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A Macroeconometric Assessment of Minsky's Financial Instability Hypothesis*

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Abstract

The Financial Instability Hypothesis associated with Hyman Minsky has profound implications for the conduct of monetary policy in modern capitalist economies. At its core is the proposition that the central bank may contribute to the financial fragility of leveraged firms in its pursuit of inflation-targeting interest rate policies. This paper develops a small macroeconomic model incorporating many of the salient features of a Minskyan economy. The imposition of the resulting theoretical restrictions in a CVAR model provides support for Minsky's main proposition that interest rate innovations can drive a wedge between the cash-inflows of firms and their debt-servicing obligations. The paper concludes that the implementation of countercyclical capital requirements can provide monetary policymakers with additional policy instruments that can be used to cool overheated sectors without recourse to the 'blunt instrument' of interest rate policy.

JEL Classifications: C32, C51, E32, E52.

Key Words: Monetary Policy, Inflation Targeting, Financial Instability Hypothesis, Cointegrating VAR, Asset Price Cycles.

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In these latter days, since the downfall, I know that there will be much talk of corruption and dishonesty. But I can testify that our trouble was not that. Rather, we were undone by our own extravagant folly, and our delusions of grandeur. The gods were waiting to destroy us, and first they infected us with a peculiar and virulent sort of madness.

Anonymous (1933, ¶27)

1 Introduction

Economic history has been characterised by booms and busts in the asset markets which seem neither predictable nor avoidable *ex ante*. A crude but representative generalisation is that as rising speculative profits fuel an increasingly bullish economic outlook, investors undertake progressively more risky positions until confidence in the sustainability of asset prices eventually fails and the bubble collapses. Subsequently, many commentators are left wondering how so many investors, seasoned and novice alike, were swept up in an *ex-post* unsustainable clamour to realise speculative gains based largely on market euphoria.

The historical inability of market participants to prevent the growth and subsequent collapse of bubbles has been well documented. This has led to a lively debate within the academic literature as to whether the central bank should (and indeed could) formulate monetary policy to intervene in financial markets (e.g. Cecchetti et al., 2000; Nickell, 2005; Posen, 2006; Roubini, 2006). Surprisingly, however, references to the Financial Instability Hypothesis (FIH) proposed by Minsky (1977, 1982) are largely absent from this literature despite its relevance. The FIH suggests that by pursuing active monetary policy, the central bank may actually *precipitate* financial crises. The link between monetary policy and financial fragility arises because by changing the interest rate in accordance with its policy objectives, the central bank is also changing the cash-commitments of leveraged firms, albeit potentially with a lag.

This paper seeks to test this mechanism at the macro level in the US. We first derive a simple four-equation macroeconomic model embedding many of the aspects central to the FIH. This framework is then used to define the long-run relations in a vector error correction model (VECM) by placing appropriate restrictions on the equilibrium vectors spanning the cointegrating space. The results support Minsky's key proposition that an interest rate shock will drive a wedge between the cash-inflows of firms and their debt-servicing commitments. In this way, a monetary tightening will indeed be associated with increasing financial fragility.

This mechanism is intimately linked with the credit channel literature, which emphasises that transaction costs, information asymmetries between borrowers and lenders and risk aversion against insolvency may collectively generate financial frictions in imperfect capital markets (Bernanke and Gertler, 1995; Greenwald and Stiglitz, 1990). A monetary tightening is likely to reduce loan supply and thereby initiate a flight-to-quality effect which will constrain the borrowing power of smaller and more informationally opaque firms (Gertler and Gilchrist, 1994; Kashyap and Stein, 1997). In addition, contractionary monetary policy may be expected to reduce both aggregate demand and aggregate profits, thereby undermining the net worth of the representative borrower and increasing the probability of default – the combined effect will therefore feed back into an increased external financing premium (Bernanke and Gertler, 1995; Bernanke et al., 1996). A further strand of the literature is concerned with credit rationing phenomena (Stiglitz and Weiss, 1981; Greenwald and Stiglitz, 1990; Größl et al., 2000). Thus, this literature posits that both the cost of credit and the conditions governing its supply should move in accordance with monetary policy decisions, with the result that the contractionary influence of a monetary tightening will be concentrated among informationally opaque firms with lower net worth (Berger and Udell, 1998).

From a Minskyan perspective, the effects of a monetary tightening are not felt only at the idiosyncratic level but also at the systemic level, because by raising the interest rate, the central bank weakens the balance sheets of all firms and creates a generalised shift toward greater fragility in the distribution of firms' financing structures. We conclude, therefore, that the central bank should generally strive to enhance the predictability of interest rate adjustments conditional on the state of the economy in order to avoid unnecessary interest rate volatility which may undermine the financial stability of leveraged firms. Furthermore, by introducing countercyclical capital requirements on financial institutions as recommended under the Basel III framework, the central bank may ensure that the precautionary reserves of financial institutions are at their strongest when asset prices are inflated.

This paper proceeds in 6 sections. In Section 2, we selectively review the literature on Minskyan modelling and derive our small macroeconomic model. Section 3 introduces the dataset, while our estimation results are presented and discussed in detail in Section 4. Section 5 discusses the controversy surrounding the role of asset prices in the formulation of monetary policy and proposes the use of countercyclical capital requirements as a means of moderating the threat of asset market cycles. Section 6 concludes, while details of the dataset and its construction may be found in the Appendix.

2 The Financial Instability Hypothesis

In a series of articles, Hyman Minsky (1976, 1977, 1982, 1986a,b) developed a sophisticated theory of financial fragility, the essence of which is neatly summarised by Erturk (2006, p. 3) as follows:

> [O]ptimistic expectations about the future create a margin, reflected in higher asset prices, which makes it possible for borrowers to access finance in the present. In other words, the capitalized expected future earnings work as the collateral against which firms can borrow in financial markets or from banks. But, the value of long-lived assets cannot be assessed on any firm basis as they are highly sensitive to the degree of confidence markets have about certain states of the world coming to pass in the future. This means that any sustained shortfall in economic performance in relation to the level of expectations that are already capitalized in asset prices is susceptible to engendering the view that asset prices are excessive. Once the view that asset prices are excessive takes hold in financial markets, higher asset prices cease to be a stimulant and turn into a drag on the economy. Initially debt-led, the economy becomes debt-burdened.

At the very core of the FIH is the concept of financial fragility, which Minsky discusses in relation to a trinity of financing strategies: hedge, speculative and Ponzi financing (c.f. Minsky, 1986a, pp. 335-341). Sordi and Vercelli (2006) define these with reference to the current and intertemporal financial ratios, k_{it} and k^*_{it}:

$$k_{it} = \frac{e_{it}}{y_{it}} \qquad \text{and} \qquad k^*_{it} = \frac{\sum_{n=0}^{h} \left\{ (1+\rho)^{-n} \, e^*_{it+n} \right\}}{\sum_{n=0}^{h} \left\{ (1+\rho)^{-n} \, y^*_{it+n} \right\}}$$

where e_{it} represents cash-outflows, y_{it} denotes cash-inflows, an asterisk signifies an expected value, ρ is the discount rate and the subscripts i and t identify firms and time periods, respectively. For any horizon, h, a firm is hedge financing if $k_{it} < 1$ and $k^*_{it} < 1$ for $t \leq h$. It is speculatively-financed if, for $s < h$, $K_{it} > 1$ for $t \in [1, ..., s]$ but $k^*_{it} < 1$ for $t \in [1, .., h]$. Finally, it is Ponzi-financing if $k_{it} > 1$ for $1 \leq t \leq h - 1$ and $k^*_{it} > 1$ for $1 \leq t \leq h$. It should be clear that hedge financing is the most robust strategy while Ponzi financing is highly risky.

In this context, Minsky emphasises the destabilising effects of interest rate policy and the conditions under which credit may be obtained. In an uncertain world, agents faced with long-lived and irreversible investment decisions engage in forward planning based on optimal forecasts of future conditions which, owing to this very uncertainty, must be heavily conditioned on recent historic experience. An element of this decision is the choice of financing structure. Under the assumption that that the equity base remains approximately constant (which is plausible under imperfect capital markets), an *ex ante* unforeseeable increase in the interest rate after such plans haven been enacted is likely to cause a general shift rightwards through the hedge-speculative-Ponzi spectrum, associated with increasing financial fragility at an aggregate level.[1]

A simple Minskyan boom-bust cycle is presented in Figure 1. In the initial recovery phase, the investment decisions of firms are based upon their tentative forecasts. As expectations grow increasingly optimistic and the previous bust is forgotten, an investment boom ensues. Minsky assumes that the investment boom is largely debt-funded and that it is associated with a rising share of profits in national income. The rising profit-share leads workers to bargain for nominal wage increases to maintain the wage-share. The resulting wage inflation is passed through to the general price level as a result of mark-up pricing (c.f. Weintraub, 1978). In accordance with its inflation-targeting mandate (*de facto* in the case of the Federal Reserve), the central bank raises the short-term nominal interest rate. This is passed through to the lending rate (perhaps incompletely or with some overshooting), raising firms' cash-outflows and increasing aggregate financial fragility. Alongside the events described thus far, financial institutions have been loosening their credit criteria and reducing their margins of safety in response to the euphoric sentiment in financial markets (we will revisit this contention shortly).[2] This leaves them particularly vulnerable to the increasing incidence of default associated with the increase in financial fragility among their borrowers. Given the difficulties faced by firms and financial institutions alike, confidence in the boom will eventually fail and the bust phase will ensue. If one assumes that memories are short and/or selective, then the cycle is free to start over.

FIGURE 1 ABOUT HERE

This stylised schematic representation summarises the key elements of a Minskyan cycle as it was originally conceptualised. However, one must not neglect the array of relevant institutional changes that have occurred gradually over the course of multiple decades and a number of such cycles. Firstly, the strong and direct linkage between wage inflation and price-level inflation has been weakened since the late 1970s but a tight link between the two nevertheless remains due to the widespread practice of negotiating wage settlements in relation either to the realised or forecast rate of inflation and the large portion of many firms' costs which is accounted for by their staffing costs (Druant et al., 2009). Furthermore, the process of weakening credit standards and thinning safety margins was particularly acute in the boom that preceded the recent crisis (Dell'Ariccia et al., 2008). Indeed, the widespread and rapid financial innovation that characterised much of the so-called Great

[1] Minsky (1982, pp. 66-8) provides a thorough discussion of the transition between financing structures.

[2] Minsky's notion of euphoria is essentially a generalised shift towards increasingly optimistic expectations.

Moderation period may have introduced a tendency toward falling credit standards which has not been confined only to the euphoric phase of the cycle, thereby generating a general trend toward increasingly fragile financing arrangements.

Figure 1 does not directly address the linkage between the short-term interest rate administered by the central bank and the longer-term rates relevant for firms' financing decisions. As discussed in Greenwood-Nimmo et al. (2013), the pass-through from short-term to longer-term rates is generally complex, exhibiting various frictions and asymmetries. Longer-term interest rates combine a discount rate[3] and an external financing premium which varies with perceived credit worthiness: it was variations in the latter which played a particularly significant role in the early stages of the Global Financial Crisis. In general, the end of the euphoric stage is likely to be associated with a significant rise in the external financing premium demanded by lenders, exacerbating the effect of any rate rise enacted by the central bank in response to inflationary pressures. Moreover, in such a setting, Greenwood-Nimmo et al. show that expansionary rate cuts intended to bolster the economy will generally not be passed on to borrowers strongly or rapidly, constraining the central bank's ability to stimulate the economy via conventional expansionary policy.

