on the existing and expected states of the economy (Chen (2012), Schwert (2012) and Nasseh and Strauss (2000). Stock market investors use every information at micro and macro levels to find a *fair* value of the stock price now, and in the future. If there were no trading activity based on expectations, the market value of the shareholders equity would be equal to the value of the capital as stated on the balance sheet of the firm.

For clarification purposes, note however that market pricing in our framework is completely derived under rational expectations. Hence there is not an irrational pricing dynamics from imperfect beliefs or temporary bubbles as for instance in Bernanke and Gertler (2001), Castelnuovo and Nistico (2010), or Carlstrom and Fuerst (2007. Nor is it a rational bubble in the way modelled in Carvalho et al (2012) or Martin and Ventura (2011). Instead the market forms expectations regarding firms' future growth possibilities and integrates them into the market price in a fully rational manner. Moreover, the price is based on micro-foundations.[13]

The contemporaneous macroeconomic research on this specific topic is expanding but it is far from reaching a consensus on the way to establish a valuation method for a firm's market value. This provides us with some flexibility in the design of it. Here I mostly benefited from the corporate finance literature, in which there is a bulk of studies exploring this subject.

In that literature, the *earnings capitalization model* of Ohlson (1995) is highly regarded and suitable since it provides a direct relation between the market value of capital, and its accounting (book) measure. The difference between the two is basically down to contemporaneous and future expected earnings.[14] The model is therefore a convex combination of a pure 'flow' (or profit capitalization) and a pure 'stock' (or balance sheet based) model of value. The earning capitalization model is attractive for many reasons of which the most important are: first, technically the approach is theoretically constructed from first principles and therefore it is straightforward to integrate in a DSGE model. Second, many studies have empirically validated and confirmed the fit to stock market data.[15] Third, the model is theoretically well recognized within the neo- classical theory and the corporate finance literature. In addition, the model does not require the Modigliani-Miller irrelevance property to hold in order for the valuation to be consistent (even if it satisfies them), which facilitates the pricing theory to be easily integrated within the financial friction structure of the DSGE models (Larran and Lopez, 2005).

THE GENERAL EQUILIBRIUM STRUCTURE

I will proceed by incorporating the earnings capitalization model for the asset price wedge in a financial accelerator model of BGG. The overall environment is a standard New-Keynesian with nominal stickiness and financial frictions on firm borrowing.

For the sake of focus, in this section I will only describe the novelty of this paper and discuss how I modify the BGG model to accommodate for it. For the full derivation of the DSGE model, I refer to Gerba (2018) and Table 3 (for variable notation).

The Endogenous Asset Price Wedge

I follow the Ohlson (1995, 2001) model in deriving an analytical expression relating the market-to book value. I start off with the neoclassical view that a firm maximises its market value, which is the present value of expected sum of dividends discounted by the risk-free rate (non-arbitrage condition):

$$\max_{S_t} \sum_{\tau=1}^{\infty} R^{-\tau} E_t[D_{t+\tau}] \tag{2}$$

where S_t represents the (stock) market value of capital, R is the risk-free interest rate and $E_t\ [D_{t+\tau}]$ is dividends that the firm is expected to generate in the future. To keep matters simple risk neutrality applies so that the discount factor equals the risk-free rate. Next, I need to relate dividend payments to the book value and firm earnings.

Let X_t be the earning on equity from period $t-1$ to t. The basic clean surplus condition of financial statements defines the fundamental relation between book value of capital Q_t, dividend payments D_t, and earnings as:

$$X_t = Q_t - Q_{t-1} + D_t \tag{3}$$

Equation 3 states that the *earnings* at the end of the period t is the sum of two components: the change in book value, and dividend payment. It means that all changes in assets/liabilities un- related to dividends must be recorded by earnings in the income statement.[16] In addition, I impose the restriction that dividends affect negatively the book value of capital, but not current earnings, i.e.:

$$\frac{\partial Q_t}{\partial D_t} = -1 : \frac{\partial X_t}{\partial D_t} = 0 \tag{4}$$

Together with 3, this represents the clean surplus relation found in many financial models.[17]

I can now use the clean surplus relation to express the market value in terms of future expected earnings in 2. However, to complete that, I first need to define an additional financial variable. In particular, I follow Ohlson (1995) and define abnormal, or *residual earnings* as:

$$X_t^{re} \equiv X_t - [R-1]Q_{t-1} \tag{5}$$

where residual earnings X_t^{re} are described as firm earnings exceeding (net) book value at time $t-1$ (times the interest rate), or the (replacement) cost of using the capital. Hence, during profitable periods, earnings are above the cost of using the capital, or 'positive residual earnings'.[18]

I am now in a position to express the market value in terms of the book value and residual earnings, by combining equations 3 and 5:

$$X_t^{re} = Q_t - Q_{t-1} + D_t - RQ_{t-1} + Q_{t-1} \Rightarrow D_t = X_t^{re} - Q_t + RQ_{t-1} \tag{6}$$

and using this last expression to replace D_{t+1}, D_{t+2}, D_{t+3}...in 2 to yield the market value as a function of the book value and the present value of future (expected) residual earnings:

$$S_t = Q_t \sum_{\tau=1}^{\infty} R^{-\tau} E_t[X_{t+\tau}^{re}] = Q_t E_t[X_{t+\tau}^{re}/R^{\tau}] \tag{7}$$

provided that $\frac{E_t[X_{t+\tau}^{re}]}{R^{\tau}} \rightarrow 1$ as $\tau \rightarrow 0$.[19] Hence, the market value in 2 can equivalently be expressed as 7, and our objective at the beginning of this section is accomplished. Relation 7 implies that fluctuations in market value are the result of two factors: the variations in the book value and the present value of future residual earnings. In other words, future profitability of capital, as measured by the present value of a sequence of future *anticipated* residual earnings reconcile the difference between the market and the book value of capital. The next step is to define the properties of residual earnings.

Residual Earnings

Next, I need to characterize the process governing residual earnings. Our main purpose is to establish a bridge between the residual earnings and the general state of the economy. Ohlson (1995, 2003) and Feltham and Ohlson (1999) assume that X^{re} follows an AR (1) process and follow- ing the insights from the empirical literature on economic drivers of the market value described earlier, I extend it to additionally depend on economic fundamentals in the next period, $F_{t+1}|I_{t+1}$ according to:

$$X_{t+1}^{re} = \rho_x(X_t^{re}) + F_{t+1}|I_{t+1} \tag{8}$$

where ρ is restricted to be positive.[20]

Investment

Our second modification of the BGG model relates to firm investment demand that is now made a function of the (expected) market value of capital.[21] Entrepreneurs' appetite for new investment is determined by the price of capital they expect on the market in the next period (inclusive of the wedge), and the increasing marginal adjustment costs in the production of capital, $\Theta(.)$ according to[22]:

$$E_t[S_{t+1}] = \left[\Theta'\left(\frac{I_t}{K_t}\right)\right]^{-1} \tag{9}$$

where $E_t\,[S_{t+1}]$ is the expected market price of a unit of capital, I is investment and δ is the parameter that governs the depreciation rate. $\Theta(.)$can be thought of as a capital production function generating new capital goods and is increasing and concave in investment. New investment (represented as percentage of the existing capital stock) will have a positive impact on the market price via the demand channel. Note that I have included a forward-looking mechanism in the determination of the investment demand in the current period by making it contingent on the expected future market value of capital instead of the current value of 'q' as in the canonical model. By doing so, I wish to incorporate the above remark that investors invest in capital only if they believe that the future (and not current) value of it will be higher than today's, and so generate higher income stream. Later on in the paper, I will quantify the general equilibrium effects from making this modification.

