ASSET PRICE, BANKING AND ECONOMIC ACTIVITY

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ABSTRACT

Asset Prices, Banking and Economic Activity
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This dissertation examines the role of asset prices to act as a transmission and amplification mechanism. Specifically, it looks at how changes in asset prices can help transmit and amplify technology shocks through the credit channel by changing the supply of loanable funds, or changing the supply of deposits, or both. Using a modified version of the Kiyotaki-Moore credit cycles model with concave utility and decreasing returns to scale production function, the dissertation illustrates that asset prices can as a credible amplification and transmission mechanism. Using concave utility and decreasing returns to scale production function allows the incorporation risk aversion into the credit cycles model. The model can help explain the gap between observed magnitude of shocks, and the corresponding changes in economic activity.

The behavior of a heterogeneous agent economy in response to a technology shock is simulated using computer programs. The simulations show that a one percent technology shock translates into a more than four percent change in capital held by the constrained agents by moving capital from one agent type to the other. This moves the economy away from a first-best equilibrium. If the technology shock is positive there is an increased demand of capital from the more productive agents, and thus a more than proportionate increase in output. If the technology shock is negative, the opposite path is followed, and economic activity falls more than proportionately. There are credit constraints built into the model. Agents' access to credit is determined by the value of collateral on offer, which in turn depends on

asset prices. Technology shocks change demand for assets, their prices, their value as collateral, and hence agents' access to credit. Further, since prices are forward looking, a shock in one period propagates through time. These simulations show that the effects of the shock can be felt up to 13 periods after it has hit.

An event analysis with housing price data from 18 countries spanning a period of more than four decades is also performed. It shows that there is strong co-movement of housing prices and economic activity. In particular, larger changes in housing prices have been accompanied by qualitatively similar changes in economic activity. The period leading up to the peak of a real estate cycle is accompanied by a more than proportionate increase in private sector lending, and once the peak has been crested, there is a more than proportionate fall in nominal private sector lending. This evidence is in sync with the earlier observation that changes in asset prices influence agents' access to credit and contribute to the persistence of the effects of the shock far into the future. Further, the preferred measure of economic health, the rate of inflation, sees no measurable change in periods leading up to a real estate peak, and beyond. This throws up the need for some other measure of economic health that is better able to capture the events in asset markets.

Policy makers have been paying more attention to this channel in the aftermath of the sub-prime mortgage crisis in the United States. There have been multiples changes in regulatory policy across the world, and specific steps are being taken to dampen exuberance in the real estate market. Only time can tell if these measures turn out to be effective, but at least a step has been taken towards realizing that housing market can lead to a wider economic and banking crisis.

To Ishaan. You gave a new meaning to life.

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CHAPTER 1

INTRODUCTION

Changes in asset prices have historically been accompanied by large macroeconomic changes. For example, the Japanese Recession of the 1990s was preceded by the bursting of the asset price bubble in Japan, and the recession that hit most of the developed world in late 2008 was preceded by the bursting of the sub-prime mortgage market in the US and the subsequent fall in housing values. The fall in the New York Stock Exchange on October 29, 1929, is usually considered to be the start of the Great Depression, though asset prices fell across the board. Housing prices fell by more than 50% between 1929 and 1933. Some researchers (see, for example, Mishkin (1978) and Bernanke (1983)) have argued that the fall in asset values during the Great Depression raised questions about firms' solvency and their credit worthiness. This loss of credit worthiness in turn was seen to be the reason responsible for prolonging the recession. Koo (2008) has gone so far to say that the fall in asset prices was the prime driver of Japan's lost decades. In all three instances above the chain of events involved an asset price collapse leading to a banking crisis, and the banking crisis in turn leading to a macroeconomic crisis. This automatically raises a question as to how asset prices are related to the state of the economy.

Asset Prices and Economic Activity

The literature talks about four channels through which asset prices influence the economy. Changes in asset prices influence household wealth that affects consumption. They can influence the price of capital relative to its replacement cost which influences investment, as in Tobin's q. They can influence international capital flows, the real effective exchange rate, and hence demand. They can influence balance sheets of banks, households and firms, which in turn can influence investment and government debt as governments try to recapitalize firms. Over the next few pages we briefly go through the first three channels. The main focus of this dissertation is on the the balance sheet effect, and we go through a more detailed analysis, and literature review, of that channel later in the chapter.