Finally, while there is a natural tendency toward increasing financial fragility in a Minsykan system, this does not mean that stabilisation policy is ineffective. Minsky (1986a) stresses the role of active stabilisation policies in preventing financial crises, crediting the increasing importance of transfer payments since World War II with the relative stability enjoyed by the US until recently. He argues that when confidence starts to fail, the scale of any contraction is reduced as increased government spending (whether a result of automatic stabilisers or discretionary policy) supports the profitability of businesses, helping them to meet their debt-servicing obligations. This view provides direct support for the use of fiscal stimuli during recessions. In this paper, we will further argue in favour of a judicious combination of conventional monetary policy and countercyclical capital requirements.

2.1 A Small Minskyan Model

While various authors have developed chaotic systems in the Minskyan tradition (Nasica, 2000, ch. 4, provides a brief survey) and a good deal of research effort has been devoted to simulation exercises (e.g. Hannsgen, 2005), direct empirical scrutiny of the FIH at the macro level is largely absent from the literature[4]. This paper attempts to address this lacuna by developing and estimating a simple macroeconomic model with many of the salient features of a Minskyan economy. The model owes an intellectual debt to Lavoie's (1986) early contribution, extending his work in a number of directions.

The model may be represented by a system of five equations: an aggregate demand function, an interest rate rule, an investment function and a pair of price- and wage-inflation equations.[5]

2.1.1 Aggregate Demand

Aggregate demand is modelled following (1) where y_t denotes real output, r_t denotes the base rate, Δp_t is the logarithmic approximation to the rate of inflation (hence $r_t - \Delta p_t$ is the real interest rate), i_t is real gross investment, y_t^* represents real potential output and $t = 0, 1, 2, \ldots, T-1$ is a deterministic time trend.

[3]For our purposes this can be thought of as the risk-adjusted opportunity cost of internal finance.

[4]Fazzari (1999) notes that there is, however, a wealth of indirect evidence to be found in the micro-founded financial economics literature. Further indirect evidence can be derived from the voluminous literature on the external financing premium.

[5]Note that all variables are expressed as natural logarithms in the following equations.

$$y_t = b_{10} + b_{11}t + \phi_{11}(r_t - \Delta p_t) + \phi_{12}i_t + \phi_{13}y_t^* + \xi_{1,t} \tag{1}$$

Imposing $\phi_{13} = 1$ allows one to interpret (1) in terms of the output gap rather than aggregate demand *per se*. In this form, the equation represents an IS curve and it is this form which is employed in estimation below.

2.1.2 The Monetary Policy Reaction Function

The central bank is assumed to follow a Taylor-type interest rate rule represented by (2), where Δp^* denotes the desired rate of inflation and r^* the natural rate of interest.

$$r_t = \widetilde{b}_{20} + b_{21}t + \varphi_{21}r^* + \varphi_{22}\Delta p_t + \varphi_{23}(\Delta p_t - \Delta p^*) + \varphi_{24}(y_t - y^*) + \xi_{2,t} \tag{2}$$

Following the approach commonly adopted in the empirical Taylor rule literature, r^* and Δp^* are assumed constant over the period under study. The constancy of these terms allows one to re-write (2) as:

$$r_t = b_{20} + b_{21}t + \phi_{21}\Delta p_t + \phi_{22}(y_t - y^*) + \xi_{2,t} \tag{3}$$

where $b_{20} = \widetilde{b}_{20} + \varphi_{21}r^* - \varphi_{23}\Delta p^*$, $\phi_{21} = \varphi_{22} + \varphi_{23}$ and $\phi_{22} = \varphi_{24}$. The empirical tractability achieved in this way comes at the expense of the ability to distinguish the constituents of the composite parameters b_{20} and ϕ_{21} without the imposition of further identifying restrictions. The magnitudes of these quantities are not, however, of interest in themselves in the current context. Lastly, note that when $\phi_{22} = 0$ then the central bank acts as a pure inflation targeter (Christiano and Gust, 1999).

2.1.3 The Investment Function

At the core of the model is a theory of investment behaviour based on that of Godley and Lavoie (2001) which, in turn, draws on Ndikumana (1999) and Fazzari and Mott (1986). The investment function is specified as follows[6]:

$$i_t = \phi_{30} + \phi_{31}f_t + \phi_{32}(r_{l,t} - \Delta p_t)l_t + \phi_{33}q_t + \phi_{34}(y_t - y^*) + \xi_{3,t} \tag{4}$$

where f_t denotes real internal funds (which proxies real cash-flow – see Fazzari et al. (1988) for a similar approach), $r_{l,t}$ the rate of interest on bank-lending, l_t the real stock of outstanding corporate debt (and hence $(r_{l,t} - \Delta p_t)l_t$ denotes the inflation-adjusted cost of servicing real debt) and q_t is Tobin's (1969) average q.[7]

This specification exhibits a number of interesting features. Firstly, monetary policy affects investment in at least two ways. A direct effect arises through the change in the cost of borrowing associated with a change in the base rate. A further indirect effect operates through the impact of a change in the base rate on the balance sheets of firms brought about by the associated change in the opportunity cost of retained earnings.

[6] This formulation exhibits two principal differences to that of Godley and Lavoie. Firstly, in order to achieve an homogeneous $I(1)$ specification, internal funds and the debt-servicing cost are deflated by the price level as opposed to being normalised by capital. Secondly, the independent variables in the Godley-Lavoie specification are lagged but they are treated contemporaneously here to provide richer contemporaneous interaction; of course the vector autoregressive framework will naturally capture lagged effects as well.

[7] Note that it is not average q which is typically of interest but marginal q, which is unobservable. However, Hayashi (1982) demonstrates that the two quantities are equal when various conditions relating to the installation function, the nature of competition and the constancy of returns-to-scale are met.

Secondly, the inclusion of Tobin's q provides a mechanism whereby market sentiment can affect the investment decision. During a financial boom, the market value of equity increases relative to the replacement cost of capital. In such a situation, the acquisition of second-hand capital assets (takeovers) becomes relatively less attractive than the purchase of new capital, which may be expected to stimulate non-financial investment. Furthermore, if one assumes that changes in q are driven predominantly by asset prices, then it may be viewed as a proxy for market sentiment. Increasing optimism among market participants will drive asset prices up, increasing q. Such bull markets typically reflect favourable conditions in the broader economy and also provide companies with easier access to investment funds, particularly if they are listed. In conjunction with the first point, it is clear that the broad credit channel of monetary transmission operates within the model.[8]

2.1.4 Price and Wage Inflation

The model is completed by two equations characterising price and wage inflation. Minsky and Ferri (1984, pp. 491-2) propose the following relationship:

$$p_t = \gamma_1 \left(\frac{w_t}{\bar{z}_t} \right) + \gamma_2 p_t^e \tag{5}$$

$$w_t = \delta_1 \left(\boldsymbol{x}_t, p_t \right) + \delta_2 p_t^e \tag{6}$$

where w_t is the nominal wage, $\bar{z}$ is average labour productivity, p_t^e is the expected price level, $\boldsymbol{x}_t$ is a vector of real factors influencing the wage-setting process and Greek letters are positive parameters. Following this approach, a general form of the price- and wage-inflation equations may be written as:

$$\Delta p_t = \widetilde{b}_{40} + \widetilde{b}_{41} t + \varphi_{41} \left(\Delta w_t - \Delta z_t \right) + \varphi_{42} \left(y_t - y^* \right) + \varphi_{43} \Delta p_t^e + \widetilde{\xi}_{4,t} \tag{7}$$

$$\Delta w_t - \Delta z_t = \widetilde{b}_{50} + \widetilde{b}_{51} t + \varphi_{51} \Delta p_t + \varphi_{52} \left(y_t - y^* \right) + \varphi_{53} \Delta p_t^e + \widetilde{\xi}_{5,t} \tag{8}$$

For generality, equation (7) follows Gordon (1985) in including the output gap as a measure of demand pressure – we will return to this issue shortly. The coefficient φ_{41} represents the markup of prices over productivity-adjusted wages. Equation (8) represents the process of wage bargaining in which the labour force demands increases in the productivity-adjusted wage rate commensurate with price-level inflation to mitigate downward pressure on the real wage. $\widetilde{\xi}_{4,t}$ and $\widetilde{\xi}_{5,t}$ are stationary mean-zero error processes. Inflation expectations are not, however, readily observable and an uncontroversial proxy remains elusive. In order to overcome this issue, Δp^e is substituted out of the model by combining (7) and (8), yielding:

$$\Delta p_t = b_{40} + b_{41} t + \phi_{41} \left(\Delta w_t - \Delta z_t \right) + \phi_{42} \left(y_t - y^* \right) + \xi_{4,t} \tag{9}$$

where:

[8] Although the investment function does not explicitly include expectations, Godley and Lavoie contend that they are incorporated implicitly in the debt-service term. They argue that any increase in the indebtedness of firms will reduce investment as higher debt in the present period reduces expected future profits.

$$
\begin{aligned}
b_{40} &= \frac{\varphi_{53}}{\varphi_{53}+\varphi_{43}\varphi_{51}}\left[\widetilde{b}_{40}-\frac{\varphi_{43}\widetilde{b}_{50}}{\varphi_{53}}\right] \;;\; b_{41} = \frac{\varphi_{53}}{\varphi_{53}+\varphi_{43}\varphi_{51}}\left[\widetilde{b}_{41}-\frac{\varphi_{43}\widetilde{b}_{51}}{\varphi_{53}}\right] \;; \\
\phi_{41} &= \frac{\varphi_{53}}{\varphi_{53}+\varphi_{43}\varphi_{51}}\left[\varphi_{41}+\frac{\varphi_{43}}{\varphi_{53}}\right] \;;\; \phi_{42} = \frac{\varphi_{53}}{\varphi_{53}+\varphi_{43}\varphi_{51}}\left[\varphi_{42}-\frac{\varphi_{43}\varphi_{52}}{\varphi_{53}}\right] \;; \\
\xi_{4,t} &= \frac{\varphi_{53}}{\varphi_{53}+\varphi_{43}\varphi_{51}}\left[\widetilde{\xi}_{4,t}-\frac{\varphi_{43}}{\varphi_{53}}\widetilde{\xi}_{5,t}\right].
\end{aligned}
$$

If $\phi_{41} = 1$ then wage costs are fully passed through to prices in the long-run while if $\phi_{42} = 0$ then inflation is modelled as a pure cost-push phenomenon in the long-run in line with Minsky and Ferri's specification. Our initial experimentation with the dataset revealed that both of these restrictions are supported by the data. The finding that demand pull factors are not significant drivers of inflation *in the long-run* is perhaps not surprising given that net excesses or deficiencies of demand should be confined to the short-run in an economy which is free to reallocate resources in response to stimuli over a suitably long time-frame.

2.1.5 The Long-Run Structure

Economic theory suggests the existence of the four long-run relationships (1), (3), (4) and (9). These may be imposed as the over-identified long-run structure in a Vector Error Correction Modle (VECM). Garratt, Lee, Pesaran and Shin (2006, GLPS) advance a long-run structural modelling approach which provides for the inclusion of weakly exogenous $I(1)$ variables. This feature may be useful in the current context as it is theoretically appealing to model potential output as weakly exogenous (c.f. GLPS, Assenmacher-Wesche and Pesaran, 2009).