Book Value of Capital

Following the outline in the BGG model, think of there being competitive capital producing firms that purchase raw output as inputs I_t and combine it with rental capital K_t to produce new capital goods via the production function $\Phi\left(\frac{I_t}{K_t}\right)K_t$ where $\Phi(.)$ is the exogenous adjustment cost function. These capital goods are then sold at price Q_t. Assuming that there are constant returns to scale in the capital-producing technology, the capital-producing firms earn zero profits in equilibrium. Entrepreneurs sell their capital at the end of period $t + 1$ to the investment sector at price $\overline{Q_{t+1}}$. Thus, capital is then used to produce new investment goods and resold at price Q_t. The difference between the two prices, the rental rate reflects the influence of capital accumulation on adjustment costs. The rental rate is determined by:

$$Q_t\Phi\left(\frac{I_t}{K_t}\right) - \frac{I_t}{K_t} - (\overline{Q}_t - Q_t) = 0 \tag{10}$$

Since $\Phi\left(\frac{I_t}{K_t}\right) = \delta$ and $\Phi'\left(\frac{I_t}{K_t}\right) = 1$ in the steady state, it implies that $\bar{Q} = Q = 1$. As a result, around the steady state, the difference between the two is marginal, and therefore I express the above equation as:

$$Q_{t+1} = \Phi\left(\frac{I_t}{K_t}\right)Q_t - \frac{I_t}{K_t} \tag{11}$$

This definition is more suitable for tangible assets, which our book value captures. In the benchmark version, the adjustment function is calibrated in such a way that the price of capital is unity in the steady state.

The Rate of Return on Capital

The return on capital occupies an important place in the determination of default risk and risk premia in the BGG model. The wedge between expected and ex-post returns on capital drives this premium and consequently the cost of external borrowing.

To derive capital return, I need to first depict the production side of the economy. Entrepreneurs produce according to the Cobb-Douglas technology:

$$Y_{t+1} = K_{t+1}^{\alpha}L_{t+1}^{1-\alpha} \tag{12}$$

The physical marginal product of capital is:

$$MPK = \frac{\alpha Y_{t+1}}{K_{t+1}} \tag{13}$$

The value of MPK at wholesale prices is thus $P_{t+1}^{w}\frac{\alpha Y_{t+1}}{K_{t+1}}$ The equilibrium implies that the value of the MPK should be equal to the nominal return on capital evaluated at retail prices:

$$P_{t+1}^{w}\frac{\alpha Y_{t+1}}{K_{t+1}} = P_{t+1}\left(1 + R_{t+1}^{sk}\right) \tag{14}$$

Defining $X_{t+1} = \frac{P_{t+1}}{P_{t+1}^{w}}$ as the average mark-up of the retail price over wholesale price, I can re-write the above expression as:

$$\left(1 + R_{t+1}^{ks}\right) = \frac{\alpha Y_{t+1}}{K_{t+1}}\frac{P_{t+1}^{w}}{P_{t+1}} = \frac{\alpha Y_{t+1}}{K_{t+1}}\frac{1}{X_{t+1}} \tag{15}$$

Approximating the relation around the steady state, I get the expected **capital demand curve** (expressed in non log-linearized terms as):

$$E_t\left[R_{t+1}^{ks}\right] = E_t\left[\frac{\left(\frac{1}{X_{t+1}}\right)\left(\frac{\alpha Y_{t+1}}{K_{t+1}}\right) + (1-\delta)S_{t+1}}{S_t}\right] \tag{16}$$

with Y_{t+1} as expected output, expected mark-up of retail goods over wholesale goods as X_{t+1}, expected capital stock as K_{t+1}, the share of capital in production by α, depreciation rate of capital as δ, the expected market return of capital as R_{t+1}^{ks}, S_t is the market value of capital at time t, and E_t is the expectations operator at t. This definition states that the expected return of a unit of capital is the sum of the mark-up over the cost of capital and net capital gains due to the change in market asset price. In contrast, in the canonical BGG model, the expected demand and return of capital depends on q_t:

$$E_t\left[R_{t+1}^k\right] = E_t\left[\frac{\left(\frac{1}{X_{t+1}}\right)\left(\frac{\alpha Y_{t+1}}{K_{t+1}}\right)+Q_{t+1}(1-\delta)}{Q_t}\right] \tag{17}$$

where R_{t+1}^k is the expected return on capital, and Q_t is the standard capital price. In our modification, the return is inclusive of intangible capital, and so the function includes the (endogenous) asset price wedge.

As capital is accumulated, it also affects the stock of net worth. Since the return in our model is defined on *total* capital, the evolution of net worth also needs to be adjusted to account for this.

Net Worth

The aggregate net worth of firms at the beginning of period $t + 1$, N_{t+1}, is given by:

$$N_{t+1} = \gamma V_t + W_t^e \tag{18}$$

where V is equity and W^e is the wage of entrepreneurs.[23] Entrepreneurial equity consists of:

$$V_t = R_t^{ks} S_{t-1} K_t - \left(R_t + \frac{\mu \int_0^{\omega_t} R^k s_t S_{t-1} K_t dF(\omega)}{S_{t-1}K_t - N_{t-1}}\right)(S_{t-1}K_t - N_{t-1}) \tag{19}$$

where $\mu \int_0^{\omega_t} R^k s_t S_{t-1} K_t dF(\omega)$ is the default cost and $S_{t-1}K_t - N_{t-1}$ represents the quantity borrowed. The external finance premium for credit given to firms is given by:

$$R_t + \frac{\mu \int_0^{\omega_t} R^k s_t S_{t-1} K_t dF(\omega)}{S_{t-1}K_t - N_{t-1}}$$

Turning to Equation 19, the second term on the right-hand-side represents the repayment of credit. On the other hand, the first term on the right-hand side, $R_t^{ks} S_{t-1} K_t$, gives the gross return on holding a unit of capital from time t to $t + 1$. Consequently, this statement implies that the entrepreneurial net worth equals gross return on holding a unit of capital minus the repayment of credit.

Since return on capital depends on the market value, I have created an explicit link between the market value and net worth. Thus, a rise in the (stock) market value of capital above its book value will lead to an increase in firm's net worth via two channels. The first is due to the fact that higher gross return on capital will inevitably lead to higher net worth accumulation. The second is because a higher R^{ks} reduces the probability of default, reducing thus the amount to be repaid on the loan to the financial intermediary.[24]

Financial Accelerator

I start with the constraint on the purchases of capital:

$$S_t K_{t+1} = N_{t+1} \tag{20}$$

That is, a firm is not allowed to borrow above its net worth. But for any firm, if the expected return is above the riskless rate there will be an incentive to borrow and invest:

$$s_t \equiv E_t\left[\frac{R^{ks}_{t+1}}{R_{t+1}}\right] \tag{21}$$

where s_t is the expected discounted return on capital. For entrepreneurs to purchase new capital in the competitive equilibrium it must be the case that $s_t \geq 1$. The investment incentive and the strength of financial accelerator are both underpinned by this ratio. This incentive can be incorporated into the borrowing constraint:

$$S_t K_{t+1} = \psi(s_t) N_{t+1} \tag{22}$$

This definition states that capital expenditure of a firm is proportional to the net worth of entrepreneur with a proportionality factor that is increasing in the expected return on capital, s_t. Putting it in another way, the wedge between R^{ks} and R and the firm's net worth underpin the investment demand to build new capital good. Equation 22 can be equivalently expressed in the following form:

$$E_t\left[R^{ks}_{t+1}\right] = s\left(\frac{N_{t+1}}{S_t K_{t+1}}\right) R_{t+1}, \qquad s < 0 \tag{23}$$

To recall, the firm borrows the amount $S_t K_{t+1} - N_{t+1}$; therefore $(N_{t+1}/S_t\ K_{t+1})$ gives the financial condition of the firm. And [23] relates the financial condition of the firm to the expected return on capital which is increasing in net worth but decreasing in borrowing. This is the financial accelerator.

