Competition Effects of Financial Shocks on Business Cycles

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Abstract

Previous work that analysed the role of financial shocks in business cycles focus on changes in the production of existing goods (the "intensive margin"). Instead, this paper focuses on the changes in the range of available goods produced (the "extensive margin"). Firms can invest into production lines of new goods (which affects competition), in addition to investing into increasing production for goods in their current product portfolio. A credit contraction induces firms to reduce product investment, leading to lower competition and higher markups. The increase in market imperfections decrease consumption demand by increasing prices, as well as lowering labour demand and wages, reducing household income. This amplifies the response of consumption to financial shocks. Relative to the counterfactual of no competition effect, the peak impact on consumption by a credit supply shock is 44% greater, and the standard deviation of consumption is 31% higher. This paper also empirically establishes VAR evidence consistent with the mechanisms, and the DSGE model is able to match the VAR impulse responses on the predicted channels. The transmission channel implies that to avoid excessive inflation, it is important to take into account the lowering of the natural rate of output – and the smaller slack – by the increase in market imperfections.

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"... almost all cyclical movements in output since 1973 are attributable to markup variations."

– Julio J. Rotemberg and Michael Woodford (1999)

1 Introduction

Since the 2008-10 global financial crisis, there has been renewed interest in how shocks originating from the financial sector have effects on the real economy. The past literature has focused on the intensive margin of investment – the changes in production of existing goods. In this paper, I instead investigate the role of the extensive margin of investment, changes in the range of available goods, to explore a novel transmission channel of financial shocks. Specifically, I document this channel empirically and theoretically, using an endogenous product variety dynamic stochastic general equilibrium model.

It is widely documented that markup cyclicality can contribute to business cycle fluctuations, and one determinant of markups is competition. The credit contraction prevents firms from investing into new product lines and results in less competition in product markets. Firms charge higher markups, impeding the recovery as goods are more expensive. This competition channel amplifies the initial financial shock by inducing a greater fall in consumption.

Firstly with a VAR, I establish empirically (like the past literature) that credit supply contractions lead to lower loan issuance and exhibit effects typical of demand shocks – reductions in output and inflation. But importantly, I also show that during tight credit conditions, the number of establishments fall and markups rise, consistent with my competition channel.

Secondly, to quantify the real effects of competition, I build in a financial sector into the Bilbiie, Ghironi, and Melitz (2012) endogenous product variety DSGE model, that incurs writeoff (financial) shocks that reduces banks' loan-issuing capacity. The results suggest that the interaction of the extensive margin of investment and countercyclical markups increases the peak consumption response to financial shocks by 44%. This corresponds to increasing consumption volatility by 31%. This implies that if the extensive margin and competition effects are not considered, a policymaker would over-attribute the cause of the real effects of credit supply shocks to the intensive margin of investment. The implication is that given competition takes time to recover, policymakers should take this into account in order not to over-estimate the amount of slack available and implement excessively stimulatory policies, as greater market imperfections imply a lower natural level of output.

The transmission channel works as follows. I model a financial shock as an asset-writeoff shock to banks, representing an exogenous credit supply contraction.[1] The financial shock forces banks to deleverage and contract their credit supply, leading firms to reduce new product investment. I abstract away from the adverse systemic risk effects on the broader financial system, and instead focus on the frictions this event creates in the real sector through competition. This has a direct reduction on household income as the sector that creates new products has to shrink, due to the credit contraction. However, I focus on the impact of this competition channel. As the number of products (competitors) fall, markups rise, resulting in a fall of consumption demand due to higher prices. At the same time, the reduction in aggregate demand decreases labour demand and wages, leading to a fall in hours worked. This leads to a further drop in household income, which exacerbates the fall in consumption demand. The DSGE model's prediction of the channels through the reduction in competition, rise in markups and the fall in real wages is confirmed by VAR evidence to a credit supply shock. The model with variable markups manages to more closely track the path of the fall in consumption demand well, while the constant markup model fails to match the magnitude of the fall in consumption.

This paper is most closely related to two strands of literature. The first strand the endogenous product variety and firm entry literature. I adopt the ideas from Bilbiie, Ghironi, and Melitz (2012) of product varieties and variable markups as a transmission mechanism in a standard RBC model. They are also the first to adopt a broader interpretation of products, rather than firms, in a business cycle setting. Note that 'product entry' does not necessarily mean research and development of new products (which tends

[1]One interpretation is that it can represent the large asset writedowns banks suffered during the 2008-10 financial crisis. For example, in the period around the end of 2007, Citigroup wrote-down approximately $39 billion of assets, largely due to its exposure to sub-prime mortgages. This is very large proportion of its $120 billion of total equity capital. At the time, Citigroup was the largest bank in the United States by total assets.

to be long-term, and is not very cyclical). Kung and Bianchi (2015) instead emphasise 'technology diffusion' – where firms invest into producing new products which have been already invented, but by entering the market increases competition. Henceforth, I will use the term 'products' and 'varieties' synonymously with technological diffusion. The new literature on enodgneous product varieties has moved away from firm entry, as start-ups tend to be small and have little aggregate implications. However, the value of product creation is much more substantial. From the production-side, Bernard, Redding, and Schott (2010) document using 5-digit SIC manufacturing data that 10% of value-weighted production is new products, in a given year. At business-cycle frequencies, this adds up to around 40% of production consists of new products, a significant amount. Interestingly, they also note that 94% of product additions occur within *existing* firms. From the consumption side, using barcode-level data, Broda and Weinstein (2010) show that 40% of a typical consumer's basket consists of products created in the last four years (roughly coinciding with the numbers from Bernard, Redding, and Schott (2010)). A similar literature on firm entry includes Bergin and Corsetti (2008), Lewis and Poilly (2012), Lewis and Stevens (2013) and others.

Furthermore, Broda and Weinstein (2010) show that net product creation is highly procyclical (a 1% increase in sales lead to a 0.35% increase in product creation). In addition, the procyclicality of net product creation is driven by gross creation, rather than product destruction. This is consistent with the idea that credit constraints affect firms' ability to finance entries, which in turn affect the economy's product base and competition. Nevertheless, if we allow for an endogenous product destruction rate in response to credit contractions (for example, see Hamano and Zanetti (2015)), this would strengthen the channel here.

The empirical linkage between competition and markups naturally comes from the international trade literature, often from estimating the Melitz and Ottaviano (2008) model. For example, Chen, Imbs, and Scott (2009) demonstrate that higher competition (proxied by import penetration) leads to lower prices and markups. Montero and Urtasun (2014) reports a more direct connection to markups using the Bank of Spain's credit registry data. They show a positive and statistically significant association between industry markups and a direct measure of market concentration, as well as a proxy of financial pressure. A review of the role of variable markups in business cycles can be seen in Rotemberg and Woodford (1999).

The second strand is the real effects of financial shocks. The paper is closely aligned, but from an extensive-margin perspective, to Jermann and Quadrini (2012). They document the cyclical properties of debt and equity financing flows, build a model that assigns a role for financing, and replicate simultaneously real aggregate variables and financial flows to see the role of financial shocks. The extensive margin is also complementary to Queralto (2014), who attempt to explain 'slow recoveries from financial crises', by supply-side effects through endogenous TFP growth by firm creation. Instead, I examine the demand-side effects occurring from changes in market structure. A complementary paper on the role of financial shocks on markups is Gilchrist, Sim, Schoenle, and Zakrajšek (2014). They have a framework that firms may wish to increase short term markups in order to boost cash flow when credit is tight. However, this only explains the high frequency fluctuations in markups, as they aim to explain inflation dynamics. This is contrary to the VAR evidence in the next section, which show a more sluggish response of markups to credit tightenings.

Related papers on financial shocks include Del Negro, Eggertsson, Ferrero, and Kiyotaki (2011), Kiyotaki and Moore (2012) and Christiano, Motto, and Rostagno (2014). This line of literature should be differentiated to the financial accelerator models, where the financial sector acts as only an amplification or propagation mechanism of traditional supply or demand shocks, rather than a source of shocks on its own. These models include Bernanke and Gertler (1989), Kiyotaki and Moore (1997), Carlstrom and Fuerst (1997), Bernanke, Gertler, and Gilchrist (1999) and many others.

The rest of the paper is structured as follows. Section 2 summarises the current empirical literature on the real effects of credit shocks, and documents the competition effect with a VAR. Section 3 outlines the DSGE model. Section 4 explains the theoretical results of the model. Section 5 quantitatively compares the theoretical predictions with the VAR results, and offers industry-level empirical evidence that the competition channel exists. Section 6 concludes.

2 The Real Effects of Credit Supply Shocks

In this section, I offer evidence that the competition channel operates in aggregate data, complementing the existing literature on the real effects of credit supply shocks.

2.1 Existing Literature

Two recent papers addressed the difficulty of separating out credit supply and demand movements, empirically documenting that credit supply shocks has significant real effects. Bassett, Chosak, Driscoll, and Zakrajšek (2014) use the Federal Reserve's Senior Loan Officer Opinion Survey, and document that a one standard deviation tightening to a measure of lending standards leads to a substantial (0.75%) decline in output and the core lending capacity by banks fall by 4%. Becker and Ivashina (2014) use Compustat data to calculate when firms start switching from bank to public debt. Any firm that raises new debt must have a positive demand for external funds, eliminating credit demand effects. Changes in debt-issuance behaviour of substituting firms inform us about conditions of aggregate bank credit supply. Despite the sample only including large firms who have access to public debt markets, the index is strong predictor of the likelihood of raising bank debt for firms which have never issued a bond (out-of-sample firms).

In addition, it is also important that credit supply drives investment levels. If firms easily substitute financing to other sources, then credit supply movements has no impact on realised investment (the Modigliani-Miller proposition). However, there is evidence that firms find it difficult and/or costly to substitute funds. Amiti and Weinstein (2013) use a comprehensive, matched lender-borrower dataset of all listed Japanese firms, to show that granular bank shocks account for a significant 40% of the fluctuations in aggregate lending and investment. Notably, they also find these shocks matter during normal times, and not just during crises. Kashyap, Stein, and Wilcox (1993) and Slovin, Sushka, and Polonchek (1993) show that while there is some attempt at substitution during credit contractions, it is not enough to compensate fully, leading to significant effects on investment.

2.2 Competition Effects and Credit Supply

I use a VAR with seven variables: a credit supply indicator, commercial and industrial loans, a competition proxy and markups, alongside the standard macro variables of consumption, inflation and the Federal Funds Rate.[2] The credit supply indicator is a measure credit standards cs_t, from the Federal Reserve Loan Officer Opinion Survey (Bassett, Chosak, Driscoll, and Zakrajšek, 2014). I use an unanticipated bank credit supply tightening in the VAR, to see if it leads to reductions in competition and higher markups. The proxy for competition is the number of establishments, from the Bureau of Labor Statistics' Quarterly Census of Employment and Wages. Establishments are defined as 'economic units' – which could be a farm, a factory, or a store – so this is a close enough proxy to the idea of production lines. Aggregate markups are imputed from the log-inverse of private business labour share, following Nekarda and Ramey (2013) and Rotemberg and Woodford (1999). Inflation is the Personal Consumption Expenditure deflator. I also include C&I loans l_t to gauge the severity of the credit supply shock on realised lending. Logarithms and the first-differencing is applied to all variables, except the credit standards index and the Federal Funds Rate. The sample is quarterly from 1990 to 2009.