Consider partitioning the m vector of variables comprising the system, $\mathbf{z}_t$, into the m_y and m_x vectors $\boldsymbol{y}_t$ and $\boldsymbol{x}_t$ of endogenous and exogenous variables (respectively). Given the general structural VECM of the form:

$$
\boldsymbol{A}\Delta\boldsymbol{z}_t = \widetilde{\boldsymbol{a}} + \widetilde{\boldsymbol{b}}t + \widetilde{\boldsymbol{\Pi}}\boldsymbol{z}_{t-1} + \sum_{i=1}^{p-1}\widetilde{\boldsymbol{\Gamma}}_i\boldsymbol{\Delta}\boldsymbol{z}_{t-i} + \boldsymbol{\epsilon}_t \tag{10}
$$

GLPS observe that one may write:

$$
\begin{pmatrix} \boldsymbol{A}_{yy} & \boldsymbol{A}_{yx} \\ \boldsymbol{0} & \boldsymbol{A}_{xx} \end{pmatrix}\begin{pmatrix} \Delta\boldsymbol{y}_t \\ \Delta\boldsymbol{x}_t \end{pmatrix} = \widetilde{\boldsymbol{a}} + \widetilde{\boldsymbol{b}}t + \widetilde{\boldsymbol{\Pi}}\begin{pmatrix} \boldsymbol{y}_{t-1} \\ \boldsymbol{x}_{t-1} \end{pmatrix} + \sum_{i=1}^{p-1}\widetilde{\boldsymbol{\Gamma}}_i\begin{pmatrix} \Delta\boldsymbol{y}_{t-i} \\ \Delta\boldsymbol{x}_{t-i} \end{pmatrix} + \begin{pmatrix} \epsilon_{yt} \\ \epsilon_{xt} \end{pmatrix} \tag{11}
$$

where:

$$
\widetilde{\boldsymbol{\Pi}} = \begin{pmatrix} \widetilde{\boldsymbol{\Pi}}_y \\ \boldsymbol{0} \end{pmatrix} = \begin{pmatrix} \widetilde{\boldsymbol{\alpha}}_y \\ \boldsymbol{0} \end{pmatrix}\boldsymbol{\beta}'
$$

and $\mathbf{0}$ denotes a null matrix. The $m_y \times m_y$ and $m_y \times m_x$ matrices $\boldsymbol{A}_{yy}$ and $\boldsymbol{A}_{yx}$ represent the contemporaneous effects of the endogenous and exogenous variables (respectively) on the endogenous variables. The $m_x \times m_y$ null matrix in the lower triangle of $\boldsymbol{A}$ obtains from the exogeneity of $\boldsymbol{x}_t$ and indicates that there can be no contemporaneous impacts of the variables in $\boldsymbol{y}_t$ on those in $\boldsymbol{x}_t$.

The matrix $\widetilde{\boldsymbol{\Pi}}$ defines how the long-run errors $\boldsymbol{\xi}_t$ feed back onto the system. The $m_y \times m$ submatrix $\widetilde{\boldsymbol{\Pi}}_y$ characterises how these errors feed back onto the endogenous variables while the restriction that the lower $m_x \times m$ submatrix of $\widetilde{\boldsymbol{\Pi}}$ is a null matrix ensures that the long-run errors do not feed back onto the variables in $\boldsymbol{x}_t$. The null matrices in $\boldsymbol{A}$ and $\widetilde{\boldsymbol{\Pi}}$ together ensure the exogeneity of the variables in $\boldsymbol{x}_t$. Noting the definition of the long-run reduced form errors, $\boldsymbol{\xi}_t = \boldsymbol{\beta}'\boldsymbol{z}_{t-1}$, and recalling that the vector $\boldsymbol{z}_t$ contains both endogenous and exogenous variables, it follows that the exogenous variables are long-run forcing for the system and can influence the endogenous magnitudes in the long.

Under the assumption of weak exogeneity in which the structural errors from the first m_y and the remaining m_x equations are joint-normally distributed such that $\boldsymbol{\epsilon}_{yt} = \boldsymbol{\Omega}_{yx}\boldsymbol{\Omega}_{xx}^{-1}\boldsymbol{\epsilon}_{xt} + \boldsymbol{\eta}_{yt}$ where $\boldsymbol{\Omega} = \begin{pmatrix} \boldsymbol{\Omega}_{yy} & \boldsymbol{\Omega}_{yx} \\ \boldsymbol{\Omega}_{xy} & \boldsymbol{\Omega}_{xx} \end{pmatrix}$, GLPS decompose equation 11 into the following two equations:

$$\boldsymbol{A}_{yy}\Delta\boldsymbol{y}_t + \boldsymbol{A}_{yx}^*\Delta\boldsymbol{x}_t = \widetilde{\boldsymbol{a}}_y^* + \widetilde{\boldsymbol{b}}_y^* t - \widetilde{\boldsymbol{\Pi}}_y\boldsymbol{z}_{t-1} + \sum_{i=1}^{p-1}\widetilde{\boldsymbol{\Gamma}}_{yi}^*\Delta\boldsymbol{z}_{t-i} + \boldsymbol{\eta}_{yt} \quad (12)$$

$$\boldsymbol{A}_{xx}\Delta\boldsymbol{x}_t = \widetilde{\boldsymbol{a}}_x + \widetilde{\boldsymbol{b}}_x t - \widetilde{\boldsymbol{\Pi}}_{xx}\boldsymbol{x}_{t-1} + \sum_{i=1}^{p-1}\widetilde{\boldsymbol{\Gamma}}_{xi}\Delta\boldsymbol{z}_{t-i} + \boldsymbol{\epsilon}_{xt} \quad (13)$$

where $\widetilde{\boldsymbol{a}}_y^* = \widetilde{\boldsymbol{a}}_y - \boldsymbol{\Omega}_{yx}\boldsymbol{\Omega}_{xx}^{-1}\widetilde{\boldsymbol{a}}_x$, $\widetilde{\boldsymbol{b}}_y^* = \widetilde{\boldsymbol{b}}_y - \boldsymbol{\Omega}_{yx}\boldsymbol{\Omega}_{xx}^{-1}\widetilde{\boldsymbol{b}}_x$, $\widetilde{\boldsymbol{\Gamma}}_{yi}^* = \widetilde{\boldsymbol{\Gamma}}_{yi} - \boldsymbol{\Omega}_{yx}\boldsymbol{\Omega}_{xx}^{-1}\widetilde{\boldsymbol{\Gamma}}_{xi}$, $\boldsymbol{A}_{yx}^* = \boldsymbol{A}_{yx} - \boldsymbol{\Omega}_{yx}\boldsymbol{\Omega}_{xx}^{-1}\boldsymbol{A}_{xx}$ and where the vectors $\widetilde{\boldsymbol{a}}$ and $\widetilde{\boldsymbol{b}}$ and the matrix $\widetilde{\boldsymbol{\Gamma}}_{yi}$ are partitioned into endogenous and exogenous sub-vectors and sub-matrices denoted by the subscripts y and x, respectively. Based on their decomposition of equation 11 into the conditional VECM for $\Delta\boldsymbol{y}_t$ (equation 12) and the marginal VAR for $\Delta\boldsymbol{x}_t$ (equation 13), GLPS write the full system as:

$$\boldsymbol{A}^*\Delta\boldsymbol{z}_t = \widetilde{\boldsymbol{a}}^* + \widetilde{\boldsymbol{b}}^* t - \widetilde{\boldsymbol{\Pi}}\boldsymbol{z}_{t-1} + \sum_{i=1}^{p-1}\widetilde{\boldsymbol{\Gamma}}_i^*\Delta\boldsymbol{z}_{t-i} + \boldsymbol{\epsilon}_t^* \quad (14)$$

denoting:

$$\boldsymbol{A}^* = \begin{pmatrix} \boldsymbol{A}_{yy} & \boldsymbol{A}_{yx}^* \\ \boldsymbol{0} & \boldsymbol{A}_{xx} \end{pmatrix}, \ \widetilde{\boldsymbol{\Pi}} = \begin{pmatrix} \widetilde{\boldsymbol{\Pi}}_{yy} & \widetilde{\boldsymbol{\Pi}}_{yx} \\ \boldsymbol{0} & \widetilde{\boldsymbol{\Pi}}_{xx} \end{pmatrix}, \ \widetilde{\boldsymbol{a}}^* = \begin{pmatrix} \widetilde{\boldsymbol{a}}_y^* \\ \widetilde{\boldsymbol{a}}_x \end{pmatrix}$$

$$\widetilde{\boldsymbol{b}}^* = \begin{pmatrix} \widetilde{\boldsymbol{b}}_y^* \\ \widetilde{\boldsymbol{b}}_x \end{pmatrix}, \ \widetilde{\boldsymbol{\Gamma}}_i^* = \begin{pmatrix} \widetilde{\boldsymbol{\Gamma}}_{yi}^* \\ \widetilde{\boldsymbol{\Gamma}}_{xi} \end{pmatrix} \text{ and } \boldsymbol{\epsilon}_t^* = \begin{pmatrix} \boldsymbol{\eta}_{yt} \\ \boldsymbol{\epsilon}_{xt} \end{pmatrix}.$$

The reduced form of the system is achieved in the usual way by pre-multiplying all terms by $\boldsymbol{A}^{*-1}$. Identification, estimation and testing then proceed in the usual manner.

Formal structural modelling is not considered here due to the dependence of the results on various strong modelling assumptions and on a limited number of deep parameters (GLPS make a similar point). Rather, orthogonalisation is achieved via Cholesky factorisation, thereby imposing a Wold-causal ordering on the variables. For this reason, the variables in $\boldsymbol{z}_t = (\boldsymbol{x}_t|\boldsymbol{y}_t)'$ are ordered as follows:

$$\boldsymbol{z}_t = (p_t^o, y_t^*, q_t, \Delta w_t - \Delta z_t, \Delta p_t, r_t, d_t, f_t, i_t, y_t)'$$

where p_t^o is the price of crude oil and $d_t = (r_{l,t} - \Delta p_t)\, l_t$. The oil price is included to account for the effects of the OPEC oil shocks, the Gulf wars and the recent turbulence in global oil markets.

The proposed ordering reflects the sequence of economic decisions. The variables p_t^o and y_t^* are placed first as they are treated as weakly exogenous $I(1)$ forcing variables. q_t is the first of the endogenous variables, followed by Δw_t and Δp_t. This ordering reflects the Minskyan view of the inflationary process. The inflationary pressure leads the central bank to raise the interest rate, r_t. The rate change will affect both the debt-servicing cost (d_t) and internal funds(f_t), which will then influence the investment decision (i_t) and output (y_t).