Note that because I am defining the expected return in terms of the entire working capital and investment demand is determined by the market value of capital, firm will borrow to finance the entire working capital. This is in contrast to some other papers where the borrowing constraint applies only to financing of investments in fixed capital, such as Angeloni and Faia (2015) or Benes and Kumhof (2015). Simply this channel in isolation may generate a heavier impact of financial frictions on investment and output fluctuations (Quadrini, 2011).

Forcing Variables

The model has two types of disturbances: productivity and asset price wedge. The following law of motion describes the productivity shock:

$$a_t = \rho_a a_{t-1} + \varepsilon^a_t \tag{24}$$

Let ε^a_t be mean zero white noise shock. I calibrate ρ_a to 0.99 and ε^a_t to 0.10. The productivity shock is small, but highly persistent in order to represent a small but important improvement in production. Most modern innovations fulfil this characteristic.

Moreover, to examine a full boom-bust cycle in asset prices, I introduce an additional shock. More specifically, I introduce an exogenous disturbance to the residual earnings equation 8. The shock can be viewed as unexpected news (good or bad) regarding future economic performance that arrives, and influences stock market investments in that period. I label it *wedge shock*. The standard error of the wedge shocks is calibrated to 1 percent.[25]

Model Solution

Both the original financial accelerator model (BGG) and the extended version in this paper are log-linearized around a steady state. The steady state is stationary and unique. The models are therefore linear. They are solved using Dynare and all shocks are temporary. While many of the new DSGE models are solved non-linearly, I want to study a linear version since it is more trans- parent and easier to compare the effects of our extension on the financial accelerator mechanism. This will particularly matter for the welfare analysis of monetary policy where non-linearities will complicate interpretation.

QUANTITATIVE ANALYSIS

TABLE 2
PARAMETERS AND DESCRIPTIONS

Parameter	Description	Value
Calibrated		Calibration
C/Y	Share of consumption in resource constraint	0.806
I/Y	Share of investment in resource constraint	0.184
C^e/Y	Share of entrepreneurial consumption in resource constraint	0.01
ε	Marginal product in investment demand	0.99
X	Gross mark-up over wholesale goods	1.10
α	Share of capital in production	0.20
Ω	Share of household labour in production	0.99
η	Labour supply elasticity	5.00
κ	Share of marginal cost in Phillips Curve	0.086
θ	Calvo pricing	0.75
β	Quarterly discount factor	0.99
δ	Depreciation rate	0.025
γ	Survival rate of entrepreneurs	0.973
R	Steady state quarterly riskless rate	1.010
K/N	Steady state leverage	2.082
v	Elast. of EFP to leverage	0.092
φ	Elast of inv. demand to asset prices	0.25
ρre	AR parameter on residual earnings	0.67
χ	Parameter on the expected state of the economy in the residual earnings equation	0.18
ρ	AR parameter in monetary policy rule	0.95
ζ_f	MP response to expected inflation	0.20
ρ_a	AR parameter of productivity shock	0.99
ε_a	Std. parameter of technology shock	0.10
ε_i	Std. parameter of information shock	1.00

Notes: The calibrated values are standard in the literature. Following Caglar (2012), the new AR parameter in the extended model, ρ_{re} is calibrated to 0.67, in line with the corporate finance literature. Elasticity of external finance premium to leverage, I calibrate to 0.13.

Calibration

I simulate a benchmark financial accelerator model as well as the extension of this paper with the endogenous asset price wedge to quantify the general equilibrium effects of introducing our modification. Table 2 lists the parameter values for both versions. Most of the parameters are calibrated following the values given in BGG (1999) and are standard to the literature. There are only a few minor differences. Our consumption-output ratio in the steady state includes both the private and public consumption, hence why the value is slightly larger in our calibration.[26] I calibrate the share of capital in production, α to 0.20. For robustness purposes, I also tried with α = 0.35, the other common value in the literature, but no differences were observed. Finally, in order to replicate the stylized facts of the asset price wedge (including the market and book values) that I outlined in section 4.2, I parameterize v, the elasticity of EFP to leverage to 0.13. It is slightly higher than the 0.05 in the original BGG model, but follows the estimation results for the US of Caglar (2012), and it represents well the post-2000 period, when the leverage of firms increased drastically, and so the sensitivity of financial lending rates to leverage was high.[27] For reasons of comparison between the canonical and extended financial accelerator models, I also calibrate v to 0.13 in the canonical financial accelerator model. In the same wave, I consider an accommodative monetary policy, replicating thus the Fed's stance during most of the past decade, and use the Taylor rule parameters of 0.2 for the feedback coefficient on expected inflation, ζ along with a value of 0.95 for the smoothing parameter.

The new parameter in the extended model is the AR(1) process of residual earnings. Borrow- ing from the insights in the corporate finance literature, and the US estimation results for residual earnings process in Caglar (2012), I set the value equal to 0.67. Lastly, the weight on expected evolution of the economy is 0.18.

Impulse Response Analysis

Technology Shock

I begin the analysis with general equilibrium effects from a technology shock, depicted in Figure 1.1. Qualitatively, the responses in both models follow the standard logic. A positive shock leads to a rise investment demand because of a rise in the marginal product of capital. This results in a rise in capital goods that feed into asset prices; corporate net worth gradually accumulates; and accordingly, external finance premium and borrowing cost fall. The reduction in external finance premium will create additional incentives for firms to increase external borrowing and to raise investment. The incentive for external borrowing will continue until the marginal return on capital is equal to the cost of external funds used to build the last unit of capital stock. Concentrating henceforth on asset prices, in the extended model I observe how market value rises beyond the book value. The spread between the two values peaks at 0.23 percent above the steady state. Hence, a technology shock does not only lead to a rise in current asset value, but because of positive expectations regarding future productivity growth (following from a better technology), the expectations generate further rise in the market value of those assets, which is maintained above the book value for 24 quarters.

Quantitatively, I see important divergences in the two model versions. Caused by the higher expansion on the stock market, investment increases by 1 percent in the extended model compared to the 0.25 percent in the benchmark. I also see a stronger wealth effect, since consumption increases by 0.1 percent and entrepreneurial consumption by 0.6 percent instead of the 0.1 in the canonical. Higher market value of assets means also that the net worth increase is significantly higher in the extended model, 0.6 percent compared to 0.13 percent in the benchmark version.[28] This allows entrepreneurs to borrow significantly more on the external loan market, resulting in *two and a half* times higher output expansion compared to the benchmark model.

Wedge Shock

In addition, I wish to explore the model dynamics in response to an update in market beliefs.[29] I consider a positive normalised shock to residual earnings (or asset price wedge), and report the responses in Figure I.2. I am interested in exploring the effects that an update of beliefs regarding expected residual earnings has on the asset price dynamics, financial constraints, and the economy. Overall, the wedge shock generates a strong (boom-bust) cycle in asset prices, firm balance sheet and the general economy. Unexpected rise in residual earnings generates positive outlook on markets since both the current finances of firms are improved as well as their possibilities for growth. This powerful expectations-channel is responsible for the much higher contemporaneous rise in market price compared to the book value. The market value increases by 0.4 percent (1.2 percent above the book value).[30] There are two effects from this. The immediate effect is that (intangible) capital is more attractive, and so incentivises higher investment. In addition, because expected excess return of capital increases, from 9 and 23, the borrowing constraints firms face will ease. As a result, they can take out more loans, and use the credit to invest further into (intangible) capital. This will increase their equity in the next period which will allow them to expand their borrowing and investment. The total effect is that net worth and investment increases by 1 percent. There is also a wealth effect on household consumption, albeit marginal of 0.015 percent. The total effect from this demand-side expansion is that output expands by 0.2 percent.