The VAR has one lag, as suggested by the Schwarz-Bayesian Information Criterion. The results do not qualitatively change for higher order lag structure, and the results remain statistically significant in a VAR(2). It is identified by a recursive Choleski scheme, with the order:

$$\mathbf{X}_t = [cs_t \; N_t \; \mu_t \; c_t \; \pi_t \; r_t \; l_t]'$$

In other words, the indicator of credit supply are ordered first, so it can affect all other variables contemporaneously, while C&I loans cannot. N is ordered before μ as the level of competition can affect current pricing decisions, but higher markups is unlikely to induce product entry within the same quarter. The ordering of the macroeconomic variables y, π and r is standard in recursively-identified VARs, for example Bernanke and Gertler (1995). Loans are ordered last as the Federal Funds Rate acts as the risk-free benchmark to the price of loans. The results are robust to various

[2]The results are robust if we use GDP instead of consumption.

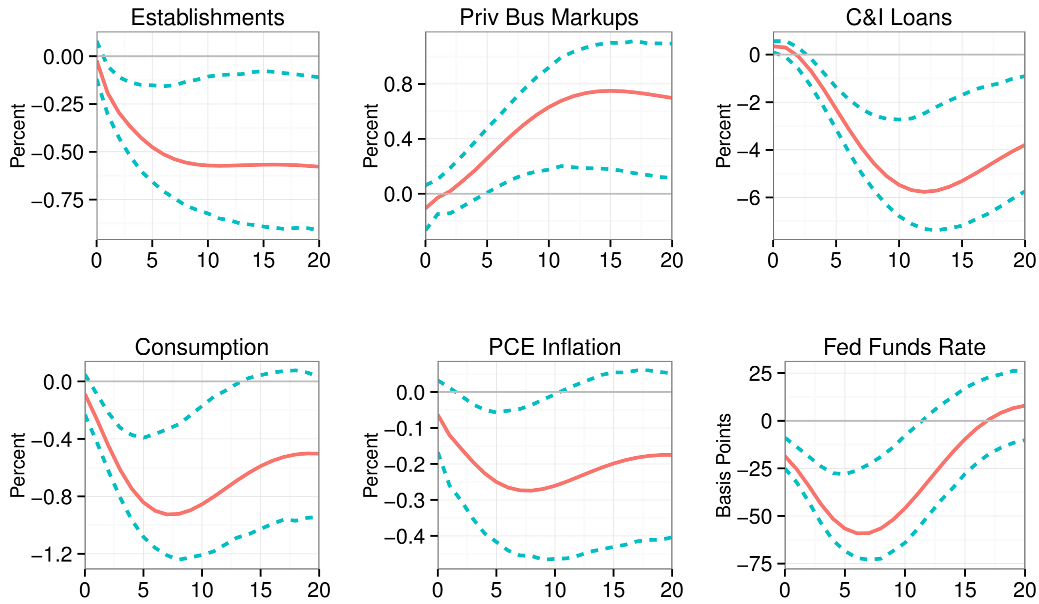

Figure 1: VAR Impulse Responses to a Credit Supply Contraction
(with 90% bootstrapped confidence intervals)

alternative ordering schemes, including when the loans are ordered before the other real variables, and when credit standards are ordered after the macro variables.

Figure 1 plots the impulse responses to a one standard deviation shock to credit standards (equivalent to a bank credit supply contraction), which is as expected for an adverse demand shock. There is a statistically significant negative response on consumption and inflation, and importantly, C&I loans. Comparing with the VAR in Bassett, Chosak, Driscoll, and Zakrajšek (2014), the magnitudes of consumption impulse responses (GDP in their paper), are consistent. Note that the result is robust to using output, instead of using consumption as the indicator of economic activity. They use ‘core lending capacity’ as they aim to measure aggregate lending, which responds less than the IRF of C&I loans here. This could be because C&I loans typically have higher risk weights than residential loans, so C&I loans are cut back more sharply during a credit contraction. However, the more interesting variables are establishments and markups. Establishments slowly fall over time, and becomes statistically significant negative. Markups also rises statistically significant above zero. In addition, the peak

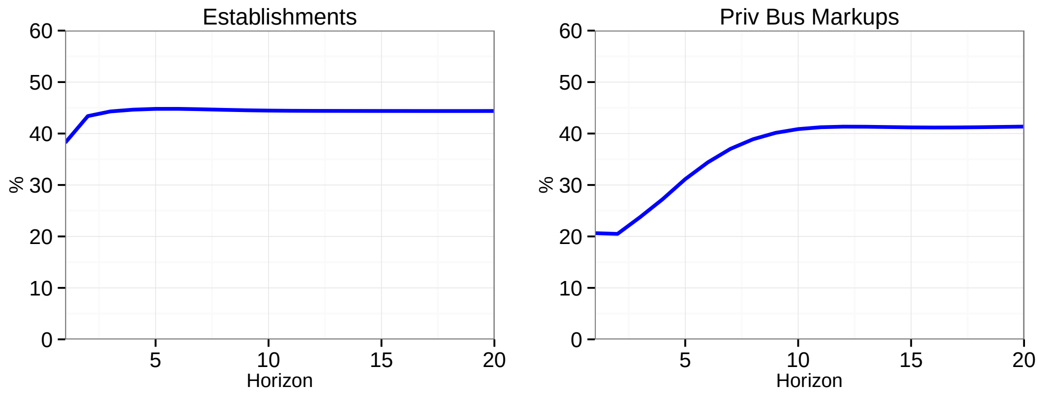

Figure 2: Relative variance decomposition by credit supply shocks

effect is close to the same horizon as the trough of establishments. This is consistent with the hypothesis that the rise is markups is due to competition effects.

Figure 2 plots the relative variance decomposition of two variables of interest. This shows the proportion of the each variable's variance that is not explained by its own shock, that is explained by credit supply shocks. In other words, this illustrates how important credit supply shocks relatively are to other shocks.[3] Credit supply shocks account for a significant 44% and 41% of the unexplained variation in establishments and private business markups, at business cycle horizons. One interesting shock to compare to is monetary policy shocks. Credit supply shocks contributes to explaining establishments and markups than monetary policy shocks, which only accounts for a tenth of what credit supply shocks account for. The results here further lend credibility to the mechanism from credit supply to competition and markups.

Lastly, the estimated DSGE literature such as Smets and Wouters (2007) find that exogenous price markup shocks are large and highly persistent. They account for 15% the fluctuations in GDP and 35-70% in inflation – both non-trivial amounts. Their model is also shown by Bils, Klenow, and Malin (2012) to be inconsistent with product-level CPI micro data on reset price inflation. More specifically, the Smets and Wouters (2007) model predicts reset price inflation to be far too persistent. Competition effects can

[3] The proportion of variance that is explained by all shocks, apart from each variable's own shock, can be seen in the appendix.

help resolve this. After an expansionary shock, competition increases and markups fall. This contributes to explaining why reset price inflation falls much faster after an expansionary shock, than actual inflation. However, I leave the implementation of this mechanism in an estimated medium-scale DSGE model for future research.

3 Model

This section describes the model built to explain the mechanism in a DSGE framework. I introduce a banking sector to the standard Bilbiie, Ghironi, and Melitz (2012) (henceforth, BGM) real business cycle model with endogenous product varieties. I start with the description of the banking sector that finances the creation of new products, as this is the main modelling contribution. I then present the Kimball (1995) aggregator preferences as a microfoundation for variable markups, the agents in the economy and the equilibrium.

3.1 Banking Sector

The role of the bank is to provide loans, which finances the creation of new products. There is a single bank in the economy, which takes in deposits D_t from the households and has its own equity capital E_t. The bank's objective is – as would a firm that maximises shareholder value – to maximise the present discounted value of dividends DIV_t^B. The bank has no limits to how much loans L_t it issues, apart from a capital adequacy ratio. The loans it issues will eventually return back as deposits, so in this sense, it 'creates credit'. These loans L_t are the only assets that the bank has. On the liabilities side of the balance sheet are household deposits D_t and equity capital E_t, leading to the balance sheet identity $L_t = D_t + E_t$. The bank is capital constrained, so equity capital and the capital adequacy ratio determines the maximum amount of loans the bank issues.

$$CAR_t \leq E_t/L_t \tag{1}$$

Like the collateral constraint literature, I assume that the shocks are small enough that the constraint is binding at all times (in steady state, it binds, as writeoffs are positive).

Equity capital at the beginning of the period, evolves with the law of motion:

$$e_{t+1}\mathbb{E}_t\pi^c_{t+1} = e_t(1-\mathbb{E}_t wr_t) + (i^L_t l_t - i^D_t d_t) - div^B_t - \frac{\kappa}{2}\left(\frac{l_t}{l_{t-1}}\right)^2 l_t \quad (2)$$

where the lower case denotes the variables in real consumption goods terms (price index P_t and consumption inflation rate $\pi^c_t = P_t/P_{t-1}$). The term wr_t denotes the asset writeoff shock. Note the timing that banks do not know the realisation of the writeoff (which occurs at the end of the period) when they are making the decision to issue loans. The second term in brackets is the net interest payments the bank receives from its loan-making and deposit-taking operations. The third term is the dividends it pays to households, and the fourth term is loan adjustment costs.

The quadratic loan adjustment costs are in the style of De Nicolò, Gamba, and Lucchetta (2012), which captures the bank's information production costs about credit quality. This is the screening and monitoring per-unit costs when increasing lending, and per-unit liquidation costs when decreasing lending. This parameter will affect the persistence of the credit crunch, initially caused by the asset writeoff shock. I calibrate this parameter to match the persistence of loans to those observed in VAR impulse response.

Thus, the bank's objective is:

$$\max_{\{div^B_t, e_{t+1}, l_t\}^\infty_{t=0}} \mathbb{E}_0 \sum_{t=0}^{\infty} \Lambda_{0,t} div^B_t$$

subject to the capital adequacy requirement, the equity law of motion and the balance sheet identity. $\Lambda_{0,t}$ is the household's stochastic discount factor. The bank's optimality conditions are:

$$i^L_t - i^D_t = \psi_t \cdot CAR_t + \zeta_t \quad (3)$$

$$1 + E_t wr_t = \mathbb{E}_t \frac{\Lambda_{t,t+1}}{\pi^c_{t+1}}\left[(1+i^D_{t+1}) + \psi_{t+1}\right] \quad (4)$$

where $\zeta_t \equiv -\kappa\left(\frac{l_t}{l_{t-1}}-1\right)\frac{l_t}{l_{t-1}} - \frac{\kappa}{2}\left(\frac{l_t}{l_{t-1}}-1\right)^2 + \mathbb{E}_t\Lambda_{t,t+1}\kappa\left(\frac{l_{t+1}}{l_t}-1\right)\left(\frac{l_{t+1}}{l_t}\right)^2$ denotes the loan adjustment cost effects and ψ_t is the Lagrange multiplier on the capital adequacy ratio constraint, which reflects the scarcity of equity capital. Equation (3) reflects how the bank sets a spread of the loan interest rate over the its external funding cost (the deposit interest rate) as an increasing function of the marginal value of equity. The writeoff shock will increase the scarcity value of equity, driving the rise in the loan interest rate. Equation (4) shows how the bank equates the marginal cost of investing into an extra unit of equity on the left hand side (the expected writeoffs), to the discounted marginal benefit of being able to issue more loans with a spread over its funding cost.