The four long-run relationships may be written in terms of the long-run deviations from equilibrium as follows:

$$\boldsymbol{\xi} = \boldsymbol{\beta}_{ov}' \boldsymbol{z}_{t-1} - \boldsymbol{b}_0 - \boldsymbol{b}_1 t$$

where $\boldsymbol{b}_0 = (b_{10}, b_{20}, b_{30}, b_{40})'$, $\boldsymbol{b}_1 = (b_{11}, b_{21}, b_{31}, b_{41})'$, and $\boldsymbol{\beta}_{ov}$ is the over-identified cointegrating matrix:

$$\boldsymbol{\beta}_{ov}' = \begin{pmatrix} 0 & 1 & 0 & 0 & -\phi_{11} & \phi_{11} & 0 & 0 & 1 & -1 \\ 0 & -\phi_{22} & 0 & 0 & \phi_{21} & -1 & 0 & 0 & 0 & \phi_{22} \\ 0 & -\phi_{34} & \phi_{33} & 0 & 0 & 0 & \phi_{32} & \phi_{31} & -1 & \phi_{34} \\ 0 & -\phi_{42} & 0 & \phi_{41} & -1 & 0 & 0 & 0 & 0 & \phi_{42} \end{pmatrix}$$

Thus far, very little has been said about the nature of the deterministic time trends included in the long-run relationships and captured by the vector $\boldsymbol{b}_1$. In general, it is likely that b_3 will be non-zero as a result of economic growth. Meanwhile, it is plausible *ex ante* that the output gap, inflation and the interest rate may co-trend. These hypotheses can be easily investigated empirically.

3 The Dataset

3.1 Data Used in Estimation

The dataset consists of 95 quarterly observations for the US economy between 1985Q1 and 2008Q3 on the following variables: the real price of crude oil (p_t^o); potential output (y_t^*); Tobin's average q (q_t); productivity-adjusted wage inflation ($\Delta w_t - \Delta z_t$); consumer price inflation (Δp_t); the Federal funds rate (r_t); the real debt-service cost (d_t); corporate non-financial internal funds (f_t); real gross corporate non-financial investment (i_t); and real GDP (y_t). All variables are logged prior to estimation. Full details of the data sources and manipulations are recorded in the Appendix.

We choose to end our sample before the switch to unconventional monetary policy in the US. The Global Financial Crisis saw drastic initial cuts in short-term nominal interest rates in the US, after which they have remained constant proximate to the zero lower bound and a combination of quantitative easing and forward guidance has emerged as the preferred policy. Consequently, it is generally acknowledged that no systematic relationship between the interest rate, inflation and output gap can be discerned in this period (Hofmann and Bogdanova, 2012). Bearing in mind that a key element of the FIH is the contention that manipulation of the interest rate may exacerbate financial fragility it would be inappropriate to estimate our model over the crisis period when no such manipulation has occurred. Rather, we will focus on the period leading up to the crisis, during which financial fragility built up and interest rate manipulation played a key role in macroeconomic management.

We compute potential output using the production function approach. This is generally considered preferable to the use of atheoretical estimates of trend output derived from statistical detrending as it makes use of available information about installed production technologies and factors of production. We adopt the 'benchmark output gap' approach used by the Bank of Japan (2003) in which potential output is defined as that level of output that would be achieved if all factors of production were utilised to the fullest possible extent, regardless of the inflationary consequences. By construction, this will always result in a negative output gap. This approach has the advantage that it avoids the controversy surrounding estimation of the NAIRU which is inherently unobservable (c.f. Staiger et al., 1997). Our computation is based on a linearly homogeneous transcendental logarithmic (translog) production function which is estimated by maximum likelihood simultaneously with the associated cost share functions to avoid the bias issues raised by Kim (1992). In order to compute potential output, we first obtain parameter estimates using realised data and then use these in conjunction with estimates of potential capital and labour inputs to impute the level of output consistent with full factor utilisation. A detailed discussion may be found in the Appendix.[9]

4 Estimation of the Model

The order of the VAR model is determined in the normal manner using model selection criteria. The results are summarised in Table 1.[10] AIC favours the inclusion of two lags while SIC selects just one. Given this ambiguity we select the VAR(2) specification in the expectation of achieving a richer dynamic structure. The Johansen cointegration test results are presented in Table 2. Based on the simulated critical values tabulated by Harbo et al. (1998), both the asymptotic as well as the small sample adjusted trace statistics indicate four cointegrating relationships.

TABLES 1 & 2 ABOUT HERE

The derivation of the long-run structure above admits a number of modelling choices relating to the reaction function of the central bank, the nature of the inflationary process etc. The structure that receives the greatest support from the data is that in which: (i.) the central bank acts as a pure inflation targeter in the long-run; and (ii.) inflation is modelled as a cost-push phenomenon in the long-run where wage inflation changes are fully passed through to price level inflation. Furthermore, empirical testing provides little support for the inclusion of deterministic trends in either (1), (3) or (9) as expected. For the reader's convenience and in the interest of clarity, the estimated long-run relations are:

$$y_t = b_{10} + \phi_{11}(r_t - \Delta p_t) + \phi_{13} y_t^* + \xi_{1,t}\ , \quad \phi_{13} = 1 \tag{15}$$

$$r_t = b_{20} + \phi_{21}\Delta p_t + \xi_{2,t} \tag{16}$$

$$i_t = b_{30} + b_{31}t + \phi_{31} f_t + \phi_{32} d_t + \phi_{33} q_t + \xi_{3,t} \tag{17}$$

$$\Delta p_t = b_{40} + \phi_{41}(\Delta w_t - \Delta z_t) + \xi_{4,t}\ , \quad \phi_{41} = 1 \tag{18}$$

while the over-identified long-run matrix $\boldsymbol{\beta}'_{ov}$ is estimated as follows:

[9] As a robustness check we also estimate potential output using a log-linearised constant returns-to-scale Cobb-Douglas function and find that the results are very similar.

[10] The figures reported result from the estimation of an unrestricted VAR model comprising y_t, r_t, Δp_t, $\Delta w_t - \Delta z_t$, i_t, f_t, d_t and q_t, as well as the exogenous variables y_t^* and p_t^o.

$$\begin{pmatrix} 0.000 & 1.000 & 0.000 & 0.000 & 8.973 & -8.973 & 0.000 & 0.000 & 0.000 & -1.000 \\ 0.000 & 0.000 & 0.000 & 0.000 & 2.809 & -1.000 & 0.000 & 0.000 & 0.000 & 0.000 \\ 0.000 & 12.880 & 0.809 & 0.000 & 0.000 & 0.000 & -0.818 & 2.072 & -1.000 & -12.880 \\ -0.001 & 0.000 & 0.000 & 1.000 & -1.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \end{pmatrix}$$

and finally $\boldsymbol{b}_1 = (0.000 \;\; 0.000 \;\; 0.004 \;\; 0.000)'$.

Estimation of this over-identified structure involves the imposition of 36 restrictions on $\boldsymbol{\beta}$, representing $36 - 4^2 = 20$ over-identifying restrictions. The resulting likelihood ratio of 88.309 indicates that the over-identified structure is firmly rejected at the 10% level where the asymptotic critical value is 31.41. However, the poor performance of the LR test in small samples is well documented (c.f. GLPS, p. 140). Therefore, we employ non-parametric bootstrapping with 1999 iterations which results in a mean likelihood ratio of 52.942, and yields critical values of 71.159 (10%), 77.316 (5%), 83.093 (2.5%) and 89.308 (1%), thereby providing support for our over-identified structure. Furthermore, the stability of the system is evident from the persistence profiles reported in Figure 2, which show that a systemwide shock exerts only a *temporary* effect, after which the system returns to its equilibrium state (Lee and Pesaran, 1993; Pesaran and Shin, 1996).

FIGURE 2 ABOUT HERE

4.1 Dynamic Analysis

4.1.1 A Positive Interest Rate Shock

The principal concern of this paper is testing the central proposition of the FIH that the central bank may exacerbate financial fragility by pursuing anti-inflationary monetary policy. To this end, Figure 3 plots the orthogonalised impulse response functions (OIRFs) following a one standard deviation positive interest rate shock. The figures include bootstrapped 90% confidence intervals as an indication of statistical significance.[11] Recall that OIRFs have a structural interpretation conditional on the ordering of the variables in the system (more accurately a Wold-causal interpretation) and that shocks to non-stationary variables can have permanent effects in cointegrating systems, so the OIRFs need not asymptote to zero as the horizon increases. We also report orthorgonalised forecast error variance decompositions (OFEVDs) in Figure 4. The OFEVDs show the percentage of the h-step-ahead forecast error variance (FEV) for each variable in the system attributable to each other variable. As such, they provide valuable supplementary information about the interlinkages among the variables in the model.

FIGURE 3 & 4 ABOUT HERE

The OIRFs provide strong evidence that a positive interest rate shock is associated with an immediate increase in the real cost of debt servicing. This finding is strongly consistent with the recent results of Drehmann and Juselius (2012) who show that changes in the central bank's short-term interest rate are transmitted to the real economy by changes in debt service costs in Europe. The observed increase is significant for approximately four quarters before it dies out.[12] After a short delay, the policy shock is also associated

[11]These intervals are based on the non-parametric method allowing for parameter uncertainty with 1999 bootstrap iterations.

[12]Interestingly, in the long-run the estimated effect of the interest rate innovation is negative, although this result is only marginally statistically significant at some longer horizons and not significant at all at others. Furthermore, it appears that this may be associated with reduced borrowing as the observed effect coincides with a stark long-run reduction in investment.

with a lasting reduction in firms' internal funds in a manner broadly consistent with the balance sheet effects stressed by the credit channel literature. Similarly, the OFEVD for debt-service cost reported in Figure 4(e) indicates that approximately 60% of the FEV is explained by interest rate innovations in the short-run and that this proportion falls but nevertheless remains non-neglible in the long-run. By contrast, the OFEVD for firms' internal funds (Figure 4(f)) indicates a relatively small role for interest rates, with the large majority of the FEV being attributable to internal funds themselves in the short-run and q in the long-run.

These results are consistent with the FIH. Recall the definitions of the current and intertemporal financial ratios offered by Sordi and Vercelli (2006) and discussed in Section 2. It is clear that the combination of increasing cash-outflows and falling cash-inflows will cause k_t to increase for the representative firm. Moreover, as agents' expectations are revised in light of the new higher interest rate, it follows that k_t^* will also increase. At the aggregate level, this will be reflected by a general shift through the hedge-speculative-Ponzi spectrum and by the prevalence of increasingly fragile financing arrangements.

Interestingly, we find that the interest rate innovation exerts no statistically significant effect on either Tobin's q or real output, although it does depress real investment with a moderate lag. The resilience of the stock market and real output is likely to be linked, and is related to the results obtained by Angeloni et al. (2003). The authors estimate a VAR model for the US economy from 1984 to 2001 using an identification scheme proposed by Gordon and Leeper (1994). Their results indicate that while private investment responds negatively to a monetary policy shock, neither private consumption nor aggregate demand show any significant response. Similarly, Boivin et al. (2010) find that an unexpected federal funds rate shock has no significant effect on real GDP based on their estimation of a factor augmented VAR as well as a simple three-equation VAR model for the US economy for the period 1984 to 2008.

Finally, we observe a mild positive reaction of productivity-adjusted wage inflation to the shock. This is consistent with the observation that labour productivity is highly procyclical while wages show a high degree of persistence and are downwardly sticky. Therefore, the positive response may result from a combination of falling productivity and relatively stable wage payments. By contrast, we observe no significant effect on price-level inflation based on the GDP deflator, a result which is again consistent with the findings of Boivin et al. and which links to the growing debate over the relative importance of good policy as opposed to good luck during the Great Moderation.

4.1.2 A Positive Inflation Shock

In order to assess the implications of the long-run cost-push inflationary process specified above, Figure 5 presents OIRFs for all variables in response to a positive inflation shock. Such a scenario may result from changes in inflation expectations or from an adverse supply shock, for example. The shock has significant effects on both price inflation and wage inflation (in the latter case only in the long-run), debt-servicing costs, the interest rate and aggregate output, but not on the remaining variables in the system.