However, as soon as the expansionary effects from residual earnings start to fade and the relative attractiveness of intangible capital to level off, expectations regarding future firm growth fall, and the market value of assets begins to drop (after the second quarter). Market capital return falls by 0.2 percent, which causes investment to fall due to the lower returns. At the same time, a reduction in the expected return increases the cost of borrowing, and thus restricts firms access to credit. This will cause a further fall in investment and net worth in the subsequent period, and so on. Hence, 4 quarters after the initial shock, market value of capital drops to below the steady state level, causing investment and output to fall below their steady state level in the subsequent quarter. Only 15 quarters after the initial shock (or 11 quarters after the start of the contraction) does the economy recover, and output turns back to its steady state level. I therefore observe the full cycle in our impulse responses.

I wish to draw attention to two facts from this analysis. First, our output (and investment) cycle is in line with the empirical literature which finds that output, on average takes longer time to recover after a stock market boom than after any other type of expansion. Second, I am capable of generating this cycle without the necessity to recur to imperfect beliefs or other type of non-linearities.

Second Moment Analysis

Next step in the analysis consists of comparing the model-generated moments to post-2000 US data. I focus on this period since, according to our facts outlined at the beginning, this is the period when volatility in asset prices, investment and borrowing costs increased.[31] Table I.1 reports the correlations to output, and Table I.2 the relative standard deviations with respect to output.[32]

To synthesize the findings in the two tables, I find a somewhat better fit of the financial accelerator model to the post-2000 US data if I introduce an endogenous asset price wedge than if I don't. In particular, it correctly captures the correlations and relative standard deviations of capital market variables such as the wedge, market value of assets, investment, net worth, and capital return. In addition, the correlation of the wedge and the policy rate to output are identical to the ones found in the data. The reason behind this improved performance is the powerful expectations channel introduced here that intensifies the financial accelerator propagation. By allowing the market value to deviate from the book value and by making investment a function of it, positive (negative) outlook on firm growth will drive the wedge up (down). This will push firm investment up (down), which will lead to higher (lower) capital return and firm net worth in the subsequent period. Since expectations about economic fundamentals are tightly linked to the general business cycle, the firm and capital market variables listed above will also become more tightly linked to the business-cycle movements at the same time as their volatilities are intensified. The policy rate will also respond in a procyclical way to these cycles to dampen the expansionary (recessionary) effects on prices from a higher growth (contraction). This is also in line with the empirical findings discussed in the introduction of this chapter and Gerba (2014) where I identify investor confidence and a higher vulnerability of firm balance sheet to stock market fluctuations as two of the main reasons behind the increased procyclicality of firm balance sheet and firm flows over the past fifteen years.[33]

Notwithstanding, there is still some room for improvement in the matching of the (relative) standard deviations of the two asset prices (including their wedge), the policy rate and inflation which, while having the right sign, are even so more volatile in the data compared to the model.

WELFARE ANALYSIS

The quantitative analysis in the previous section showed that the economy turns two to three times more responsive to same shocks compared to a baseline BGG model because investment and external finance premium become more elastic to asset price movements and credit is used to finance the entire working capital. Consequently, firm balance sheet becomes much more volatile. In such circumstances the role of monetary policy in dampening these large fluctuations turns out to be crucial. During the pre-2007 boom period, monetary policy had been blamed for contributing to this instability by remaining very loose, while during the Great Recession the key role of monetary policy effectively became to smoothen the bust.

In a standard financial accelerator framework, Bullard and Schaling (2002) and Bernanke and Gertler (1999) showed that a sufficiently aggressive inflation (and output) targeting is both sufficient and optimal to dampen the negative effects from a boom-bust cycle in asset prices.[34] However, having extended the baseline mechanism in this paper, I wish to re-assess this Kansas City consensus and test whether they still hold under the modified model, or whether a policy rule that explicitly includes stock market developments performs better in stabilizing the economy, as Bordo and Jeanne (2002), Cecchetti et al (2000, 2002) and Mussa (2002) have argued. For that purpose, I will conduct a welfare analysis of alternative policy rules by comparing the losses in consumer welfare that each of them generates. More specifically, I will contrast policies that include explicit asset price target to a standard Taylor rule. In addition, I will identify the optimal weights in each of the arguments of the monetary rule that performs the best.

Loss Function

In the following welfare experiments, the central bank is assumed to minimize a quadratic loss function of consumers (or welfare function) for each monetary policy rule. I use the loss function derived in Gerba (2018) to conduct the experiments.

In addition to estimating the minimum losses, the optimal weights on each variable in the monetary policy reaction function are estimated for that particular minimum loss. The following points summarize the steps I will follow in these experiments:

1. Define the loss function based on consumers' welfare in the model. It is important to keep the loss function unaltered throughout the experiments.
2. Define two alternative monetary policy reaction functions. One that includes an asset price target, and another that doesn't.
3. The minimum aggregate consumption loss of a particular reaction function is computed using grid-search methods. The experiments are repeated for two scenarios: an economy with-and without an asset price wedge.
4. The optimal weights in the reaction functions for that particular minimum loss are also estimated.
5. Alternative reaction functions and their corresponding weights are evaluated using the minimum consumption loss as a general criterion. The monetary policy that generates the smallest loss is strictly preferred.

The loss function in Gerba (2018) is derived via a second order approximation to the utility of consumers, as initially described in DeFiore and Tristani (2013), Chadha et al (2010), and Woodford (2003). The approximation to the objective function takes a form which is relatively standard to the New-Keynesian model (see Woordford, 2003):

$$\underset{\theta \epsilon \Theta}{\operatorname{argmin}}\, l\left(\theta_j, (\alpha, \beta)\right) = E_t\left(\varepsilon * \chi_y \sigma_Y^2 + \varepsilon * \chi_\pi \sigma_\pi^2\right) \tag{25}$$

with χ_y denoting the weight on output y_t and χ_π the weight on inflation π_t . θ is the vector of estimated optimal weights in the monetary policy reaction function that generates the minimum loss. The two constituents of the loss function, $\sigma_Y^2$and σ_π^2 are the variances of output and inflation. ε is the frequency of the losses I estimate.[35] The corresponding weights of output and inflation in the loss function are, as shown in Gerba (2018), [0.05,1]. Hence, the function depends mainly on the variance of inflation, and only to some extent of output. The two terms are common to the New-Keynesian family of models. Intuitively, social welfare decreases with variations of inflation around its target, and of the output around its steady state level. The first reason for disliking variations in the output gap is that consumers wish to have a smooth consumption pattern over time. Just as in the benchmark new-Keynesian model, the consumption smoothing motive applies to total output variation. Second, households wish to smooth their labor supply (DeFiore and Tristani, 2013).

It might seem slightly counterintuitive that the social welfare function 25 is a standard New-Keynesian since one would expect that a model including financial frictions would produce a loss function which includes financial factors, such as asset prices. However, because only firms face financial constraints in this framework, and they are the ones exposed to stock market fluctuations, a second-order approximation of household welfare will not include financial prices since their welfare does not directly depend on variations in these variables. Since households are assured a non-state contingent and risk-free return on their deposits (by financial intermediaries), they do not internalize the risks from financial fluctuations, and therefore only variability in the real variables matter for them.

Monetary Policy Rules

In order to facilitate the comparison of our policy experiments to that of Bernanke and Gertler (2001), I will evaluate two types of reaction functions in what follows. The first is a standard inflation-forecast-based (IFB) rule extended to include output. Levin et al (2003) find that this type of rule is robust provided that the horizon of the inflation lead is short. The second rule is augmented with a response to fluctuations in the market price:

$$R_t = E_t(\pi_{t+1}) + y_t \tag{26}$$

$$R_t = E_t(\pi_{t+1}) + y_t + s_t \tag{27}$$

where $E_t\ (\pi_{t+1})$ is the expected level of inflation at t, y_t is the current output level, and s_t is the current market value of assets. Following the conclusions of Bernanke and Gertler (1999) I will directly deal with a market price target, since it is easily recognizable and available, instead of a wedge target, that is hard to identify.