In steady state, equation (4) results $\psi = wr/\beta > 0$, where $wr > 0$ is the amount of steady state writeoffs, implying that the CAR constraint binds in steady state. This is equivalent to the standard financial friction models where there is probability of bank's capital being transferred to households, to ensure a financial constraint binds. Equation (3) implies that the steady state spread $i^L - i^D = \psi \cdot CAR$. From this, I can calibrate the steady state CAR and writeoffs (which determine ψ) to match average loan interest rate to the risk-free rate spread, and either observed CAR or writeoffs from the data.

3.2 Preferences

3.2.1 Kimball (1995) Aggregator

A crucial ingredient to the model is a micro-foundation for variable markups. The more conventional translog preferences from Feenstra (2003), adopted by BGM, has one parameter that pins down both the steady state markup and the elasticity of markups with respect to competition. However, the parameter that would match the steady state markup implied by estimated demand elasticities would result in a markup elasticity that is too small compared to the empirical estimates in Section 5.2. Therefore, to achieve both steady state markup and markup elasticities that are empirically grounded, I use the Kimball (1995) consumption aggregator, with the functional form in Dotsey and King (2005) that has two parameters to pin the steady state markup and the markup elasticity.

The aggregator creates a smoothed-kinked (concave) demand curve. At the firm's normal relative share of production, it is easier to lose customers when it raises relative prices, as compared to gaining customers when lowering relative prices. An increase in competition, or the number of varieties, leads to a reduction in the relative share, as consumers value variety and spread their consumption over a larger number of varieties. This effectively shifts demand curve down for a subsidiary producing a particular variety, and more importantly for the channel, it faces a higher demand elasticity – lowering markups. The aim of Kimball (1995) is to use a more flexible demand function that creates another strategic complementarity that amplifies effects of nominal disturbances, to make a model of sticky prices plausible. The effect of the variable demand elasticity is countercyclical markups. Sbordone (2007) also uses this aggregator to investigate the effect of globalisation (i.e. a permanent increase in the number of varieties) on the slope of the Phillips curve. Other uses of the aggregator is in the macro pricing literature (Dotsey and King, 2005; Eichenbaum and Fisher, 2007; Levin, Lopez-Salido, and Yun, 2007; Vigfusson, Sheets, and Gagnon, 2009).

The household's expenditure minimisation problem with the Kimball aggregator and endogenous varieties is:

$$\min_{c_t(\omega)} \int_0^{N_t} p_t(\omega) c_t(\omega) d\omega \quad \text{subject to} \quad \int_0^{N_t} \Psi\left(\frac{c_t(\omega)}{C_t}\right) d\omega = 1, \tag{5}$$

where $\Psi'(\cdot) > 0, \quad \Psi''(\cdot) < 0$. Full derivations can be found in the Appendix. I focus on the symmetric equilibrium (that all subsidiaries produce and charge the same price):

$$\int_0^{N_t} \Psi\left(\frac{c_t(\omega)}{C_t}\right) d\omega = 1 \Rightarrow N_t \Psi\left(\frac{c_t(\omega)}{C_t}\right) = 1 \tag{6}$$

Therefore, the relative share $x_t(\omega) \equiv c_t(\omega)/C_t = \Psi^{-1}\left(\frac{1}{N_t}\right)$ so typically the relative share x_t is not the market share $1/N_t$. The welfare-relevant price index P_t is:

$$P_t = \int_0^{N_t} p_t(\omega) \frac{c_t(\omega)}{C_t} d\omega = \int_0^{N_t} p_t(\omega) \Psi^{-1}\left(\frac{1}{N_t}\right) d\omega$$

Noting that in the symmetric equilibrium $p_t(\omega) = p_t(j)\ \forall i, j \in N$, so:

$$P_t = p_t N_t \Psi^{-1}\left(\frac{1}{N_t}\right)$$
$$\rho_t = \frac{p_t}{P_t} = \frac{1}{N_t \Psi^{-1}\left(\frac{1}{N_t}\right)}$$

where ρ_t is the relative price, which can be thought as the ratio of the producer price index and the consumer price index. This relative price measure will be important for correctly deflating the welfare-relevant variables into the empirically relevant variables.

3.2.2 Dotsey and King (2005) Specification

The Dotsey-King specification is:

$$\psi(x) = \frac{1}{(1+\eta)\gamma}\left[(1+\eta)x - \eta\right]^{\gamma} - \left[1 + \frac{1}{(1+\eta)\gamma}\right] \tag{7}$$

Dotsey and King (2005) highlights that a convenient property of this specification is that the Dixit-Stiglitz CES aggregator is a special case when $\eta = 0$. However, the counterfactual of 'no competition effects' will not be this due to discontinuities is the preferences when $\eta = 0$, causing different behaviour. I will instead use a parameterisation of $\eta < 0$ and γ that generates very low elasticities of markups with respect to varieties. The welfare-relevant aggregate price index can be written as:

$$P_t = \frac{1}{1+\eta}\left[\int_0^{N_t} p_t(\omega)^{\gamma/(\gamma-1)} d\omega\right]^{(\gamma-1)/\gamma} + \frac{\eta}{1+\eta}\int_0^{N_t} p_t(\omega) d\omega \tag{8}$$

The symmetric equilibrium implies that there is a common relative price to all varieties, $\rho_t(\omega) = p_t(\omega)/P_t$. It can be derived from rearranging:

$$P_t = \frac{1}{1+\eta}\left[N_t p_t^{\gamma/(\gamma-1)}\right]^{(\gamma-1)/\gamma} + \frac{\eta}{1+\eta} N_t p_t \tag{9}$$

$$1 = \frac{1}{1+\eta} N_t^{(\gamma-1)/\gamma} \rho_t + \frac{\eta}{1+\eta} N_t \rho_t \tag{10}$$

$$\rho_t = \frac{1+\eta}{N_t^{(\gamma-1)/\gamma} + \eta N_t} \tag{11}$$

As Sbordone (2007) noted, the literature does not offer much guidance for plausible values of η and γ. However, in this instance, there are two obvious calibration targets – the markup elasticity and steady state markups.

Firstly, using the derivations in the Appendix and the functional form, the elasticity of demand and desired markups are:

$$\theta_t = \frac{\Psi'(x_t)}{x_t \Psi''(x_t)} = \frac{\eta - (1+\eta)x_t}{(\gamma - 1)(1+\eta)x_t} \tag{12}$$

$$\mu_t = \frac{\theta_t}{\theta_t - 1} = \frac{\eta - (1+\eta)x_t}{\eta - \gamma(1+\eta)x_t} \tag{13}$$

where the market share x_t is:

$$x_t = \Psi^{-1}\left(\frac{1}{N_t}\right) = \frac{1}{1+\eta}\left\{\eta + \left[(1+\eta)\gamma\left(\frac{1}{N_t} + 1\right) + 1\right]^{1/\gamma}\right\} \tag{14}$$

It can be clearly seen that markups are a function of the relative share x_t, which in turn is a function of the number of varieties N_t. This is the competition effect. Lastly, the elasticity of markups with respect to varieties (around the steady state) is composed of two components through the relative share x:

$$\frac{d \ln \mu}{d \ln N} = \frac{d \ln \mu}{d \ln x} \cdot \frac{d \ln x}{d \ln N} \tag{15}$$

$$\frac{d \ln \mu}{d \ln x} = \frac{\eta(\gamma - 1)(1+\eta)x}{(\eta - (1+\eta)x)(\eta - \gamma(1+\eta)x)} \tag{16}$$

$$\frac{d \ln x}{d \ln N} = -\frac{1}{N \cdot x \cdot \Psi'(x)} = -\frac{1}{N \cdot x \cdot [(1+\eta)x - \eta]^{\gamma - 1}} \tag{17}$$

where the time subscripts are omitted to show the variables are in steady-states. For parameter values in real space, there is no guarantee of a particular sign of the markup elasticity, or the steady state markup. Therefore, one has to be very careful on using the correct parameter space to achieve economically meaningful elasticities and steady state markups. The markup elasticity will be calibrated to values found in industry-level data, discussed in Section 5.

3.3 Independent Subsidiaries

Following BGM, there are monopolistically competitive independent subsidiaries $\omega \in [0, N_t]$ that produce one variety each. Therefore, I will refer to these variety producers as firms and subsidiaries interchangeably. Subsidiaries use labour, with production function $y_t(\omega) = Z_t h_t^C(\omega)$, where Z_t is an exogenous aggregate productivity shock and $h_t^C(\omega)$ is the labour input for a consumption-good producer ω.

Subsidiaries are owned by the parent firm, who they pass on their profits to as dividends:

$$div_t^S(\omega) = \left(\frac{\mu_t(\omega) - 1}{\mu_t}\right)\frac{C_t}{N_t} = \left(1 - \frac{1}{\mu_t}\right)\frac{C_t}{N_t} \tag{18}$$

where the last equality holds as we focus on the symmetric equilibrium. The preferences imply subsidiaries' optimal rule is to set relative prices to a markup $\mu_t = \theta_t/(\theta_t - 1)$ over marginal cost, so $\rho_t = \mu_t \cdot w_t/Z_t$.

3.4 Parent Firm

The parent firm is responsible for maintaining the product base in the economy. It shields the banking sector from defaults, as the product varieties fail randomly. This allows us to abstract away from default effects on the provision and demand of credit, and to focus on competition effects. Like banks, the parent firm maximises the expected present discounted value of dividends it pays to households. It receives profits from all subsidiaries, and pays back the loan it takes from the bank to finance the creation of new varieties N_t^E. The cost of each new variety is c_t^E, and varieties are destroyed at a rate δ. Therefore, the parent firm maximises:

$$\max_{\left\{div_t^P, N_{t+1}, N_t^E\right\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \Lambda_{0,t} div_t^P \tag{19}$$

subject to:

$$div_t^P = N_t div_t^S - (1 + r_{t-1}^L) l_{t-1} \tag{20}$$

$$l_t = c_t^E N_t^E \tag{21}$$

$$N_{t+1} = (1 - \delta)(N_t + N_t^E) \tag{22}$$

where $(1+r^L_{t-1}) = (1+i^L_{t-1})/\pi^C_t$ is the real interest rate on loans. In other words, the dividends div^P_t is the leftover profits after debt servicing. It takes the real interest rate on loans and the cost of entry c^E_t as given. I assume that that new varieties can only be debt financed. This is reliant on the aforementioned stylised fact that firms find it difficult to substitute funds. Equation (22) is the law of motion for varieties, noting that the death shock δ also hits entrants, so only $(1-\delta)N^E_t$ entrants survive to produce next period.

This creates first order conditions very similar to BGM:

$$v_t = \mathbb{E}_t \Lambda_{t,t+1}\left[div^S_{t+1} + (1-\delta)v_{t+1}\right] \tag{23}$$

$$(1-\delta)v_t = \mathbb{E}_t(1+r^L_t)c^E_t \tag{24}$$

where v_t is the Lagrange multiplier on the law of motion of varieties, or the value of a *new* variety. Equation (23) shows that the value of a variety is the present discounted value of the stream of dividends, accounting for product lifetime by the destruction rate δ. Equation (24) is reminiscent of the free-entry condition in BGM. It equates the value of a variety, conditional on survival to produce next period, to the expected cost of servicing the loan.