The two most important results are the positive responses of the nominal interest rate and the cost of debt-servicing to the inflation shock. The former reflects the systematic operation of anti-inflationary monetary policy during the sample period given the well documented *de facto* inflation targeting mandate of the Federal Reserve. This is also reflected in the FEVDs reported in Figure 4(d) which show that inflation innovations explain approximately 30% of the total FEV for the interest rate in the long-run. This is a very large proportion when one considers that the majority of the interest rate FEV is accounted for by the interest rate itself, a result which is strongly consistent with the well established literature on inertial monetary policymaking (Greenwood-Nimmo and Shin, 2013).

FIGURE 5 ABOUT HERE

Our finding that the shock exerts a profound and persistent positive effect on the real cost of debt-servicing is very interesting and is certainly consistent with the remarkable increase in business borrowing over our sample period given that inflation remained low and stable for the majority of this time (i.e. low inflation rates were associated with low interest rates and rapid growth of the debt stock). The observed positive response is likely to be driven by different forces in the short-run as opposed to the long-run. In the short-run, the inflationary erosion of the loan principle may encourage firms to take on more debt.[13] Such behaviour is consistent with opportunism on the part of firms which act to exploit the benefits that a high inflation environment affords borrowers. In the longer-term, as a result of inflation-targeting monetary policy, the real interest rate faced by borrowers increases. This can be readily seen in the OIRFs as the long-run response of inflation to the shock is smaller than that of the nominal interest rate. In the longer-term, firms are therefore faced with higher ongoing costs of servicing their debts. The interpretation of the remaining OIRFs is generally straightforward. The inflationary shock is associated with mild wage inflation in the long-run, in keeping with the nature of wage settlements and wage indexation in modern economies. Meanwhile, the shock exerts a contractionary influence on economic activity in the long-run reflecting the contractionary increases in both the nominal and real rates of interest triggered by the inflationary pressure.

4.1.3 'Irrational Exuberance'

Finally, the model can be used to investigate the nature of so-called *irrational exuberance* (Greenspan, 1996). Figure 6 presents OIRFs of all variables to a positive shock to Tobin's q, reflecting the inflation of equity prices relative to the replacement cost of capital assets. Firstly, it is important to note the significant increase in both realised output and real investment which last for between twelve and fifteen quarters. From a Minskyan perspective, this reflects a generally euphoric market sentiment associated with robust demand and minimal financing constraints. The importance of innovations to Tobin's q in explaining the variance in private investments and aggregate output is also clearly reflected in Figures 4(g) and 4(h).

Given the expansionary nature of the shock, it is not surprising to note that it exerts a significant positive effect on the interest rate. Importantly, however, the shock has no noticeable effect on the rate of inflation; indeed, the FEVDs reported in Figure 4(c) suggest that variations in Tobin's q contribute a negligible proportion of the FEV for the inflation equation. Interestingly, it is also the case that q does not contribute significantly to the interest rate FEV (Figure 4(d)). As noted above, however, the shock exerts a powerful influence on both real output and real investment, both of which do contribute significantly to the interest rate FEV. This suggests that the effect of Tobin's q on the interest rate may come about indirectly. These findings are intimately linked with the extensive literature on the optimal monetary policy response to the stock market. Recall that a central bank pursuing a pure inflation targeting strategy would *not* respond to a stock market shock unless it was reflected in a change in its targeted inflation index – here, that is not the case. By contrast, it follows that a central bank whose reaction function includes an output term such as the rate of output growth or the output gap may raise rates in this case as the

[13] The reasoning is as follows: if Δp_t increases by more than r_t, then for $(r_t - \Delta p_t)\, l_t$ to remain constant, l_t must increase.

shock exerts a non-negligible expansionary influence on economic activity. Hence, there may be good reasons for the inclusion of the output gap in monetary policy rules if one believes that interest rates should indirectly respond to conditions in the asset markets.

Figures 6(f) and 4(f) reveal a strong negative response of internal funds to the Tobin's q shock, a finding which seems counter-intuitive at the first glance. However, careful consideration of the definition of the internal funds employed here offers a plausible explanation. Internal funds are defined as profits after corporate income tax plus capital consumption allowance minus net dividends. Therefore, a negative response of f may arise if dividend payouts increase more strongly than profit income in response to an asset price shock. Such a procyclical effect of dividend payouts is in line with recent findings by Covas and Haan (2011) who study the cyclical behavior of debt and equity finance of US firms. Firms are inclined to increase dividend payouts as they do not face such restrictive conditions when accessing external capital as their net worth position improves as well.

FIGURE 6 ABOUT HERE

5 Implications for Monetary Policy

Our principal finding that conventional monetary policies may exacerbate the frailties of the financing arrangements of firms raises a number of issues for policymakers. Given the fundamental linkage between Minskyan financial fragility and speculative booms discussed above, these issues are perhaps best discussed in relation to the existing literature on the relationship between asset prices and monetary policy.

The general view of central bankers toward smoothing asset cycles is eloquently captured by ex-Chairman Greenspan (2002, ¶17):

> [N]othing short of a sharp increase in short-term rates that engenders a significant economic retrenchment is sufficient to check a nascent bubble. The notion that a well-timed incremental tightening could have been calibrated to prevent the late 1990s bubble is almost surely an illusion. Instead, we...need to focus on policies to mitigate the fallout when it occurs and, hopefully, ease the transition to the next expansion.

Four main reasons underlie the popular focus on inflation-targeting and the neglect of asset price terms in the monetary policy rule. Firstly, the *Schwartz Hypothesis* (Schwartz, 1988, 1998) that price level instability begets financial instability is typically offered as justification for inflation-targeting strategies that omit asset price growth.[14] Secondly, following Tinbergen (1952), it is often argued that the number of targets of monetary policy should be at most equal to the number of instruments. Thirdly, many commentators highlight the difficulties in identifying bubbles *ex ante* (Gurkaynak, 2005, provides a good survey). Finally, it is often argued that the cost-benefit analysis of bubble-pricking interest rate policies is unfavourable due to the collateral damage that would be inflicted on non-bubble sectors of the economy (c.f. Posen, 2006; Nickell, 2005).

However, a substantial minority has dissented from this view. They argue, firstly, that the Schwarz Hypothesis has been violated by the existence of bubbles during prolonged periods of stable inflation. Secondly, speculative excesses are distributionally sub-optimal, diverting investment from productive to speculative ends, and furnishing an *a priori* case

[14] Schwartz argues that instability of the price level (particularly disinflation) may cause financial instability. She stresses that it may exacerbate the problems associated with informational asymmetries and introduce greater uncertainty in the lending process, especially as regards the evaluation of the expected returns to debt-funded investment projects.

for intervention. Thirdly, in the event of a large price correction, the solvency of financial institutions may be compromised (Schwartz, 2002). This effect has been highlighted emphatically during the GFC. Finally, there is little reason to believe that the identification of bubbles poses problems not already experienced in the estimation of potential output and the equilibrium exchange rate (c.f. Cecchetti et al., 2000). Three positions are dominant among the dissenting authors. The first holds that asset market indicators should enter the objective function directly (see Roubini, 2006, and the references therein). The second is that the targeted measure of inflation should include various asset prices, appropriately weighted (Goodhart, 2001). The final approach, associated with Cecchetti et al. (2000), is that policymakers should consider but not target asset prices.

Our results have implications for both sides of the debate. On the one hand, our results stress that financial fragility as defined above is intimately linked to speculative excesses, suggesting that to prevent the latter would also mitigate the former. While Schwartz (2002, p. 23) stresses that the central bank "is not the arbiter of the correct level of asset prices", it has become clear through recent events that markets left unfettered and free may be rather self-destructive. The underlying issue is not the desirability of avoiding boom-bust cycles but rather the issue of how to achieve this end. Our model has implications for this debate as it is built upon Minskyan foundations which suggest a close link between interest rate changes and financial fragility, and thereby cautions against the use of the interest rate to influence the trajectory of asset prices. We therefore reject both the *laissez-faire* approach advocated by Greenspan (2002) and the activist approach associated with Roubini (2006) and instead we identify a need to manage asset cycles *without* recourse to manipulation of the interest rate.

In the words of Chairman Bernanke (2006), the interest rate is a 'blunt tool' incapable of addressing individual overheated markets. However, in the era of unconventional monetary policy, it is clear that the central bank possesses alternative policy instruments that may be used to smooth asset cycles in a more targeted fashion. In the case where one's intention is to stimulate the markets, a combination of quantitative easing and forward guidance has emerged as the preferred and seemingly successful policy measure (Bernanke, 2012). Where the intention is to cool an overheated market then one may employ countercyclical capital requirements (CCRs). Such a countercyclical system has been proposed under the auspices of the Basel III framework, although considerable ambiguity over the precise details of its implementation remains.

An early contribution that clearly outlines the role of capital requirements was provided by Schwartz (2002), who stresses that the use of quantity constraints to curtail unsafe lending in excessively bullish markets directly protects the portfolios of financial institutions from large corrections in the value of collateral assets. Schwartz advocates that the central bank should engage in the active management of capital requirements to ensure that the balance sheets of financial institutions are not compromised in the event of a substantial correction in the price of collateral assets. Indeed, in a sentiment that has gained much resonance in recent years, she stresses that it is the role of the central bank to ensure that taxpayers' money is not used to reinforce the balance sheets of failing financial institutions where it can be avoided by judicious pre-emptive action (p. 2). This safeguarding of the liquidity of financial institutions is achieved without relying on the promise of lender of last resort interventions, which Minsky argued would increase the losses associated with moral hazard on the part of lenders, thereby contributing to financial fragility (c.f. Minsky, 1986a, p. 64). Furthermore, by raising the operating costs of financial institutions, CCRs provide incentives for the modification of lending practices without coercion, thereby providing a mechanism by which capital allocation is adjusted endogenously rather than by decree.

Contemporary research in the field has largely focused on the design and implementation of CCRs and has yielded insights into the operational framework including tackling the fundamental issue of identifying periods in which buffers should either be accumulated are disbursed (e.g. Drehmann et al., 2010, 2011). A rapidly developing strand of the literature is concerned with the effectiveness of CCRs in stylised macroeconomic models. Working with the large BoC-GEM-Fin model at the Bank of Canada, de Resende et al. (2013) argue that a combination of conventional monetary policy and CCRs can successfully attenuate both real and financial cycles. This is a key point for our analysis – the adoption of CCRs is consistent with the ongoing use of conventional monetary policy via manipulation of the short-term nominal interest rate. Indeed, by granting policymakers an extra tool, the introduction of CCRs allows policymakers to conduct conventional policy to maintain price stability even as they use CCRs in the pursuit of financial stability.

Our results can feed into the development of this literature as they demonstrate a link between interest rates and financial fragility. A central bank faced with high levels of financial fragility may therefore strive to maintain a roughly constant or at least highly predictable path of nominal interest rates to avoid exacerbating conditions in the financial markets. Therefore, the central bank is free to pursue anti-inflationary interest rate policy provided that it does not risk precipitating a deterioration in the soundness of the financial system insodoing. If it is felt that interest rate rises may contribute to unacceptable levels of financial fragility, then the central bank must desist as its primary responsibility is to ensure the stability of the financial system.[15] However, by judicious use of CCRs, the central bank may be able to avoid the emergence of excessive fragility in the first instance.