I consider three shocks in our experiments: productivity, wedge and standard monetary policy shock.[36] I assume the shocks to be uncorrelated, and to have the variance-covariance matrix of a diag[1 1 1].

Results

Results from the welfare experiments are reported in Tables I.3 (economy with an asset price wedge) and I.4 (economy without a wedge). The column with initial guesses represent the coefficients/weights given to the different variables in the reaction function before the estimation process, while *Optimal weights* represents the optimal estimated weights on those variables. The optimizer uses the quasi-Newton method with BFGS updates, via the inverse positive definite Hessian in order to find the minimum value of the loss function (or the negative likelihood of the objective loss function) for a set of initial values of the reaction function.[37]

The key question I want to answer in the analysis below is **whether the benefits of responding strongly to inflation (and output) exceed the benefits of additionally responding to stock market developments** in terms of reduced losses.

Targeting Vs. Not Targeting Asset Prices

Beginning with an economy with an asset price wedge, I generally observe a lower loss with a policy that includes a market price target. For the same weights on inflation and output in both types of reaction functions, the loss that the policy *including* market price reaction generates is, on average, 10 percent (or 0.0004 units) lower. In addition, our simulations show that the global minimum for the two likelihood functions, one for each reaction function, is lower for the monetary policy that, in addition, reacts to asset prices (0.0033 vs 0.0034 units when excluding it). In other words, for standard parameter weights in the reaction function within the interval [0,2], the policy that also reacts to asset prices generates a lower global welfare loss in terms of foregone consumption compared to the standard Taylor rule. Assessing the estimated optimal weights for both reaction functions, I find that the weights on inflation and output are largely the same in both functions, but that the additional weight on asset prices (0.24) in the rule including it is what reduces the losses further (i.e. is welfare improving).

Turning to the economy without a wedge, I find that the policy that targets market prices is welfare improving for low weights on inflation and output (below the joint weights [1.5, 0.5]), while the opposite is true when I increase the weights on those two variables. However, for an aggressive inflation and output policy (weight of [2, 0.5]), I find that the policy that does not target asset prices generates smaller losses and is therefore favoured. Thus, only for an *aggressive monetary policy response in an economy without an asset price wedge* do the results in Bernanke and Gertler (2001) hold.

Moreover, I find that the likelihood function for the policy rule that **does not** include asset prices (in both economies) is **more elastic** than the alternative. In relative terms, this means that small changes in weights on policy targets can change the welfare of consumer by a considerable amount. Therefore, for a monetary authority that does not choose to target asset prices, the choice of weights becomes more critical for the success of their policy, than for an authority that chooses to include stock market developments. This can be interpreted as the asset price target being, apart from the above, a safer option for stabilizing/controlling the economy. This is very different to the findings of Bernanke and Gertler (2001).

FINAL REFLECTIONS

The 2008 financial turmoil has revived the debate on whether the central banks should respond to asset price movements. Previous studies in this literature had suggested that strong inflation- and output targeting was sufficient in reducing cyclical swings and control inflation expectations. However, these studies often relied on the premise that expansionary effects from asset price over- valuation are quickly and completely transmitted to inflation and output. Moreover, since over- valuations are hard to identify, a policy maker that tries to target them might increase the range of instability of models (Bullard and Shaling, 2002). Recent empirical studies from the crisis have, nonetheless, pointed out that the unusually low Federal Funds rate during the entire 2000 boom period fuelled the stock-and property-market rise. Capitalising on these insights, this paper reviews the conclusions from this pre-crisis debate.

Findings here suggest two facts. A monetary policy that does not target asset price movements will inevitably feed a surge in an asset price wedge, even if unintentional. While not necessarily negative in itself, the susceptibility of the economy to a deeper subsequent contraction is also higher. The welfare experiments show that consumers are, on average, 10 percent better off in terms of foregone consumption with a monetary policy that also targets stock market prices com- pared to simpler alternatives. Second, even if it is hard to identify an *unhealthy* asset price boom, the economy is still, on average, better off with a monetary policy that explicitly responds to stock market movements as it improves aggregate economic and financial stability L.

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ENDNOTES

1. See Chart 2 (p.6). For further discussion on the developments in the bank capital market, see the June 2012 issue of the Financial Stability Report.
2. The data was downloaded from Federal Reserve's St. Louis database.
3. On the downside after 2007, the default risk increased, pushing investors' required earnings sharply up.
4. See the analysis on the firm capital price-and investment cycles in Section 2 of this paper.
5. At the same time, Chen (2014) showed that both types of capital have a similar depreciation rate, which means that their stock evolution is very similar.
6. The error terms are not correlated.
7. In Gerba (2018)m I also performed the estimation using only the stationary cyclical component of those variables. The cyclical components were extracted using the standard HP-filter.
8. The data was logged before the estimation, except for the BAA-rate and the wedge, since they are already expressed in percentage terms.
9. The extended figures and analysis for the HP-filtered series can be found in Gerba (2018).
10. I de-trended the data using the standard HP filter. The correlations and relative standard deviations are expressed relative to output.
11. A longer discussion of the Q theory of investment and its shortcomings are described in Gerba (2018).
12. Not on the book value of assets or the Q ratio, as is standard in the literature so far.
13. The most common approach to incorporate an asset price wedge in DSGE financial friction models has been by introducing an exogenous AR(1) type of process on top of the fundamental capital price that allows the two prices to diverge. The resulting 'bubble' is temporary and remains only for some time before it bursts. In order to trigger the 'bubble', you need to shock the process directly. While no micro-founded justification is given for the process, nor is it derived from fundamental principles, the rationale is that sentiments or temporary irrational pricing of capital can lead to a temporary divergence of capital prices. This divergence is self-fulfilling for some time, but bursts as soon as agents realise that the capital has been overpriced. Examples of these models include Carlstrom and Fuerst (2007), Castelnuovo and Nistico (2010), and Hilberg and Hollmayr (2011) or Bernanke and Gertler (2001). There is also a growing literature that has elaborated a more sophisticated mechanism of imperfect beliefs (or heterogeneous expectations), which may or may not result in asset price wedges. However, to achieve this, rational expectations need to be abandoned.
14. Since the model is based on the clean surplus relation of accounting statements, all changes in assets and/or liabilities unrelated to dividends must pass through the income statement. That is why the model considers earnings as its argument.
15. See Gregory et al (2005), McCrae and Nilsson (2001) and Dechow et al (1999).
16. The reason lies with the dividend policy of a firm. Following a rise in the value of firm stocks, a firm can choose not to pay them out as dividends and use them as retained earnings, which would contribute to larger earnings in the subsequent period.
17. See Larran and Lopez, 2005 for a review on the application of the clean surplus relation in financial and accounting models.
18. One can link this idea back to the BoE 2012 report by viewing the profitable periods as periods of optimism. During periods of high market confidence, the capital is expected to generate a present value of future earnings above the required demanded by investors, or the same as saying 'positive residual earnings'. On the contrary, during times of distrust, the capital is not expected to generate future earnings above investors' required, either because the capital profitability has fallen, or investors' required earnings have increased, or a mix of both, implying that residual earnings will be negative.
19. In the Ohlson (1995) paper, the author expresses the market value in linearized terms. However, because I am interested in studying the non-linear dynamics before I linearize the system, I express the value in non-linear terms
20. For a more detailed discussion on the economic fundamentals that are relevant for this model, see Gerba (2018).
21. I will show later that this is equivalent to making investment contingent on the (expected) asset price wedge since the wedge is the actual price of capital above its fundamental value.
22. In steady state, the price of capital is unitary, meaning that the adjustment cost function is normalized.
23. Which I calibrate in a way to play a marginal role in this setting.