3.5 Upstream Suppliers

The upstream suppliers provides the parent firm with the infrastructure for a new variety to be produced (production line) to produce the new varieties. The sector only uses labour, so its production function is $N^E_t = Z_t \cdot \frac{h^E_t}{f^E}$. It is also exposed to the aggregate productivity shock, and f^E is only a scaling parameter that does not affect a first-order solution of the model. The sector operates under perfect competition, so entries are charged at marginal cost $c^E_t = \frac{w_t}{Z_t} \cdot f^E$.

3.6 Households

Households are fairly standard. There is a measure $[0,1]$ of households, who consume an aggregated consumption good and supply labour $H_t = H^C_t + H^E_t$, where $H^C_t = N_t h^C_t$ is the total labour supply to the consumption goods sector, and H_t^E to the upstream suppliers. Following Gertler, Kiyotaki, and Queralto (2012), the households have Greenwood, Hercowitz, and Huffman (1988) (hereafter, GHH) preferences with habit formation, and maximise:

$$\max_{\{c_t,h_t\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{1}{1-\sigma}\left[c_t - b\cdot c_{t-1} - \frac{\chi}{1+1/\varphi}H_t^{1+1/\varphi}\right]^{1-\sigma} \tag{25}$$

subject to:

$$c_t + d_t = (1+r_{t-1}^D)d_{t-1} + w_t H_t + div_t^B + div_t^P + wr_t e_t \tag{26}$$

where b is the degree of habit formation, $(1+r_{t-1}^D) = (1+i_{t-1}^D)/\pi_t^C$ is the real interest rate on deposits, σ is the constant relative rate of risk aversion and φ is the Frisch elasticity of labour supply. The choice of GHH preferences is to get comovement between hours and real wages, which would be useful in replicating the empirical impulse responses later. Define:

$$U_t \equiv c_t - b\cdot c_{t-1} - \frac{\chi}{1+1/\varphi}H_t^{1+1/\varphi} \tag{27}$$

The first order conditions are:

$$MUC_t = U_t^{-\sigma} - \beta b \mathbb{E}_t U_{t+1}^{-\sigma} \tag{28}$$

$$MUC_t = \beta MUC_{t+1}(1+r_t^D) \tag{29}$$

$$\chi H_t^{1/\varphi} = w_t\left[1 - \beta b\left(\frac{U_{t+1}}{U_t}\right)^{-\sigma}\right] \tag{30}$$

Equation (28) denotes the marginal utility of consumption. Equation (29) is the household's Euler equation for deposit savings, from which I derive the stochastic discount factor $\Lambda_{t,\tau} = \beta^{\tau-t}MUC_\tau/MUC_t$. Equation (30) is the household's labour supply equation.

To see the role of wealth effects in helping to quantatitively match the VAR's consumption impulse response, I also plot the impulse responses of a household with King, Plosser, and Rebelo (1988) preferences (which has wealth effects), with habit formation as before. The flow utility of this preference structure is:

$$\frac{1}{1-\sigma}(c_t - b \cdot c_{t-1})^{1-\sigma} - \frac{\chi}{1+1/\varphi} H_t^{1+1/\varphi} \tag{31}$$

and the first-order conditions are:

$$(c_t - b \cdot c_{t-1})^{-\sigma} = \beta \mathbb{E}_t (c_{t+1} - b \cdot c_t)(1 + r_t^D) \tag{32}$$

$$\chi H_t^{1/\varphi} = w_t \cdot \mathbb{E}_t \left[(c_t - b \cdot c_{t-1})^{-\sigma} - \beta b (c_{t+1} - b \cdot c_t)^{-\sigma} \right] \tag{33}$$

3.7 Market Clearing and Exogenous Variables

The aggregate expenditure $P_t C_t = p_t y_t N_t$ can be rearranged for the output of the consumption goods sector, $C_t = \rho_t y_t N_t$. Using the two production functions $y_t = Z_t h_t^C$, $N_t^E = Z_t \cdot H_t^E / f^E$ and labour market clearing $H_t = N_t h_t^C + H_t^E$, leads to:

$$C_t = Z_t \rho_t \left(H_t - \frac{f^E N_t^E}{Z_t} \right) \tag{34}$$

so for a given aggregate labour supply H_t, new product entries soak up resources and crowds out the consumption goods sector.

I focus on the financial shock in the form of asset writeoffs, wr_t, that follows the process $\ln wr_t = \rho_{wr} \ln wr_{t-1} + \varepsilon_t^{wr}$. I assume productivity and the capital adequacy constraint remains constant. This leaves room for interesting analyses in optimal macroprudential policy in the form of countercyclical capital ratios, but I leave this for future research.

3.8 Calibration

For the vast majority of the real sector, the calibration follows BGM. In the baseline calibration, periods are treated as quarters. Thus, β is set to 0.99 to match 4% annualised average interest rate. Product destruction rate is set to $\delta = 0.025$ to match the annual product destruction in Bernard, Redding, and Schott (2010). I set the disutility of labour parameter ξ to ensure a steady state total hours worked of 1. Steady state productivity Z and entry cost f^E are also set to 1. These are merely normalisations with no impact on the impulse responses. Frisch elasticity φ is set to 3, commonly found in the literature. The habit formation parameter b is set to a conventional value 0.75, like in Gertler, Kiyotaki, and Queralto (2012). The steady-state elasticity of substitution θ is calibrated to 3.8, from Bernard, Eaton, Jensen, and Kortum (2003) to fit US plant and trade data. The Dotsey-King parameters η and γ are calibrated to match the steady state markup implied by the steady-state elasticity of substitution and the markup elasticities. The markup elasticities chosen are -0.56 for the model with competition effects, and the counterfactual with almost no competition effects has an elasticity of -0.02. As previously mentioned, a markup elasticity of zero is achieveable if $\eta = 0$ where the Dotsey-King aggregator collapses to a Dixit-Stiglitz CES aggregator. However, due to the discontinuities in the preferences, I elect to use a very low markup elasticity instead. This is to see the impact of competition effects are, rather than a comparison of preference structures. The markup elasticity itself is calibrated to the value found empirically in Section 5.

The banking sector parameters are calibrated to match the impulse responses and steady-state averages. The CAR is set to 14.89%, to match average observed equity to loan ratio of banks in aggregated Federal Reserve Call Reports data. In addition, I use the average spread of C&I loan interest rates over the Federal Funds Rate of 0.49% per quarter. With this, the steady state writeoffs wr is calibrated to ensure the model's steady state loan to deposit rate spread matches the data.

The loan adjustment cost and the AR(1) coefficient of the writeoff shocks determine the persistence of the loan contraction. The AR(1) coefficient is set to match an AR(1) regression of the Loan Officers' survey on credit standards, implying $\rho_{wr} = 0.89$. The loan adjustment cost is calibrated in order to match persistence of the VAR loan contraction, from the peak effect, that lasts for 10 quarters – resulting in $\kappa = 20$. In turn, the standard deviation of the writeoff shock is set so that the peak loan contraction matches the peak impact of the credit shock on the VAR impulse response in C&I loans, at 5.76%.

4 Simulation Results

In this section, I simulate a one standard deviation writeoff shock, calibrated to the VAR IRF as previously mentioned. This is equivalent to 1.23% of assets.

As noted in Ghironi and Melitz (2005) and BGM, empirically relevant

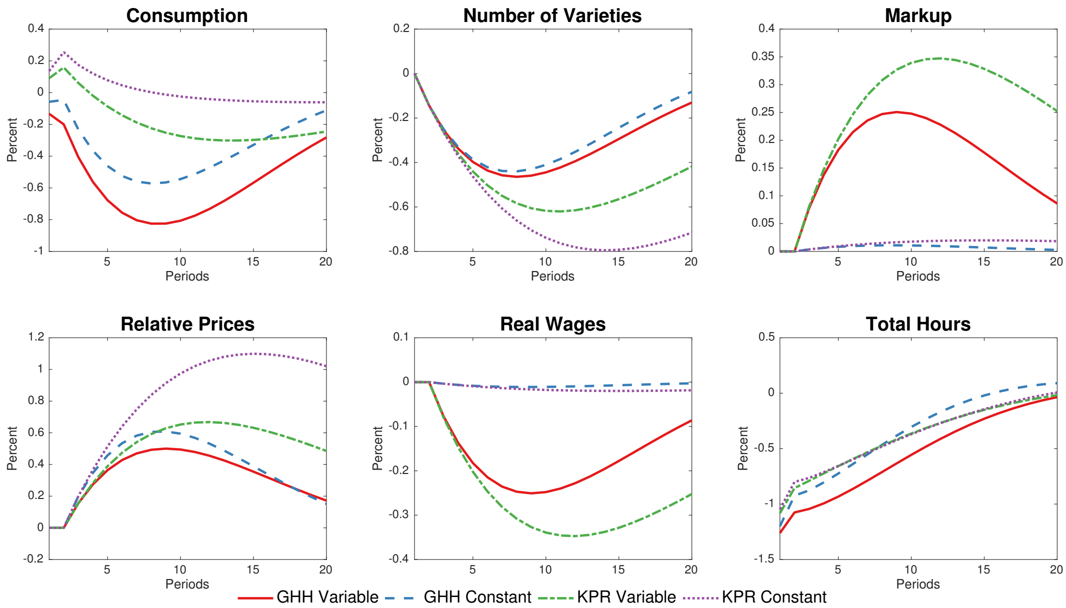

Figure 3: Impulse Responses of Real Variables

variables – rather than welfare-consistent variables – net out the effect in the product variety available. In short, consumer price indices do not adjust the basket for the availability of new products at business cycle frequencies, unlike the welfare-consistent price index P_t. Therefore, CPI is closer to p_t, as opposed to P_t. Thus, to compare to data, the data-relevant variables (i.e. deflated by a data-consistent price index), $X_{R,t} = P_t X_t / p_t = X_t / \rho_t$ should be used to compare to the data instead. However, the welfare-consistent variables remain important – they are what drives the dynamics of the model.

The impulse responses plotted of real variables – that is, those deflated by the welfare-consistent price index P_t – are the data-consistent version. The impulse responses for the welfare-consistent versions are in the appendix. On the impulse responses in Figure 3 and 4, I plot four lines. The 'baseline' in the solid red line is the main model of GHH preferences and variable markups. The dashed blue line is GHH preferences, but with (near-) constant markups. To see the role of wealth effects on labour supply, I also plot variable and constant markup versions of the model with KPR preferences, denoted by the dash-dot green and dotted purple lines, respectively. The difference between the constant and variable markup impulse responses, within preference types, is the effect of competition.