6 Concluding Remarks

This paper has developed a small macroeconomic model embodying many of the key attributes of the Minskyan Financial Instability Hypothesis. The model is composed of a simple IS curve, an inflation-targeting interest rate rule, an investment function inspired by that of Godley and Lavoie (2001), and a mark-up pricing rule. This theoretical framework was then imposed as the over-identifying long-run structure in a VECM.

The results suggest that the manipulation of the interest rate by the central bank in order to achieve an inflation target may contribute to the financial fragility of leveraged firms. Raising the interest rate reduces firms' internal funds while increasing their debt-burden, thereby undermining their ability to service existing debt. Furthermore, the results indicate that price level inflation may not capture conditions in the financial markets, an observation which is consistent with the combination of low and stable price level inflation and high levels of asset price inflation experienced by many developed countries during the Great Moderation. This suggests that if monetary policymakers respond solely to fluctuations in the rate of price level inflation, they will not react to the inflation of nascent asset market bubbles. By contrast, our results suggest that where policymakers also respond to the output gap then they will indirectly respond to asset market conditions as well. Our results therefore highlight an important practical distinction between a pure inflation targeting mandate and a dual mandate.

Our findings raise the difficult issue of how policymakers can approach the smoothing of asset cycles and the management of nascent bubbles. We conclude that the central bank must acknowledge that conditions in financial markets may impose constraints on its freedom to pursue anti-inflationary interest rate policy and that it must remain mindful of its fundamental responsibility to maintain financial stability. Furthermore, by employing countercyclical capital requirements, the central bank would gain the ability to target

[15] Mimir et al. (2012) also note that there may be difficult a tradeoff between financial stability and price stability because CCRs prove inflationary in their model.

overheated markets in a manner that would strengthen the balance sheets of financial institutions while simultaneously reducing the speculative excesses that are among the main drivers of financial fragility. By pursuing this combined approach, interest rate volatility may be kept to a minimum, uncertainty in credit markets may be reduced, and the monetary authority would gain the power to achieve multiple goals in a manner consistent with the targets-and-instruments approach originated by Tinbergen (1952).

Appendix

The Estimation of Potential Output

The transcendental logarithmic (translog) specification is written as:

$$\begin{aligned} ln(Y_t) &= ln(A_0) + \alpha_L ln(L_t) + \alpha_K ln(K_t) + \frac{1}{2}\beta_{LL}\{ln(L_t)\}^2 + \frac{1}{2}\beta_{KK}\{ln(K_t)\}^2 \\ &+ \beta_{LK} ln(L_t) ln(K_t) + \beta_{tL} ln(L_t) t + \beta_{tK} ln(K_t) t + \alpha_t t + \beta_{tt} t^2 + \epsilon_t \end{aligned} \quad (19)$$

where Y_t, L_t and K_t denote output, labour input and capital input in non-logged form. In order to achieve a tractable specification, linear homogeneity is imposed by setting $\alpha_L + \alpha_K = 1$, $\beta_{LK} = \beta_{KL}$, $\beta_{LL} = \beta_{KK}$, $2\beta_{LL} = -\beta_{LK}$ and $\beta_{tL} = -\beta_{tK}$. Substituting these restrictions into (19) yields:

$$\begin{aligned} ln(Y_t) &= ln(A_0) + \alpha_L ln(L_t) + (1-\alpha_L) ln(K_t) + \frac{1}{2}\beta_{LL}\{ln(L_t)\}^2 + \frac{1}{2}\beta_{LL}\{ln(K_t)\}^2 \\ &- 2\beta_{LL} ln(L_t) ln(K_t) + \beta_{tL} ln(L_t) t - \beta_{tL} ln(K_t) t + \alpha_t t + \beta_{tt} t^2 + \epsilon_t \end{aligned} \quad (20)$$

It is well established that OLS estimation of (20) is biased (see, for example, Kim, 1992). To overcome this problem, maximum likelihood estimation is employed in the simultaneous estimation of equation 20 and the associated cost-share equations, which Kim defines as:

$$\begin{aligned} S_L &= \frac{\delta ln(Y)/\delta ln(L)}{\delta ln(Y)/\delta ln(L) + \delta ln(Y)/\delta ln(K)} \\ S_K &= \frac{\delta ln(Y)/\delta ln(K)}{\delta ln(Y)/\delta ln(L) + \delta ln(Y)/\delta ln(K)} = 1 - S_L \end{aligned}$$

where S_L and S_K denote the cost shares of labour and capital, respectively, and sum to unity by construction. Under the assumption that S_L and S_K are logistic-normally distributed, one may log-linearise as follows:

$$ln(S_L) = \frac{\delta ln(Y)}{\delta ln(L)} - \left[\frac{\delta ln(Y)}{\delta ln(L)} + \frac{\delta ln(Y)}{\delta ln(K)}\right]$$

$$ln(S_K) = \frac{\delta ln(Y)}{\delta ln(K)} - \left[\frac{\delta ln(Y)}{\delta ln(L)} + \frac{\delta ln(Y)}{\delta ln(K)}\right]$$

from which it is straightforward to obtain:

$$ln\left[\frac{S_L}{S_K}\right] = ln\left[\frac{\alpha_L + \beta_{LL} ln(L) - 2\beta_{LL} ln(K) + \beta_{tL} t}{\alpha_K + \beta_{LL} ln(K) - 2\beta_{LL} ln(L) - \beta_{tL} t}\right] + e_t \quad (21)$$

where $e_t \sim N(0, \sigma_e^2)$ is an idiosyncratic error process. In order to estimate potential output from (20) and (21), parameter estimates are first obtained using realised data, and these are then used in conjunction with estimates of potential capital and labour inputs to impute the level of output consistent with full factor utilisation.

Data Used in Estimation of the CVARX Model

The following sources were consulted in collecting the data:

FRB: The Federal Reserve Board of Governors

NIPA: The National Income and Product Accounts

FoF: The Flow of Funds Accounts (Release Z1)

BLS: The Bureau of Labor Statistics

FRED: The Federal Reserve Economic Data Service

Realised output, y_t, is the log of real GDP (NIPA: GDP Table 1.1.6 row 1, SA) converted into index form with base year 2000.

The base rate, r_t, is the Federal funds rate (FRB: H15/H15/RIFSPFF_N.M) converted from monthly to quarterly frequency and logged. To maintain the annual rate characteristics of the series, the following log-transofrmation is employed: $r_t = \frac{1}{4} ln\left(1 + \frac{R_t}{100}\right)$.

Price level inflation, Δp_t, is computed as the log-difference of the GDP deflator (NIPA: GDP Table 1.1.4 row 1), again expressed as an annual rate.

Real cash flow, f_t, is proxied by internal funds, defined as the book value of US internal funds of the nonfinancial corporate sector (FoF: FA106000135.Q, SA), deflated by the GDP deflator. The series is indexed and logged.

Tobin's q is the ratio of the market value of corporate equity (FoF: FL103164103.Q, adjusted using Census X12) to the linearly interpolated net corporate total fixed capital stock (NIPA: Fixed Assets Table 6.1). The series is indexed and logged.

Real investment, i_t, is corporate non-financial gross fixed capital investment (FRB: Z1/Z1/FA105019005.Q, SA) deflated by the GDP deflator, indexed and logged.

The real debt-service cost, d_t, is defined as the product of the real prime loan rate and the deflated stock of outstanding corporate credit market liabilities excluding equities (FoF: FL384104005.Q, SA). The real prime lending rate is constructed as the prime loans rate (FRB: H15/H15/RIFSPBLP_N.M) minus the rate of inflation (monthly data is converted to quarterly frequency). The series is then indexed and logged.

Productivity-adjusted wage inflation, $\Delta w_t - \Delta z_t$ is the logarithmic approximation computed as 400 times the difference between the first difference of the log of hourly compensation (BLS: PRS88003103, SA) and the log of hourly output (BLS: PRS88003093, SA) for the non-financial corporate sector. The resulting series is logged and expressed as an annual rate.

The price of crude oil, p_t^o, is the West Texas Intermediate spot oil price (FRED: OILPRICE, NSA, X12) converted from monthly to quarterly frequency, indexed and logged.

Data Used in the Computation of Potential Output

Realised output, Y_t, is quarterly GDP data in chained 2000 dollars (NIPA: GDP Table 1.1.6 row 1, SA).

The realised labour input, L_t, is equal to the product of civilian employment (BLS: LNS12000000, SA) and hours worked (regular hours (BLS: CES0500000007, SA) plus overtime in the manufacturing sector (BLS: CES3000000009, SA)). Quarterly employment data is generated from monthly data.

Potential labour input, L_t^*, is equal to the civilian labour force (BLS: LNS11000000, SA) multiplied by the maximum legal working hours before overtime (assumed to be 40 per week here) plus the trend overtime hours calculated by HP filtering ($\lambda = 1600$).

The utilised capital input, K_t, is the product of total net capital stock (private and governmental – NIPA: Fixed Asset Table 1.1, row 2) and the utilisation rate (FRB: G17/CAPUTL/CAPUTL.B50001.S.Q). Quarterly capital stock data is computed by linear interpolation. The series is deflated by the GDP deflator.

The potential capital input, K_t^*, is equal to the deflated total net capital stock.

Technical progress, t, is a simple cumulative sum process, $t = 0, 1, 2, ..., T - 1$.

The labour cost-share, S_L, is defined as the sum of employee compensation (NIPA: GDP Tables 6.2A-D, row 1), employer social security contributions (NIPA: GDP Tables 6.10B-D, row 1) and pension and insurance contributions (NIPA: GDP Tables 6.11A-D, row 1). All series are deflated by the GDP deflator. The labour share is computed as labour cost/(labour + capital cost).

The capital cost-share, S_K, is equal to the deflated total net capital stock multiplied by the real loan rate plus deflated depreciation (NIPA: Fixed Asset Table 1.3, row 2). The capital share is computed as capital cost/(labour + capital cost). Note that S_L and S_K sum to unity by construction.

Finally, note that the NIPA data used in the computation of potential output was at annual frequency and was therefore linearly interpolated to generate quarterly series. Note also that the value taken by potential output in the base year is not 100. Rather, it is indexed relative to the level of potential output in the base year to maintain the negative sign of the output gap.

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Lags	LL	AIC	SIC	p(LR)
5	2796.2	-51.6	-42.3	0.0000
4	2712.5	-51.2	-43.6	0.0003
3	2652.8	-51.3	-45.5	0.0151
2	2607.3	-51.7	-47.6	0.0000
1	2536.3	-51.5	-49.1	

NOTE: LL denotes the log-likelihood, AIC the Akaike Information Criterion, SIC the Schwarz Information Criterion and p(LR) the p-value of the likelihood ratio test.

Table 1: Selection of the VAR Lag Length

Rank	Eigenvalue	Trace statistic	p-value (asymp.)	p-value (adj.)
0	0.650	349.7	0.000	0.000
1	0.553	249.9	0.000	0.000
2	0.458	173.4	0.004	0.002
3	0.313	115.1	0.029	0.069
4	0.313	79.4	0.081	0.134
5	0.184	46.1	0.312	0.378
6	0.161	26.8	0.324	0.363
7	0.100	10.0	0.455	0.474

NOTE: This table reports results for the Johansen trace statistic for the VAR(2) model under Case IV (unrestricted constant and restricted trend) conditional on the I(1) variables p_t^o and y_t^* which are restricted to the cointegrating space. p-values are computed via Doornik's gamma approximation. Both asymptotic and sample-size adjusted p-values are shown.