24. Nolan and Thoenissen (2009) find that a shock to the default rate in the net worth equation is very powerful in driving the entire model dynamics, and the shock accounts for a large part of the variation in output. It is also strongly negatively correlated with the external finance premium.
25. In Gerba (2018), I also examine the effect of a monetary policy shock. However, for the sake of focus, I have not included it here.
26. In the canonical BGG (1999) model, the *C/Y* ratio is calibrated to 0.568. However, if I also include the public consumption in that ratio, which they calibrate to 0.2, the value is almost the same to our, which I calibrate to 0.806.
27. See Gerba (2014) on the balance sheet changes and the financial exposure that firms underwent during the past decade.
28. This is almost equivalent to saying that the return on capital is 5 times higher in the extended model.
29. For instance, Gertler and Karadi (2011) consider a similar shock in their version of the financial accelerator model.
30. The drop in book value is due to the relative increase in attractiveness of intangible capital. An increase in residual earnings makes intangible capital more profitable compared to tangible, since its value has increased. This will incentivise firms to invest more in intangibles at the expense of tangibles. This translates into a rise in market value and a drop in the book value. This dynamics will be reversed as more intangible capital is being accumulated, since the marginal return of it falls while that of tangible capital rises.
31. The data were downloaded from Federal Reserve St Louis database on April 2012. All data, except for the policy rate, capital return and capital prices (book and market values) are expressed in real terms. Consumption is for non- durables and services only. Only the nominal consumption series were available. They were converted into real terms using the CPIU. The investment series does not include residential investment and is for the private sector only. I have multiple candidates for capital return in the data so I include both short-term (corporate paper and prime) and long-term (AAA and BAA) rates in order to capture both segments of the financial market. Likewise, for inflation I use three candidates: GDP deflator, Urban Consumer Price index, and Producer Price index.
32. The theoretical second moments are calculated after introducing jointly the three shocks in the models. For the extended model, those are productivity, (contractionary) monetary policy and an asset price wedge shock jointly. For the baseline BGG the joint shocks are to productivity, (contractionary) monetary policy, and government spending. Following common practice in the literature, I have used the standardised value of 1 standard deviation for all shocks except for technology, where I applied a value of 0.1 standard deviation. The technology shock generates a sufficiently large variation in the model that I chose to apply a smaller size.
33. For robustness purposes, in Gerba (2018), I also identified the shocks that generate the highest volatility in both the extended and the canonical models. To do so, I 'switched on' one shock at the time and calculated the relative standard deviation with respect to output.
34. Since it does not increase the range of instability of models caused by the high information uncertainty related to the identification of an asset price bubble, nor depress 'healthy' economic growth.
35. Which I express in annual terms, and hence set ε=4.
36. Bernanke and Gertler (2001) only considered two shocks in their welfare experiments: productivity, and bubble shocks.
37. For a more detailed description of the routine, please refer to Gerba (2018). ”””—”—”′o¿

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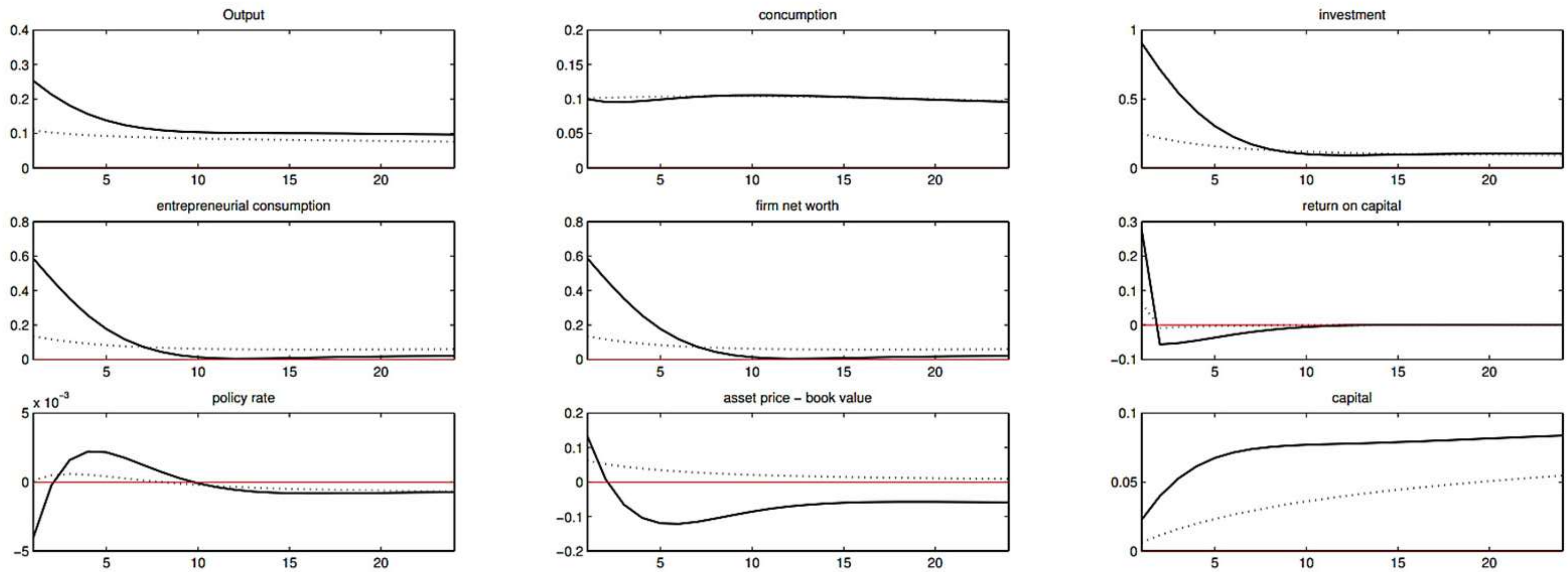
APPENDIX

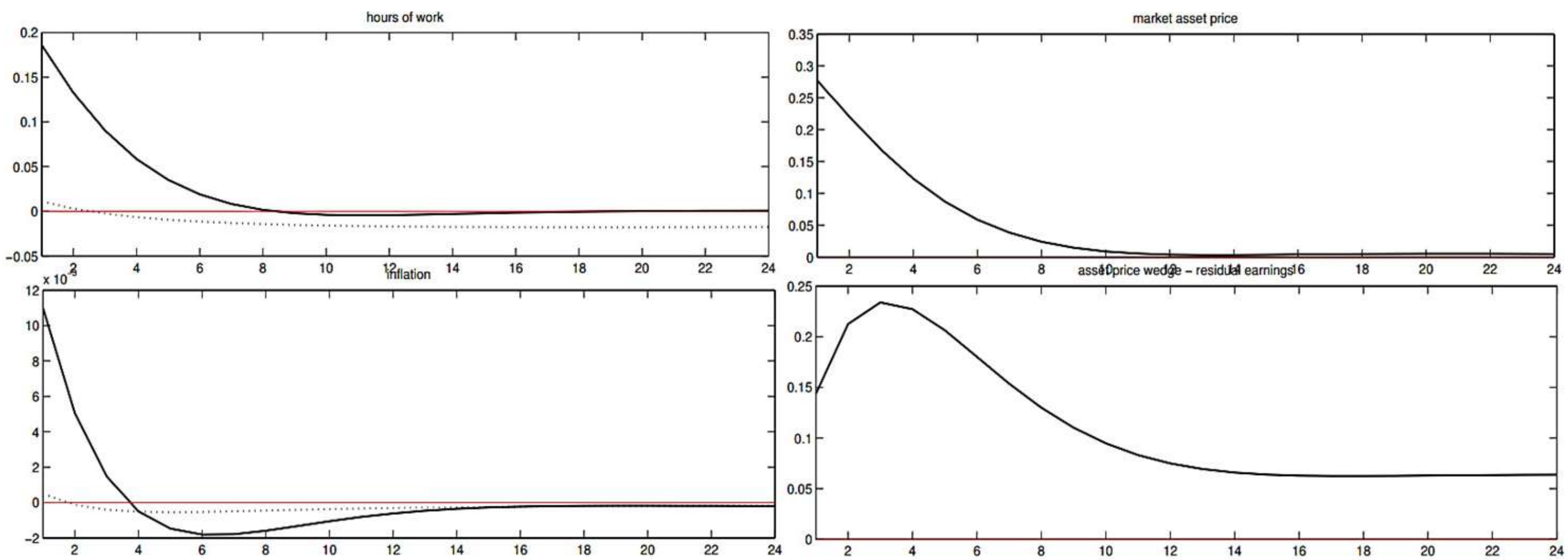
TABLE 3
MODEL VARIABLES AND DESCRIPTIONS