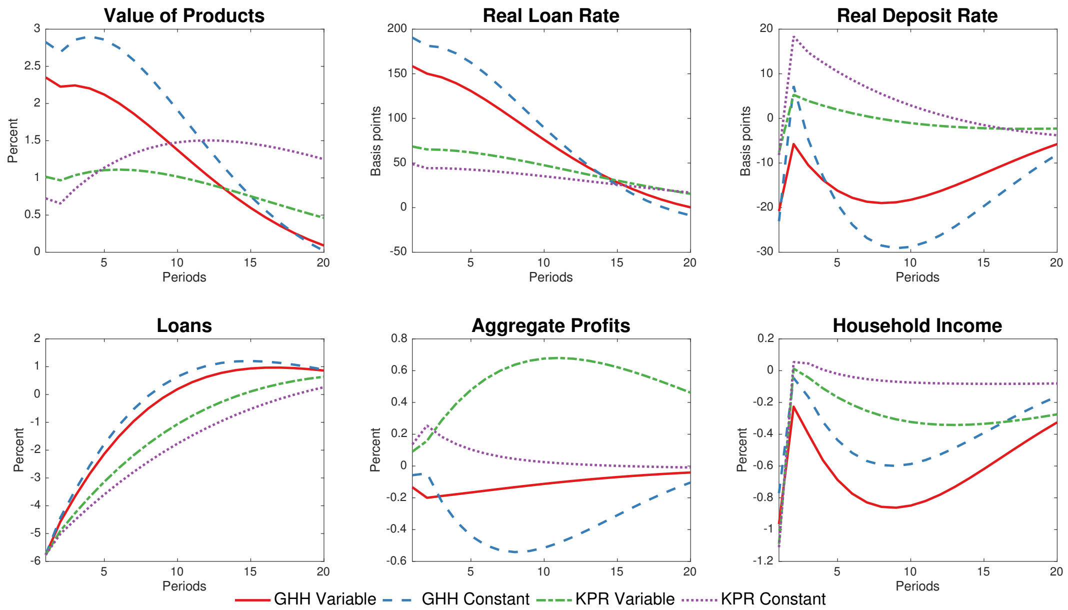

Figure 4: Impulse Responses of Financial Variables

This financial shock induces the bank to reduce loan issuance to satisfy the capital adequacy ratio. Given that the parent firm is dependent on bank loans to finance its investment into new varieties, product investment immediately falls and somewhat persistently so due to the bank's loan adjustment costs. However, since the number of products is a pre-determined variable, it falls gradually. Correspondingly, markups rise slowly over time as well. Consumption also falls on impact because less income being generated from the upstream suppliers. On impact, there is no effect on the number of varieties N_t, given that it is a pre-determined variable.

In subsequent periods however, the impulse responses begin to diverge, in particular for consumption. A markup elasticity of -0.56 implies the peak impact of the financial shock on consumption is 44% larger than the case of constant markups. On average, this amplification results in consumption is 31% more volatile when there is variable markups (with GHH preferences). The mechanism works from to two interlinked channels – competition and the labour market. Firstly, as the number of varieties begin to fall over time, markups also start to rise for the model with competition effects. This decreases demand as prices are higher than other they would have been under the constant markup case.

Secondly, the impulse responses between the constant and variable markup

KPR preferences show that the competition channel operates remains even in the presence of wealth effects on labour supply. However, without wealth effects, the competition channel's amplification effects in enhanced by the labour market and helps it to match the data better (see Figure 7). To be more precise, the decrease in demand in the product market leads to a corresponding decrease in labour demand. This induces real wages fall more under variable markups, relative to the constant markup model.[4] With GHH preferences, this results in a fall in hours worked in the consumption good producing sector due to the substitution effect, reducing the output of that particular sector even further.[5] Combined, the drop in real wage and hours worked lead to an even larger decrease in household income, which contributes to the fall in aggregate demand. As Figure 4 shows, the reduction in household income closely mimics the fall in consumption. Note that most of the mechanism still holds true under KPR preferences. However, it is just that hours worked in the consumption goods sector actually increase initially. This dampens the effect on household income and thus, the effect on consumption too. Jermann and Quadrini (2012) also emphasise the role of hours worked for financial shocks to have real effects. They use a working capital constraint that forces firms to borrow to pay their wage bill in advance. This mechanism ensures that financial shocks translate to movements in hours worked, and thus, aggregate fluctuations.

The behaviour of the value of a *new* variety v_t increases above the steady state is somewhat counterintuitive. This is caused by equation (24), where the value of a new variety is equalised to the cost of entry. As the cost of entry increases due to loan interest rates increasing, v_t also increases. Intuitively, this can be thought of that due to the scarcity of funding, only projects into new products with a high return are funded. This is consistent with survey evidence that suggests start-ups that begin operations during

[4]Note that these are the data-consistent variables. The welfare-consistent real wage actually rise (see Appendix), but in the model with variable markups, they do not rise by as much. The rise in the relative price imply that the data-consistent real wage hardly moves under constant markups.

[5]The hours worked in the consumption good producing sector is also the data-consistent consumption (given that technology does not change). With KPR preferences, hours worked in that sector initially *rise*. This is because the tighter credit constraint on the variety producing sector, labour is reallocated away to the consumption goods sector. An increase in hours worked after a contractionary financial shock is contrary to the VAR impulse responses.

a recession are more likely to be profitable in the future.[6]

The fall in varieties is amplified mildly in the model with variable markups, which in turn amplifies the increase in markups, due to v_t being lower under variable markups. This occurs despite the increase in markups leading to an increase in profits at each subsidiary. The cause is due to the higher cost of equity by the parent firm, which governed by the household's stochastic discount factor. The steeper fall in consumption implies that households would prefer to have dividends now in order to smooth out their consumption, rather than the parent firm investing into new varieties to get long-term profits. This makes the parent firm discounts future profits by each subsidiary more, and discourages it to invest into new products – exacerbating the fall in varieties and the rise in markups.

The amplification is also mild because of a general equilibrium response from banks. The bank reacts to (relatively) lower loan demand by lowering interest rates – or at least, loan interest rates do not increase by as much.[7] In the impulse response for loan interest rate, the difference does not seem much (around 40 basis points). However, considering that the steady state loan interest rate is only 150 basis points per quarter, this represents a fairly significant boost to encouraging investment.

Note that the banking sector recovers its equity capital and loan-issuing capabilities after around 10 quarters after the shock, as a result of the calibration of the loan adjustment costs and persistence of the writeoff shocks. Meanwhile, consumption recovers after around 20 quarters with constant markups, and with variable markups, even longer than that due to high markups persisting after credit supply is restored. Furthermore, the balance sheet variables of the bank does differ slightly across the markup elasticities. From the reduced loan demand, lower loan interest rates imply reduced spreads. This results in the bank's equity capital base recovering more slowly. This occurs even when the banks are handing out less dividends to the households under variable markups.

Bank dividends actually increase after the financial shock, despite the fact that there is a scarcity of equity capital. This is because of the loan adjustment costs.[8] It is too costly to extend loan in the aftermath of the

[6]Hiscox International DNA of an Entrepreneur Report 2014

[7]Loan interest rates still increase from steady state because of a scarcity of bank equity capital.

[8]Without adjustment costs, the equity capital base recovers much more quickly. Div-

financial shock, reflective of the lack of investment opportunities and difficulty in monitoring the loan adjustment costs is supposed to capture. This is exactly what a firm should do when it has a lack of profitable investment opportunities – buybacks to the shareholders. However, it has the ramification that the equity capital base takes longer to recover. A policy implication would be to restrict dividends to ensure the recovery of the capital base, as many governments have done to systemically important banks in the aftermath of the 2008-10 financial crisis.

It is worthwhile noting that (product) investment – given that there is no physical capital – is defined as the value of new varieties, $v_t N_t^E$. In a model with physical capital, I expect the behaviour to be much more similar to consumption. The investment goods sector is also subject to decreased competition and increased markups during a credit crunch. Therefore, it would have the same effect of dampening investment good demand as the relative price of investment increases. The increase in new variety investment is likely to have minimal impact as new variety investment is a much smaller part of GDP, relative to physical capital investment.

5 Empirical Results

5.1 Comparison with VAR

In this subsection, I compare the DSGE model's predicted impulse responses to the financial shock to the IRFs of a VAR, both qualitatively and quantitatively. Recall that the DSGE model is calibrated to match the persistence and size of the impulse response of loans and the credit standards index. The aim of this exercise is to see given this calibration strategy focusing on the financial sector, whether the DSGE model can match the empirical dynamics of the *real* sector. More specifically, I seek to test if the predicted mechanisms through competition and the labour market also exist in the data. In addition, I examine whether the consumption path predicted by the variable markups model fit the VAR's impulse response well. The grey bands are 90% bootstrapped confidence intervals.

idends go negative (i.e. an equity issuance) which partly helps to boost the capital base, but not fully as it is very expensive to do so when the marginal utility of consumption is already high. Most of the capital recovery is through retained earnings, as spreads become

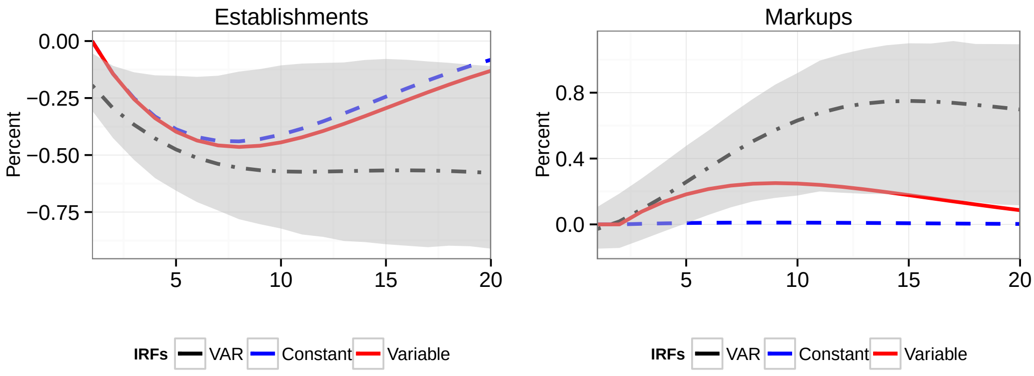

Figure 5: Competition

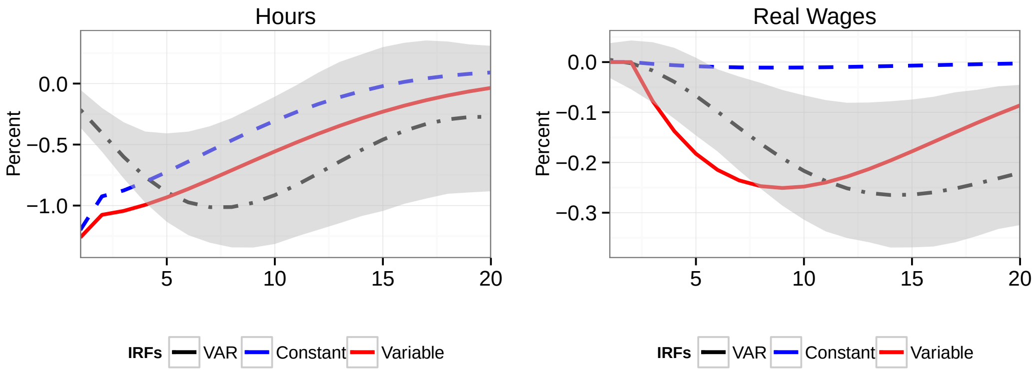

Figure 6: Labour Market

As already demonstrated in Section 2.2, the VAR suggests the competition mechanism exists. The movements of the number of varieties, both the constant and variable markups models, exhibit similar dynamics. In Figure 5, it shows that both models get quite close quantitatively to the VAR's impulse response in N_t to a credit standard tightening shock – especially in closely matching the peak impact of the shock, and the horizon of the peak impact. With respect to markups, obviously the model with constant and variable markups differ in dynamics. The variable markup DSGE model does seem to underestimate the VAR's peak effect. This could be because of other factors affecting the markup that the model does not capture (for example, nominal rigidities), or an under-estimation of the true markup elasticity. While I calibrate the elasticity to 0.56 to the micro-data evidence

very high.