Table 2: Selection of the Cointegrating Rank of the System

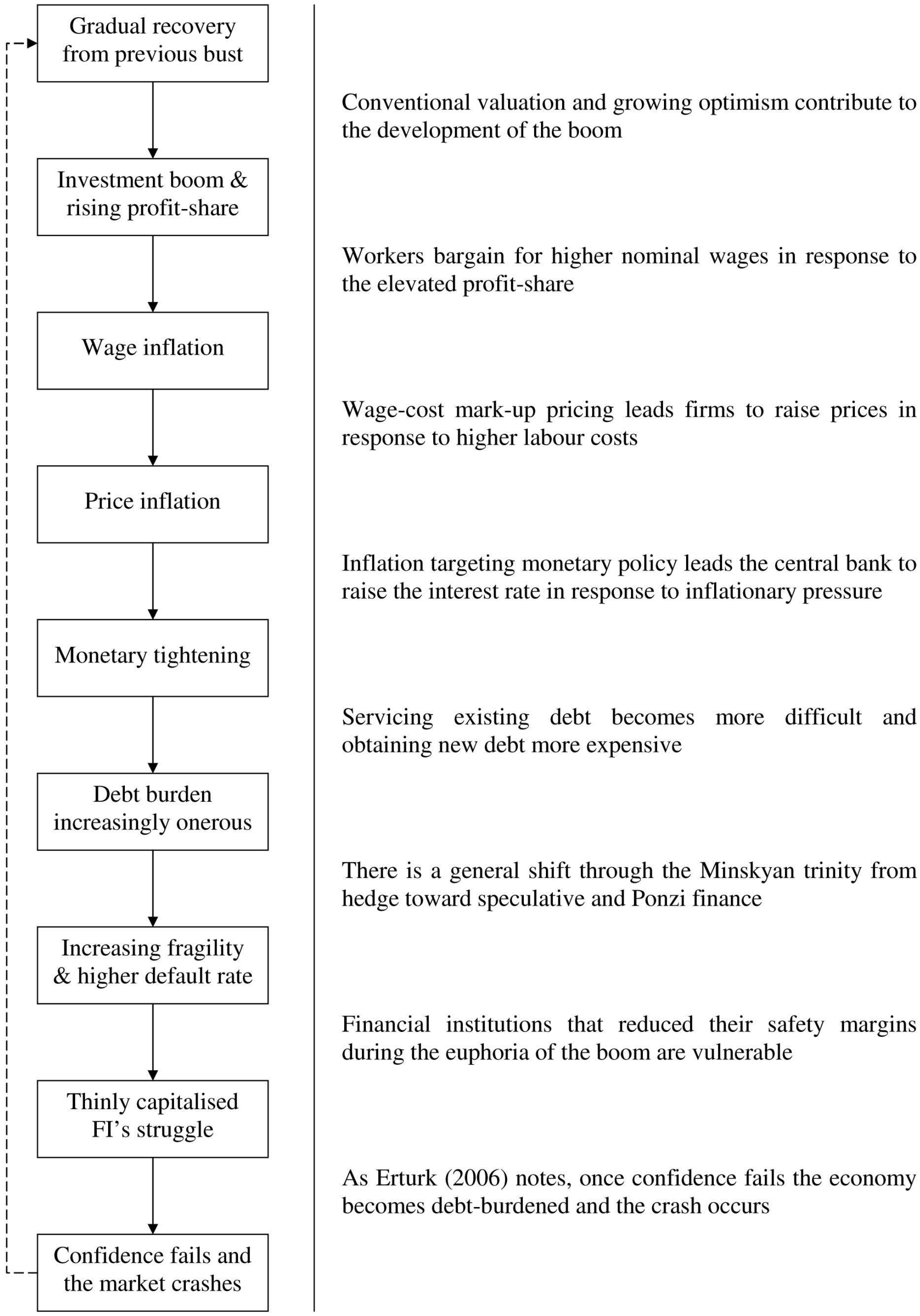
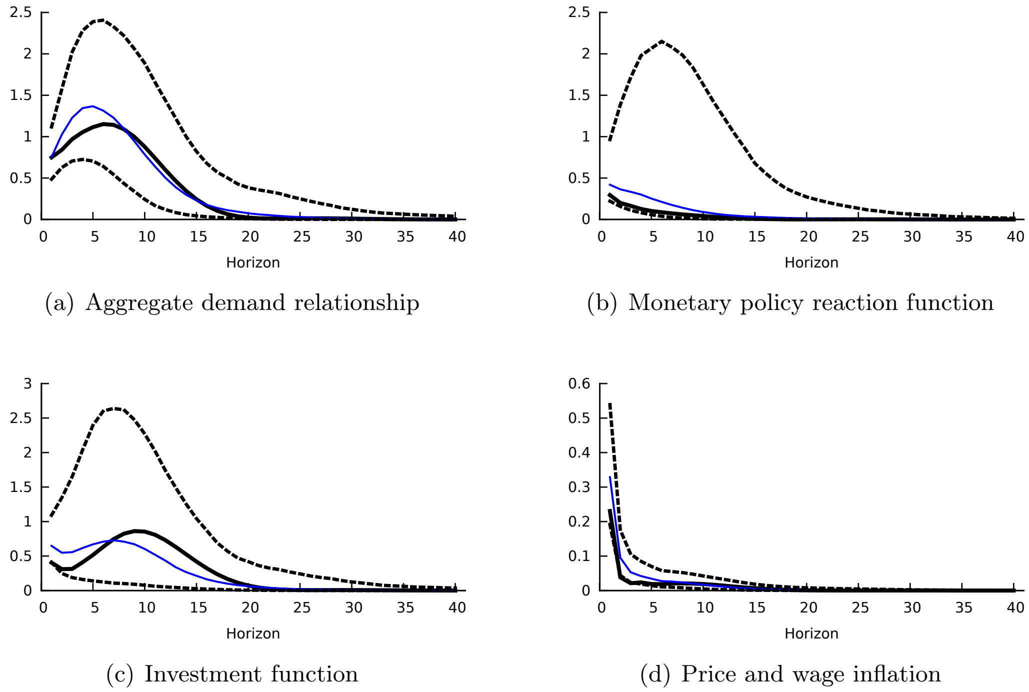


Figure 1: A Schematic Representation of the Minksyan Boom-Bust Cycle



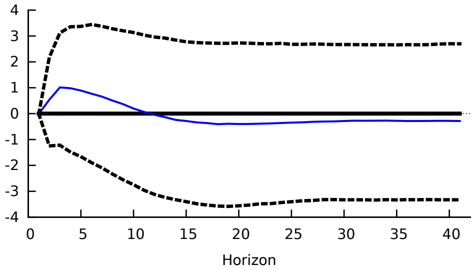
(a) Aggregate demand relationship

(b) Monetary policy reaction function

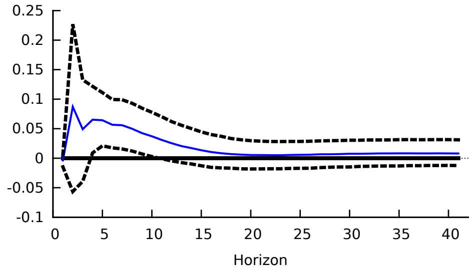
(c) Investment function

(d) Price and wage inflation

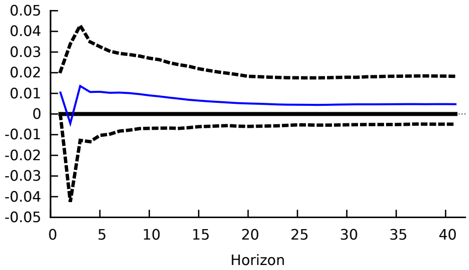
Figure 2: Persistence Profiles of the Effect of a System-wide Shock to the Cointegrating Relations with 90% bootstrapped confidence intervals (blue line: bootstrapped median value)



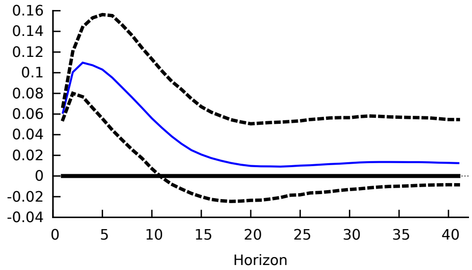
(a) q (percentage change)



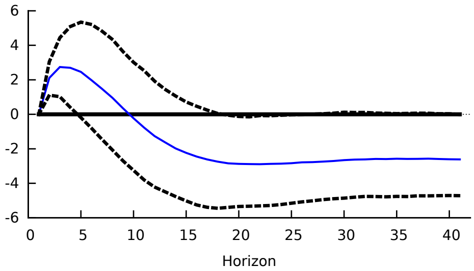
(b) $\Delta w - \Delta z$ (% per annum)



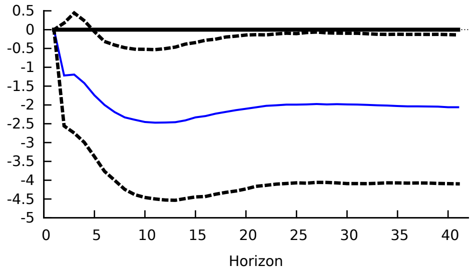
(c) Δp (% per annum)



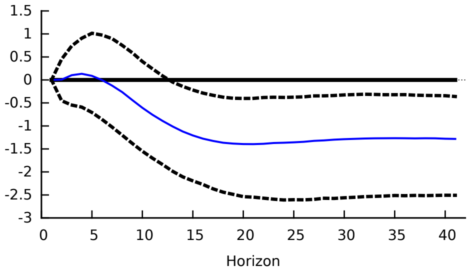
(d) r (% per annum)



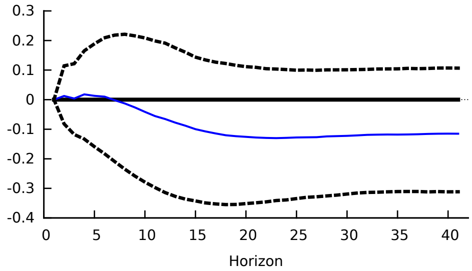
(e) d (percentage change)



(f) f (percentage change)