Variable	Definition
y	Output
c	Household consumption
c^e	Entrepreneurial consumption
i	Investment
g	Government spending
r^n	Nominal interest rate
r	Real interest rate (also the (net) deposit rate of households)
r^k	Rate of return on capital
q	Book value of capital
s	Market value of capital
re	Residual/Abnormal earnings
efp	External finance premium
k	Capital stock
n	Entrepreneurial net worth
x	Mark-up of final good producers
h	Hours of labour input in production
π	Inflation
a	Technological progress
e_i	Information shock

FIGURE I.1
RESPONSES TO A PRODUCTIVITY SHOCK

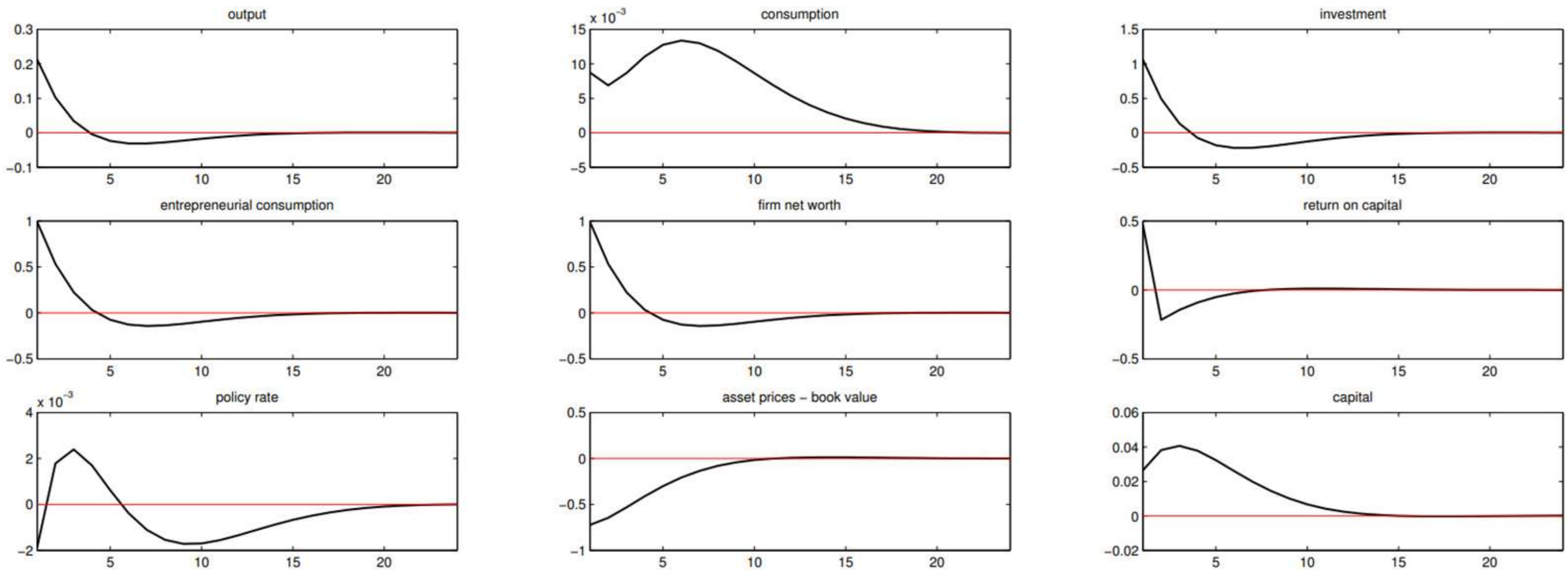


Notes: Impulse responses to a technology shock in both the canonical BGG and Gerba models. The dotted lines are the responses in the BGG, and the full lines in the Gerba model. The responses of asset prices - book value is the ‘q’ in both models, and the wedge is equivalent to residual earnings in the Gerba model.



Notes: Impulse responses to a wedge shock in the Gerba model only. The responses of asset prices - book value is the ‘q’ in both models, and the wedge is equivalent to residual earnings in the Gerba model.

FIGURE I.2
RESPONSES TO A WEDGE SHOCK I



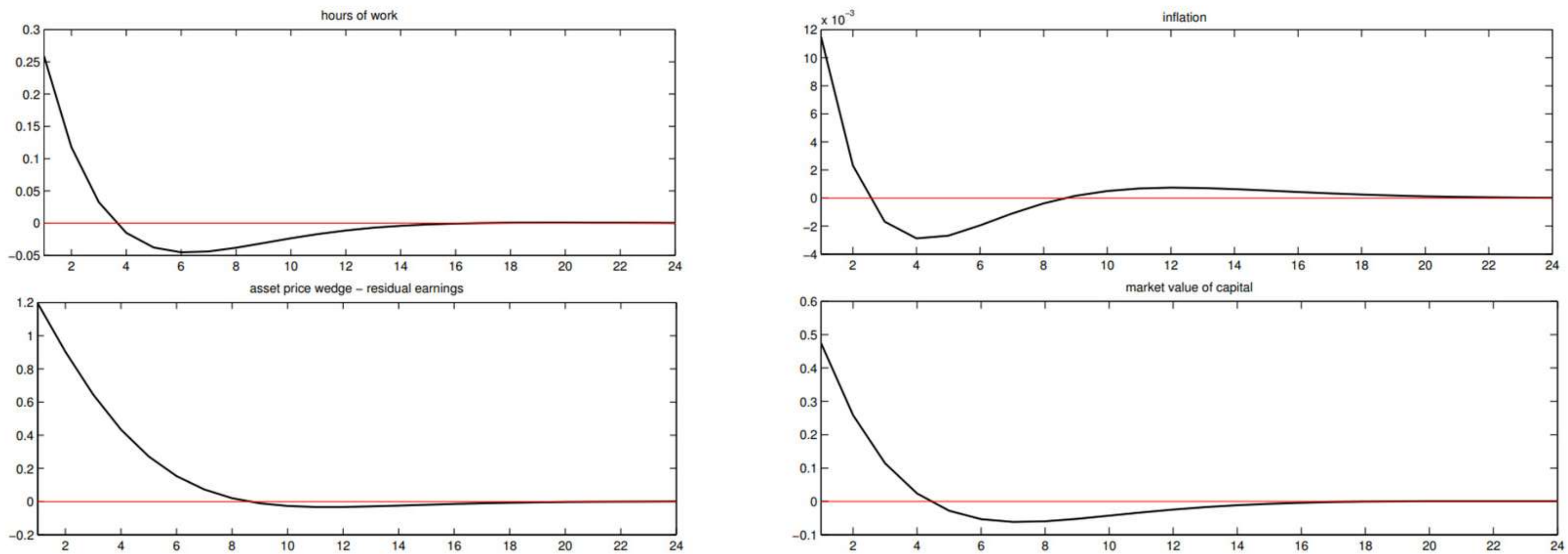

hours of work
inflation
asset price wedge – residual earnings
market value of capital

TABLE I.1
CORRELATIONS

Variables	Correlation Extended model (Gerba)	Correlation Canonical model (BGG)	Correlation US data
(consumption, output)	0.70	0.83	0.73
(book value, output)	0.50	0.98	0.90
(market value, output)	0.98	-	0.83
(asset price wedge, output)	0.69	-	0.76
(investment, output)	0.99	0.98	0.94
(capital, output)	0.21	0.20	-
(net worth, output)	0.99	0.89	0.76
(capital return, output)	0.59	0.72	0.77/0.38/0.15/0.76
(policy rate, output)	0.79	-0.93	0.76
(inflation, output)	0.92	0.90	0.46/0.52/0.76

Notes: Correlations generated by the two versions of the financial accelerator model are compared to US data. The data correlations were obtained from 2000:I to 2011:II.