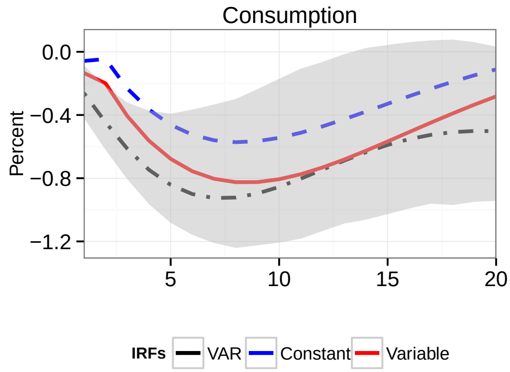

Figure 7: Consumption

in the next section, the VARs suggest that the markup elasticity could be larger than 1 – establishments fall by 0.6%, while markups rise by almost 0.8%. The next subsection on calibrating this elasticity to the manufacturing micro-data will explain in greater detail that the DSGE model's calibration is a lower-bound estimate. Note that the Gilchrist, Sim, Schoenle, and Zakrajšek (2014) predicted markup dynamics (strong effect on impact after a credit supply shock) that is not supported by the data. A slower-moving markup, that is more consistent with being driven by competition, seems to fit the data better.

Secondly, in Figure 6, I examine the predicted mechanism through the labour market. For this, we need to add the relevant labour market variables to the VAR. I use the Non-farm Business Sector Hours for hours worked, and Total Private Real Average Hourly Earnings of Production and Nonsupervisory Employees for real wages. The VAR is recursively identified as before, with the order: $\mathbf{X}_t = [cs_t \; N_t \; \mu_t \; w_t \; h_t \; y_t \; \pi_t \; r_t \; l_t]'$. Given the large size of the VAR, information criteria suggest that one lag is optimal. In hours worked, the DSGE model's predictions does not vary much with constant or variable markups. They both get quite close to the peak effect on hours in the VAR, but fail to replicate the hump shape. Recall that the hours worked jumps on impact due to the new variety producing sector's output falling due to the tighter credit constraints. A crucial mechanism and prediction of the DSGE model is through real wages, where there is a marked difference between constant and variable markups. The VAR evidence supports this predicted mechanism after the credit contraction shock. The DSGE model quite closely matches the trough of the IRF, although underestimating the horizon of it by five quarters. Like the IRFs of the markups, the constant markup model falls out of the confidence bands while the variable markups stay mostly within it (and also, stays somewhat closely to the point estimate).

Lastly, in Figure 7, I demonstrate the predicted consumption path of the DSGE model under variable markups more closely track the VAR. The constant markup case is out of the 90% confidence interval in the first four quarters. The peak impact of the variable markups case is also close to the VAR's, while in the constant markup case underestimates the peak impact (albeit remaining inside the confidence bands). To summarise, this subsection documents how the DSGE model's prediction come close to the empirical VAR impulse responses through the two key mechanisms, and matching closely the path of consumption once competition effects are allowed to enter.

5.2 Markup Elasticities

I use the NBER-CES Manufacturing Industry Database to get estimates of the crucial parameter at a micro-level – the elasticity of markup with respect to competition. The data is annual from 1990-2006 at six-digit NAICS level. It is then merged with the number of establishments from the BLS QCEW database. This results in a panel database of 479 industries. The regression specification is as follows:

$$\Delta \ln \mu_{i,t} = \alpha_i + \varphi \mathbf{T}_{it} + \sum_{j=0}^{J} \beta_j \Delta \ln N_{i,t-j} + \sum_{k=1}^{K} \gamma_k \Delta \ln \mu_{i,t-k} + \Gamma S_{it} + \varepsilon_{it} \quad (35)$$

where $\mu_{i,t}$ is industry i's markup, $N_{i,t}$ is the number of establishments within industry i and $S_{i,t}$ is the value of shipments to control for cyclicality of markups. α_i are industry fixed effects and $\mathbf{T}_{i,t}$ is a vector of time controls. Lags of N_t and the dependant variable are added as it may take time for the effects of higher competition to be reflected in markups. The lag structure itself is chosen by statistical significance. For time controls, I use industry-specific linear time trends, because preliminary inspection of markups reveal that there is significant industry heterogeneity in their secular trends, perhaps due to the differing impacts of technological change

	OLS	OLS	OLS	A-B	A-B	A-B
LR Elasticity	-.32***	-0.20***	-.36***	-.54***	-.44***	-.56***
	(.063)	(.070)	(.099)	(.11)	(.11)	(.11)
J	4	4	4	4	4	4
K	1	1	1	1	1	1
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Time Controls	None	Agg. Trend	Ind. Trend	None	Agg. Trend	Ind. Trend
Observations	6069	6069	6069	5596	5596	5596
# of Industries	473	473	473	473	473	473

Clustered standard errors around industries
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 1: Estimates of Long Run Markup Elasticity

to the industries during the sample period. Therefore, the variation used in the regression with linear trends is the within-industry movement of markups around the detrended series. Given that it is a dynamic panel, the well-known bias emerges when estimating with fixed effects. Therefore, I also run the regression using the Arrellano-Bond dynamic panel GMM.[9] The long-run elasticities of the various specifications and estimation methods are reported in Table 1.

It is worth noting the probable endogeneity bias: higher markups would induce more entry. This would have an upward bias to the negative coefficients. Thus, the industry estimates here can be seen as the lower bound estimate of the magnitude of markup elasticities. That said, the endogeneity bias from reverse causality is likely to be minimal as current markups is unlikely to influence past entry. All estimates are statistically significant at 1% level. It is important to note that these elasticities are significantly higher than those suggested by translog preferences, of around -0.18 (Lewis and Stevens, 2012), compared to the baseline estimate of -0.56 that is used in the quantitative analysis. This demonstrates the importance of using a more flexible preference structure with the Kimball aggregator as described earlier.

In conclusion, the markup elasticities estimated here give a range of parameter values for the DSGE model. The impulse responses from the aggregate VAR also give some supporting evidence for the theoretical predictions from the competition channel. In particular, the responses of es-

[9]There are less observations for Arellano-Bond as an extra lag is required to instrument the lagged dependant variables in the regression.

tablishments and markups to the bank credit supply shock, as well as the channel through the labour market.

6 Conclusion

To conclude, by augmenting an endogenous product variety RBC model with financial shocks, I have described a novel transmission channel of financial shocks. Using the DSGE model, I demonstrate that competition effects can amplify the effect of a financial shock on consumption by 31% through an increase in markups, leading to a slow recovery of consumption after the financial shock. This is the core amplification mechanism. Empirically, using aggregate data, I show that the predicted competition effects occur after a bank credit supply contraction – the number of establishments falls and markups rise, as well as the effects through the labour market that depress household income. This brings the implication that if policymakers decide to use demand-side policies to stimulate the economy after a financial shock (as the appropriate response to a demand shock) – then they would need to be take into account the effects of higher markups on the natural level of output. The increase in market imperfections imply a decrease in the natural level of output. This is important in order for policymakers to not overestimate the amount of slack in the economy, which would lead to excessively stimulatory policies and high inflation.

While the current model has already shown its success in matching the behaviour of consumption, future avenues of research is to add physical capital investment to enhance the model in two dimensions. One would be to reproduce the dynamics of output by taking into account physical capital investment and how the investment goods producing sector are also exposed to reduced competition and subject to the same amplification mechanism as consumption goods. Secondly, the mechanism would propagate the shock even further, as higher start up costs from more expensive capital goods would disincentivise entry, leading to a greater persistence of lower competition and high markups. In addition, the variable markups mechanism also leads to an explanation to why the estimated DSGE literature finds such large and highly persistent markup shocks, which are inconsistent with the micro data evidence on reset price inflation in Bils, Klenow, and Malin (2012). An upcoming research project is to embed this mechanism in a Smets and Wouters (2007) type model and see how much of the variance in markups can be explained by other shocks, through the competition effect.

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A Robustness Checks for VAR

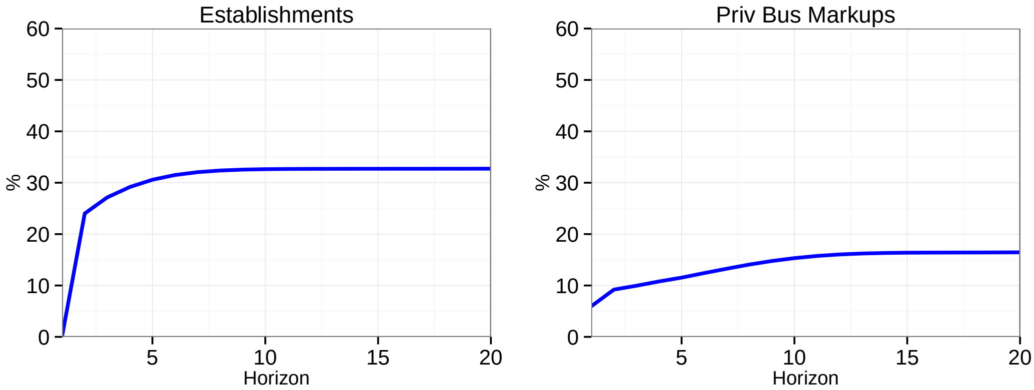

Figure 8: FEVD of all shocks other than the variable's own shock

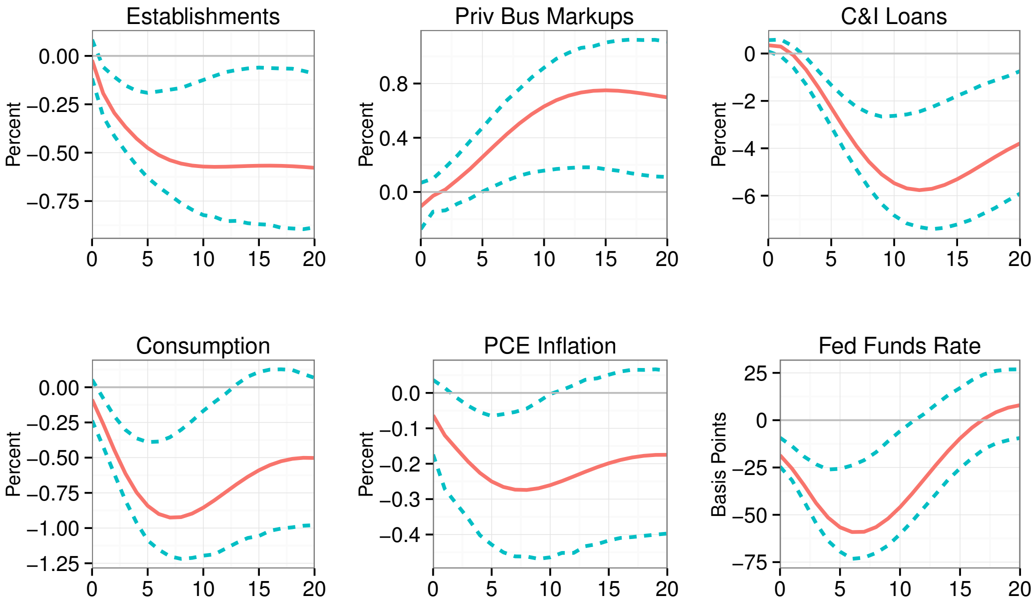

Figure 9: VAR ordering: $\mathbf{X}_t = [cs_t \ l_t \ N_t \ \mu_t \ c_t \ \pi_t \ r_t]'$