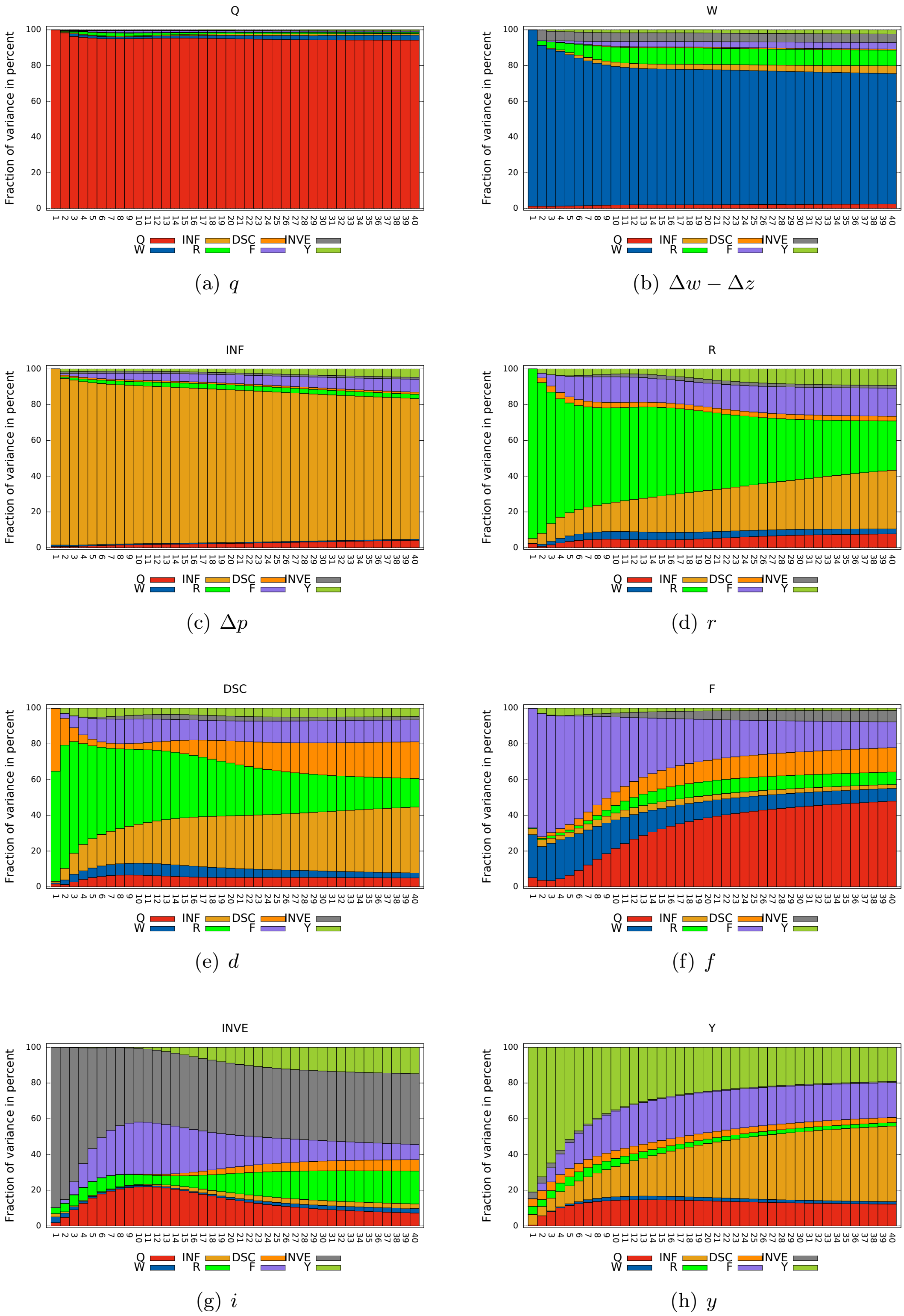


(g) i (percentage change)



(h) y (percentage change)

Figure 3: OIRF of a Positive Shock to the Interest Rate on all Variables with 90% bootstrapped confidence intervals (bootstrapped median value)



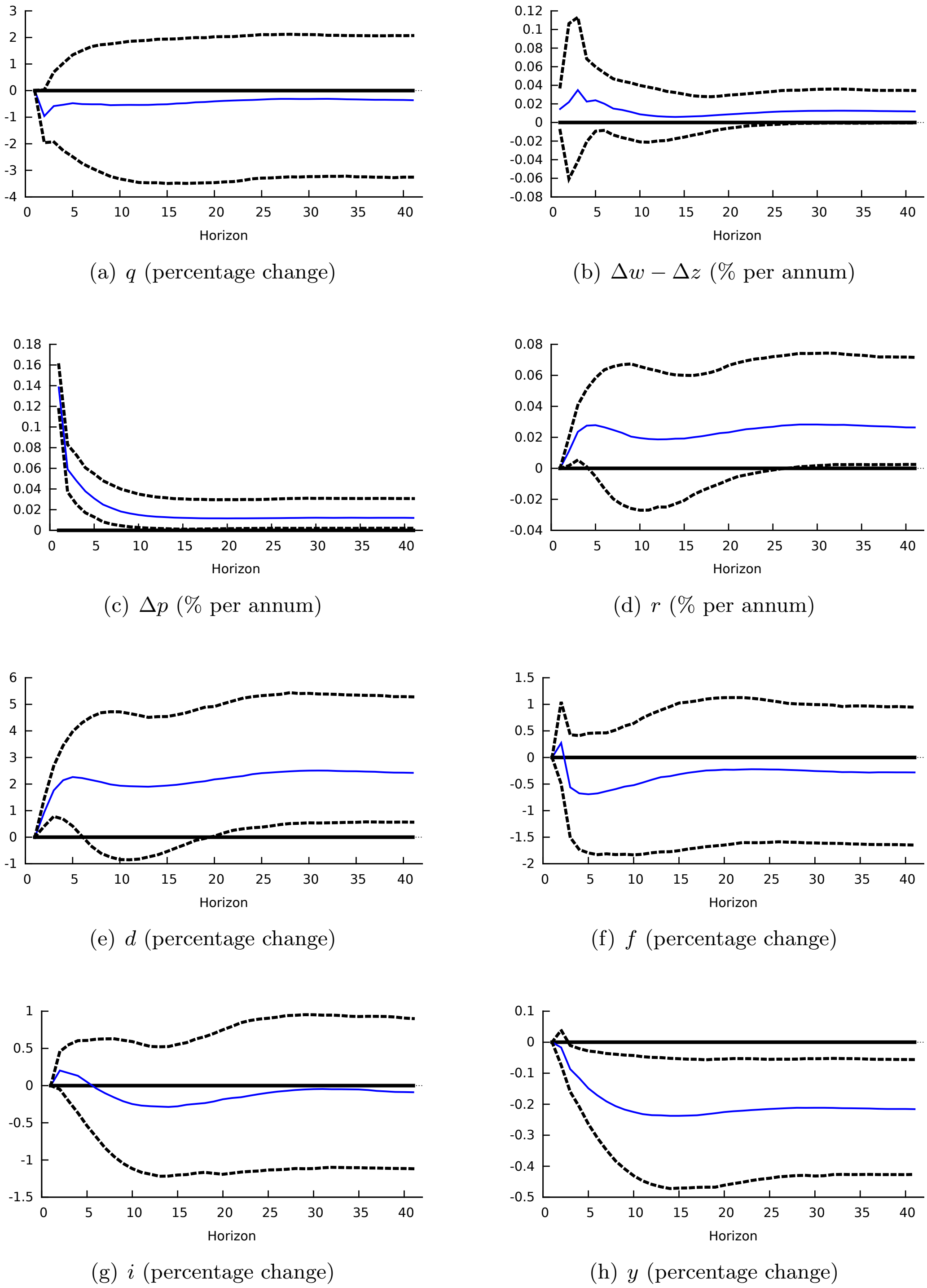
(a) q (b) $\Delta w - \Delta z$

(c) Δp (d) r

(e) d (f) f

(g) i (h) y

Figure 4: FEVD of all Variables, in %. Q, W, INF, R, DSC, F, $INVE$ and Y refer to Tobin's q, the rate of wage inflation, price inflation, the interest rate, debt-servicing costs, cash flow, investment demand and aggregate output



(a) q (percentage change)

(b) $\Delta w - \Delta z$ (% per annum)

(c) Δp (% per annum)

(d) r (% per annum)

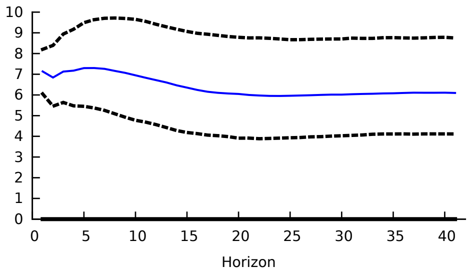
(e) d (percentage change)

(f) f (percentage change)

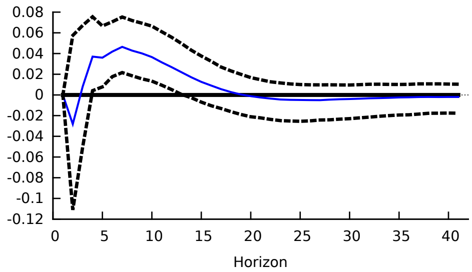
(g) i (percentage change)

(h) y (percentage change)

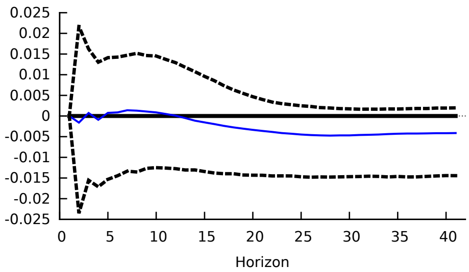
Figure 5: OIRF of a Positive Shock to Inflation on all Variables with 90% bootstrapped confidence intervals (bootstrapped median value)



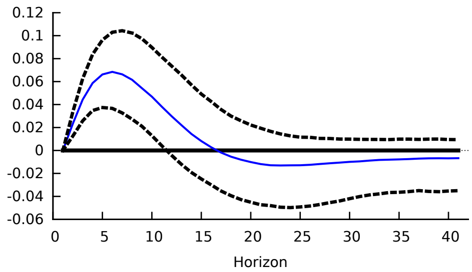
(a) q (percentage change)



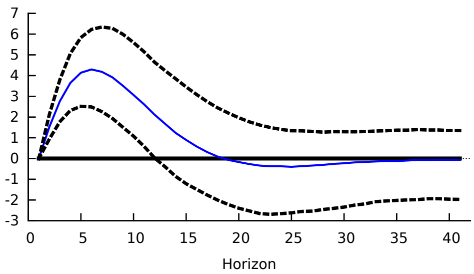
(b) $\Delta w - \Delta z$ (% per annum)



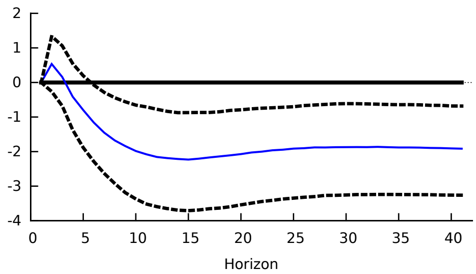
(c) Δp (% per annum)



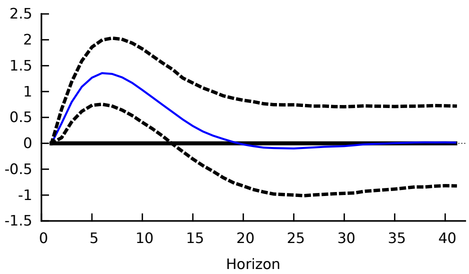
(d) r (% per annum)



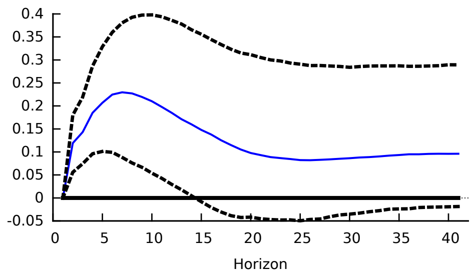
(e) d (percentage change)



(f) f (percentage change)



(g) i (percentage change)



(h) y (percentage change)

Figure 6: OIRF of a positive Shock to Tobin's q on all Variables with 90% bootstrapped confidence intervals (bootstrapped median value)