TABLE I.2
RELATIVE STANDARD DEVIATIONS

Variables	Rel.std.dev. Extended model (Gerba)	Rel.std.dev. Canonical model (BGG)	Rel.std.dev. US data
(consumption, output)	0.25	0.46	0.43
(book value, output)	1.0	1.04	2.01
(market value, output)	1.52	-	10.33
(asset price wedge, output)	1.45	-	12.42
(investment, output)	4.53	4.12	5.87
(capital, output)	0.29	0.23	-
(net worth, output)	3.67	2.47	4.52
(capital return, output)	1.36	1.29	0.94/0.25/0.38/0.91
(policy rate, output)	0.26	0.53	0.85
(inflation, output)	0.09	0.09	0.36/0.71/2.67

Notes: Relative standard deviations generated by the two versions of the financial accelerator model are compared to US data. The data standard deviations were obtained from a post-2000 sample ranging from 2000:I to 2011:II. I report four US data variables as an analogue to the capital return variable in the model: 3-month Prime rate, Long-term AAA-rate, Long-term BAA-rate, 3-month Corporate paper rate. Likewise for inflation, I use GDP deflator/CPIU/PPI. %vspace-5 mm

WELFARE EXPERIMENT RESULTS

TABLE II.1
LOSS FUNCTION ANALYSIS 1 - ECONOMY WITH A POSITIVE WEDGE

Reaction function	Initial weights	Loss value	Optimal weights
$[E_t(\pi_{t+1}), y_t]$	(1, 0.5)	0.0045	(0.77,0.73)
$[E_t(\pi_{t+1}), y_t]$	(1.5, 0.5)	0.0041	(0.99,1.01)
$[E_t(\pi_{t+1}), y_t]$	(2, 0.01)	0.0041	(0.996, 1.01)
$[E_t(\pi_{t+1}), y_t]$	(2, 0.1)	0.0041	(1.04, 1.06)
$[E_t(\pi_{t+1}), y_t]$	(2, 0.5)	0.0039	(1.23, 1.27)
$[E_t(\pi_{t+1}), y_t]$	(2, 1)	0.0037	(1.48, 1.52)
$[E_t(\pi_{t+1}), y_t]$	(2, 2)	0.0034	(2.01, 1.99)
$[E_t(\pi_{t+1}), y_t, s_t]$	(1, 0.5, 0.2)	0.0041	(0.96,0.54,0.24)
$[E_t(\pi_{t+1}), y_t, s_t]$	(2, 0.5, 0.2)	0.0035	(1.65,0.85,0.55)
$[E_t(\pi_{t+1}), y_t, s_t]$	(2, 0.01, 0.2)	0.0037	(1.58,0.43,0.62)
$[E_t(\pi_{t+1}), y_t, s_t]$	(2, 0.1, 0.2)	0.0037	(1.59,0.51,0.61)
$[E_t(\pi_{t+1}), y_t, s_t]$	(2, 1, 0.2)	0.0034	(1.75,1.26,0.46)
$[E_t(\pi_{t+1}), y_t, s_t]$	(2, 2, 0.2)	0.0033	(1.96,2.04,0.24)
$[E_t(\pi_{t+1}), y_t, s_t]$	(2, 0.5, 0.01)	0.0035	(1.55,0.95,0.46)
$[E_t(\pi_{t+1}), y_t, s_t]$	(2, 0.5, 0.1)	0.0035	(1.60,0.90,0.50)
$[E_t(\pi_{t+1}), y_t, s_t]$	(2, 0.5, 0.2)	0.0035	(1.65,0.85,0.55)
$[E_t(\pi_{t+1}), y_t, s_t]$	(2, 0.5, 0.3)	0.0035	(1.71,0.79,0.59)
$[E_t(\pi_{t+1}), y_t, s_t]$	(2, 0.5, 0.4)	0.0035	(1.77,0.74,0.64)
$[E_t(\pi_{t+1}), y_t, s_t]$	(2, 0.5, 0.5)	0.0035	(1.82,0.68,0.68)

Notes: The first column in the table states whether the simulations are based on a standard policy, or a market price augmented one. The second column reports the initial weights given to each and every variable in the reaction function prior to the estimation, while the (fourth) last column reports the optimal weights of each variable that was estimated for that specific (minimum) loss.

TABLE II.2
LOSS FUNCTION ANALYSIS 2 - ECONOMY WITHOUT A WEDGE

Reaction function	Initial weights	Loss value	Optimal weights
$[E_t(\pi_{t+1}), y_t]$	(1, 0.5)	0.0043	(0.77,0.73)
$[E_t(\pi_{t+1}), y_t]$	(1.5, 0.5)	0.0039	(0.99,1.01)
$[E_t(\pi_{t+1}), y_t]$	(2, 0.01)	0.0039	(0.997, 1.03)
$[E_t(\pi_{t+1}), y_t]$	(2, 0.1)	0.0038	(1.04, 1.06)
$[E_t(\pi_{t+1}), y_t]$	(2, 0.5)	0.0033	(1.23, 1.27)
$[E_t(\pi_{t+1}), y_t]$	(2, 1)	0.0031	(1.48, 1.52)
$[E_t(\pi_{t+1}), y_t]$	(2, 2)	0.0030	(2.01, 1.99)
$[E_t(\pi_{t+1}), y_t, s_t]$	(1, 0.5, 0.2)	0.0039	(0.96,0.54,0.24)
$[E_t(\pi_{t+1}), y_t, s_t]$	(2, 0.5, 0.2)	0.0033	(1.65,0.85,0.55)
$[E_t(\pi_{t+1}), y_t, s_t]$	(2, 0.01, 0.2)	0.0035	(1.58,0.43,0.62)
$[E_t(\pi_{t+1}), y_t, s_t]$	(2, 0.1, 0.2)	0.0035	(1.59,0.51,0.61)
$[E_t(\pi_{t+1}), y_t, s_t]$	(2, 1, 0.2)	0.0032	(1.75,1.26,0.46)
$[E_t(\pi_{t+1}), y_t, s_t]$	(2, 2, 0.2)	0.0031	(1.96,2.04,0.24)
$[E_t(\pi_{t+1}), y_t, s_t]$	(2, 0.5, 0.01)	0.0033	(1.55,0.95,0.46)
$[E_t(\pi_{t+1}), y_t, s_t]$	(2, 0.5, 0.1)	0.0033	(1.60,0.90,0.50)
$[E_t(\pi_{t+1}), y_t, s_t]$	(2, 0.5, 0.3)	0.0033	(1.71,0.79,0.59)
$[E_t(\pi_{t+1}), y_t, s_t]$	(2, 0.5, 0.4)	0.0033	(1.77,0.74,0.64)
$[E_t(\pi_{t+1}), y_t, s_t]$	(2, 0.5, 0.5)	0.0033	(1.82,0.68,0.68)