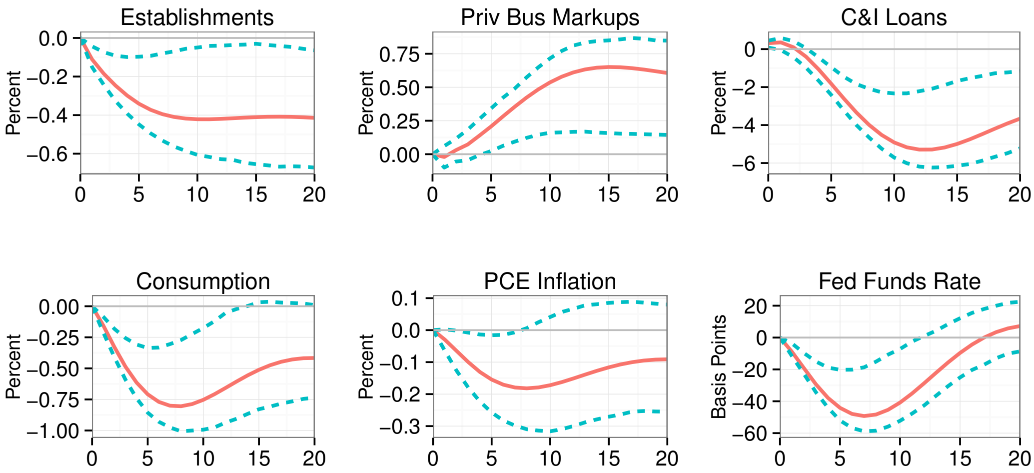

Figure 10: VAR ordering: $\mathbf{X}_t = [N_t\ \mu_t\ y_t\ \pi_t\ r_t\ l_t\ cs_t\ l_t]'$

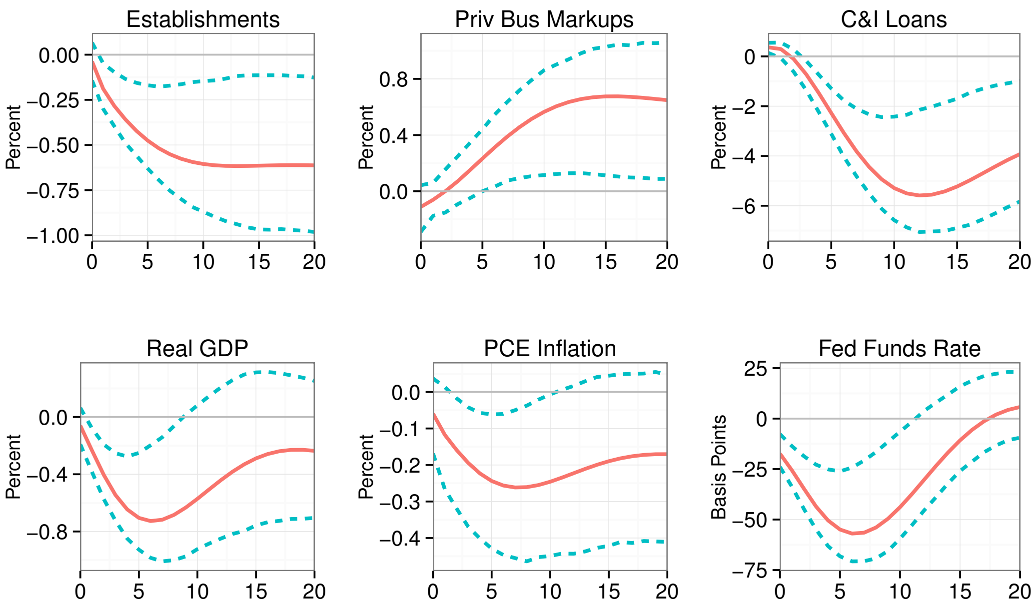

Figure 11: VAR (with GDP) ordering: $\mathbf{X}_t = [cs_t\ N_t\ \mu_t\ y_t\ \pi_t\ r_t\ l_t]'$

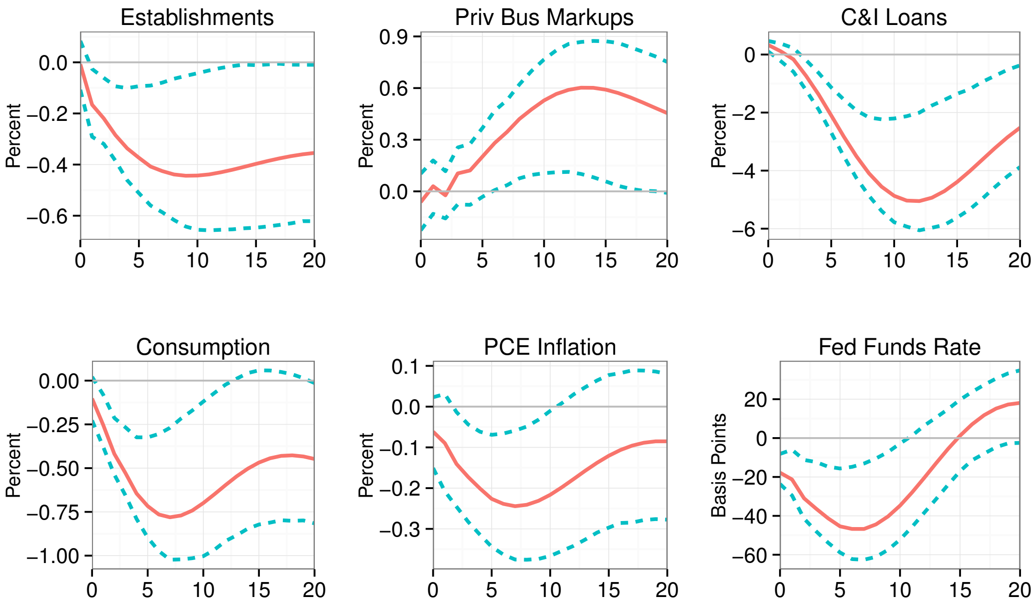

Figure 12: VAR (with GDP) ordering: $\mathbf{X}_t = [cs_t \; N_t \; \mu_t \; y_t \; \pi_t \; r_t \; l_t]'$

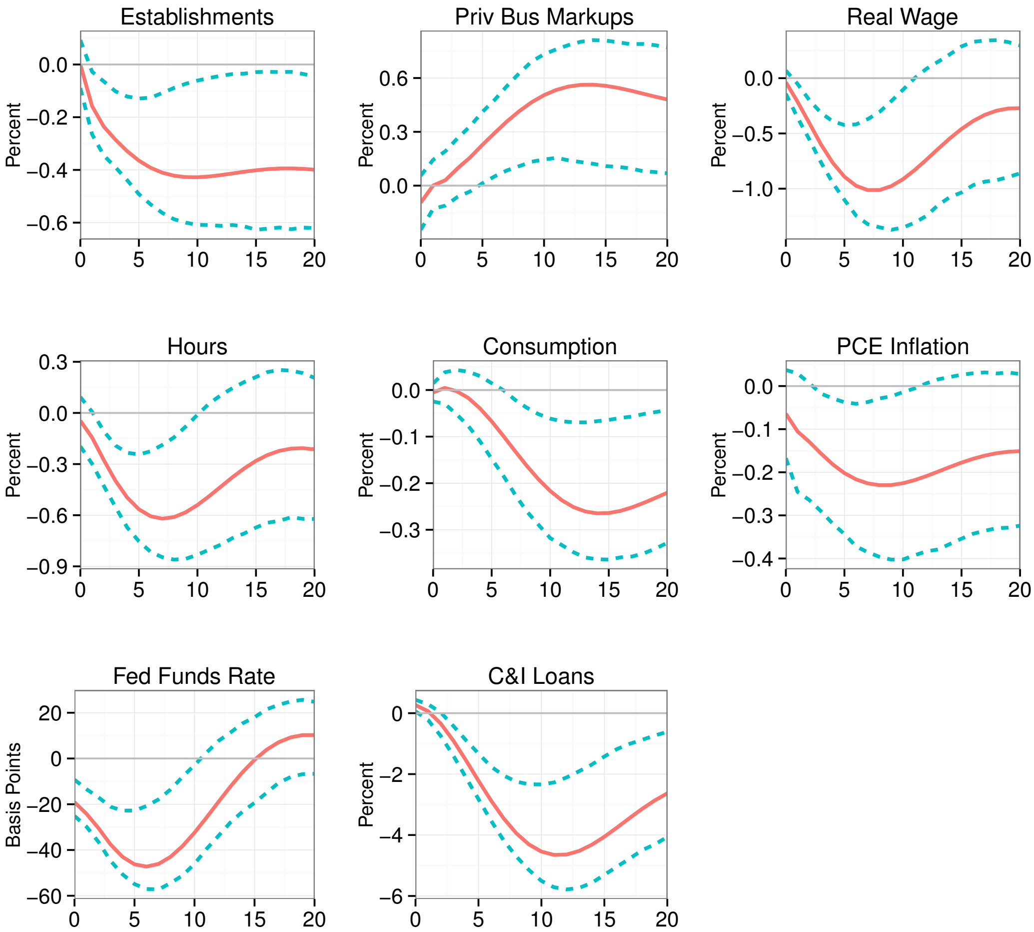

Figure 13: VAR (with labour market) ordering:
$\mathbf{X}_t = [N_t \ \mu_t \ w_t \ h_t \ c_t \ \pi_t \ r_t \ l_t \ cs_t \ l_t]'$

B Industry-level Regressions

VARIABLES	(1) OLS	(2) OLS	(3) OLS	(4) A-B	(5) A-B	(6) A-B
$\Delta ship_t$	0.358***	0.376***	0.362***	0.342***	0.363***	0.357***
	(0.021)	(0.022)	(0.027)	(0.020)	(0.023)	(0.021)
$\Delta ship_{t-1}$	0.013	0.029**	0.036*	-0.036*	-0.019	-0.028
	(0.015)	(0.015)	(0.019)	(0.020)	(0.021)	(0.018)
$\Delta ship_{t-2}$	-0.051***	-0.046***	-0.066***	-0.085***	-0.073***	-0.073***
	(0.010)	(0.010)	(0.016)	(0.013)	(0.014)	(0.013)
$\Delta ship_{t-3}$	-0.039***	-0.032**	-0.056***	-0.058***	-0.047***	-0.049***
	(0.013)	(0.013)	(0.019)	(0.014)	(0.014)	(0.012)
$\Delta ship_{t-4}$	-0.039***	-0.030***	-0.056***	-0.050***	-0.039***	-0.043***
	(0.010)	(0.010)	(0.016)	(0.011)	(0.012)	(0.010)
$\Delta ship_{t-5}$	-0.025*	-0.011	-0.039**	-0.031**	-0.019	-0.026*
	(0.014)	(0.014)	(0.018)	(0.014)	(0.015)	(0.014)
$\Delta ship_{t-6}$	0.005	0.017	-0.010	-0.006	0.005	-0.001
	(0.012)	(0.011)	(0.015)	(0.012)	(0.012)	(0.012)
ΔN_t	-0.093***	-0.074**	-0.106***	-0.133***	-0.123***	-0.137**
	(0.032)	(0.032)	(0.037)	(0.041)	(0.042)	(0.057)
ΔN_{t-1}	-0.033	-0.025	-0.063	-0.070	-0.062	-0.078*
	(0.042)	(0.042)	(0.046)	(0.047)	(0.045)	(0.045)
ΔN_{t-2}	-0.059	-0.034	-0.077*	-0.088**	-0.071*	-0.091**
	(0.039)	(0.039)	(0.044)	(0.042)	(0.042)	(0.042)
ΔN_{t-3}	-0.091**	-0.057	-0.095*	-0.114***	-0.094**	-0.115***
	(0.043)	(0.045)	(0.050)	(0.044)	(0.045)	(0.037)
ΔN_{t-4}	-0.081**	-0.032	-0.085*	-0.152***	-0.113**	-0.154***
	(0.035)	(0.036)	(0.044)	(0.048)	(0.050)	(0.057)
$\Delta \mu_{t-1}$	-0.104***	-0.124***	-0.185***	-0.037	-0.043*	-0.027
	(0.024)	(0.024)	(0.025)	(0.026)	(0.025)	(0.024)
year		0.003***			0.002**	
		(0.000)			(0.001)	
Constant	0.015***	-6.001***	-4.089***	0.013***	-3.378**	0.002*
	(0.001)	(0.850)	(1.280)	(0.001)	(1.326)	(0.001)
LR Elasticity	-0.32***	-0.20***	-0.36***	-0.54***	-0.44***	-0.56***
	(0.06)	(0.07)	(0.10)	(0.11)	(0.11)	(0.11)
Observations	6,069	6,069	6,069	5,596	5,596	5,596
R-squared	0.33	0.33	0.39			
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Time Control	None	Agg. Trend	Ind. Trend	None	Agg. Trend	Ind. Trend

Clustered standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

C Derivation of Kimball Aggregator

C.1 Price Indices

The first order condition of the household's expenditure minimisation problem is:

$$p_t(\omega) = \frac{1}{\Lambda_t C_t} \Psi' \left(\frac{c_t(\omega)}{C_t} \right)$$

Relative demand or market share is:

$$\frac{c_t(\omega)}{C_t} = \Psi'^{-1} \left(p_t(\omega) \Lambda_t C_t \right)$$

where Λ_t is implicitly defined by substituting the demand function into the definitions of the aggregator:

$$\int_0^{N_t} \Psi \left(\Psi'^{-1} \left(p_t(\omega) C_t \Lambda_t \right) \right) di = 1$$

and define some price index $\widetilde{P}_t \equiv 1/\Lambda_t C_t$ (note that this is not the conventional price index):

$$\int_0^{N_t} \Psi \left(\Psi'^{-1} \left(\frac{p_t(\omega)}{\widetilde{P}_t} \right) \right) di = 1$$

The conventional (welfare-relevant) price index is instead:

$$P_t = \frac{1}{C_t} \int_0^{N_t} p_t(\omega) c_t(\omega) di = \int_0^{N_t} p_t(\omega) \Psi'^{-1} \left(\frac{p_t(\omega)}{\widetilde{P}_t} \right) di$$

Using the demand equation, the price index $\widetilde{P}_t$ is

$$\Rightarrow \widetilde{P}_t = \frac{p_t(\omega)}{\Psi' \left(\Psi^{-1} \left(\frac{1}{N_t} \right) \right)} \tag{36}$$

C.2 Elasticity of Demand

$$\theta(x_t(\omega)) \equiv -\frac{dc_t(\omega)}{dp_t(\omega)} \cdot \frac{p_t(\omega)}{c_t(\omega)} \Rightarrow \frac{1}{\theta(x_t(\omega))} = -\frac{d \ln p_t(\omega)}{dc_t(\omega)} \cdot c_t(\omega)$$

By assuming that each variety ω cannot affect the price index $\widetilde{P}_t$ and using equation (36):

$$\ln p_t(\omega) = \ln \widetilde{P}_t + \ln\left(\Psi'\left(\frac{c_t(\omega)}{C_t}\right)\right) \tag{37}$$

$$\frac{d\ln p_t(\omega)}{dc_t(\omega)} = \frac{\Psi''\left(\frac{c_t(\omega)}{C_t}\right)\frac{1}{C_t}}{\Psi'\left(\frac{c_t(\omega)}{C_t}\right)} \tag{38}$$

Using the definition $x_t \equiv c_t(\omega)/C_t$,

$$\frac{1}{\theta(x_t(\omega))} = -\frac{\Psi''(x_t(\omega))x_t(\omega)}{\Psi'(x_t(\omega))} \quad \Rightarrow \quad \theta(x_t) = -\frac{\Psi'(x_t)}{x_t\Psi''(x_t)}$$

Kimball assumes $\theta'(x_t) < 0$, and the number of competitiors rise, market share falls $x(N_t) < 0$, as N rises then θ increases too.

C.3 Markup Elasticity

Define:

$$\varepsilon_\mu(x) \equiv \frac{\partial \ln \mu(x)}{\partial \ln x} = x\frac{\mu'(x)}{\mu(x)} \tag{39}$$

$$\frac{d\ln\mu}{d\ln N} = \frac{d\ln\mu}{d\ln x}\cdot\frac{d\ln x}{d\ln N} = \varepsilon_\mu(x)\cdot\frac{d\ln x}{d\ln N} \tag{40}$$

From equation (6):

$$\frac{1}{N} = \Psi(x) \quad \Rightarrow \quad \ln N = -\ln\left(\Psi(x)\right) \tag{41}$$

$$\frac{d\ln N}{dx} = -\frac{\Psi'(x)}{\Psi(x)} \tag{42}$$

$$\frac{d\ln N}{d\ln x} = -\frac{x\Psi'(x)}{\Psi(x)} = -N\cdot\Psi^{-1}(1/N)\Psi'\left(\Psi^{-1}(1/N)\right) \tag{43}$$

where the last line uses the definition of market share in symmetric equilibrium, equation (6) again. Therefore, the elasticity of markups w.r.t. varieties is:

$$\frac{d\ln\mu(x)}{d\ln N} = -\varepsilon_\mu(x)\cdot\frac{1}{N\cdot\Psi^{-1}(1/N)\Psi'\left(\Psi^{-1}(1/N)\right)} = -\varepsilon_\mu\cdot\frac{1}{N\cdot x\cdot\Psi'(x)} \tag{44}$$

C.4 GHH Preferences Impulse Responses

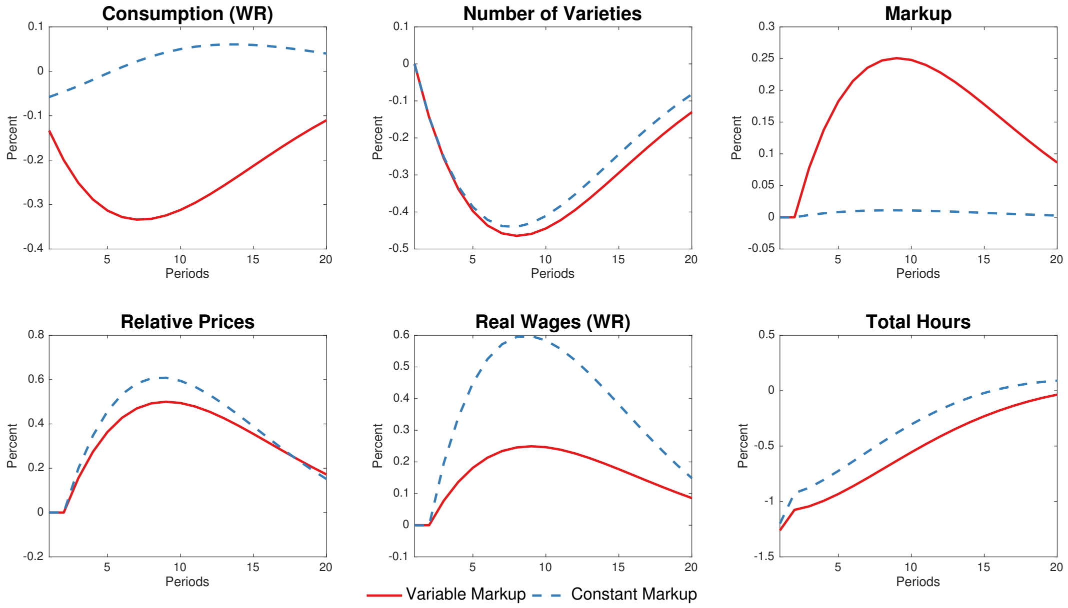

Figure 14: Welfare-Relevant Real Variables

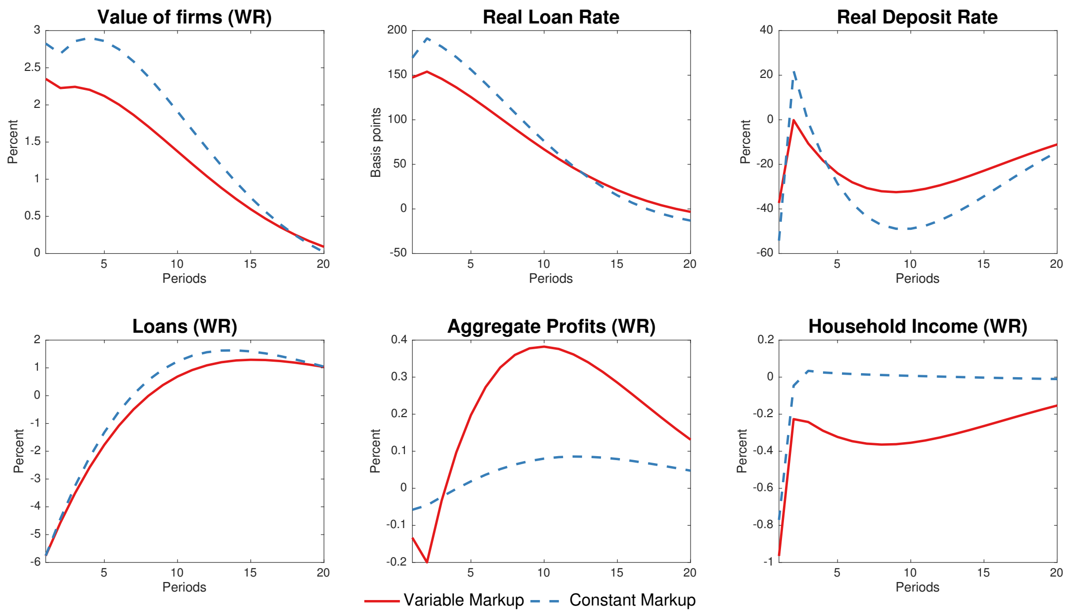

Figure 15: Welfare-Relevant Financial Variables