Asset Prices and Consumption

Changes in asset prices influences household wealth. This in turn is seen to influence household consumption. There are two standard theories that are used to analyze this link: Friedman's permanent income hypothesis (Friedman (1957)) and Modigliani's life-cycle model (Ando and Modigliani (1963)). Friedman's permanent income hypothesis distinguishes between permanent and temporary changes in income without specifying which changes should be considered permanent, and which should be considered temporary. On the other hand, Modigliani's life-cycle hypothesis does not make this distinction. Modigliani suggested that every dollar change in household wealth changed their consumption by 5 cents, either contemporaneously, or subsequently (Modigliani (1971)). This number has been widely accepted by both academics and policy makers. One counter to this widely held belief was presented by Lettau and Ludvigson (2004) who argue that wealth changes of households are

either 'permanent' or 'transitory,' and aggregate consumption does not change with transitory changes in wealth, but with permanent changes mirroring Friedman's permanent income hypothesis. They further argue that most changes in the postwar net worth of households can be seen as transitory, while a small amount (about 12%) of the change was permanent. This would mean that the generally accepted wealth effect on consumption may be overstating the case. They took changes in value of stock holdings as transitory changes, changes in labor income were considered to be permanent changes, thus clarifying what was permanent and what was transitory. Many subsequent studies have looked at the same question with one difference: they have looked at the impact of changes in financial and housing wealth.

There are important reasons for distinguishing the two. Housing is both a consumption good and an asset. Changes in housing prices would thus influence households in opposite ways: an increase in house prices can make people richer, but it will also increase the cost of housing services. Similarly, a fall in housing prices can make people poorer, but it will simultaneously reduce the cost of housing services. This would suggest that housing's impact on consumption should be ambiguous, and will largely depend on the share of home owners versus renters. This ambiguity does not exist with financial assets. Housing wealth also tends to be more evenly distributed than financial wealth. Most financial assets are held by richer people, and they tend to have lower marginal propensity to consume (Takhtamanova (2008)). Thus changes in housing prices may have a larger impact on consumption, given that it is more evenly distributed. It may also be the case that households view changes in housing wealth to be more permanent than comparable changes in financial wealth, and if we go by what was presented in Lettau and Ludvigson (2004), it would mean changes in housing wealth will have a larger impact on consumption.

Various studies have tried to analyze this link empirically. Empirical evidence

suggests that for every dollar change in housing value, household consumption changes by 3 to 10 cents (Case, Quigley, and Shiller (2005) and Carroll, Otsuka, and Slacalek (2011)). Changes in financial wealth (proxied by changes in stock market) seem to have negligible impact on consumption. This result has been shown to hold in many geographies. It has been shown to hold in data from the United States (Case et al. (2005)), the United Kingdom (Campbell and Cocco (2007)), as well as a panel of rich countries (Ludwig and Sløk (2004)). A slightly different result came from Dvornak and Kohler (2007) who use data from Australia to show that changes in housing wealth has lower per unit effect on consumption, but given that households have about three times as much wealth in housing than in the stock market, the net effect of changes in both sectors is about the same. A wider survey of these results can be seen in Poterba (2000) and Paiella (2009). There have been some arguments that housing prices did not matter as much earlier (see, for example, Ludwig and Sløk (2004)), but with the deregulation of mortgage markets and the availability of tools to access equity in housing the relationship has become more important (Aoki, Proudman, and Vlieghe (2004)). This is consistent with what Alan Greenspan said in his inaugural address at the 2001 Jackson Hole meeting of central bankers that the marginal propensity to consume from housing wealth may be higher than from stock market wealth. Thus, this channel suggests that housing values are an important component in determining aggregate consumption, and hence economic activity.

Asset Prices and Investment

Asset prices influence investment by altering the ratio of the market value of capital and the replacement cost of capital. It has been argued that the market value of equities, relative to the replacement cost of capital, is one of the most important determinants of investment (Brainard and Tobin (1968), Tobin (1969)). The model

was given a more formal structure by Hayashi (1982) who established the relationship between average q and marginal q, thus making future empirical works easier to conduct. The idea that investment is influenced by asset prices follows from the Keynesian idea that new issue of shares is an important determinant of investment. Tobin and Brainard also document empirical evidence using data from 1960-1974 in a later study (Tobin and Brainard (1977)). They show that the ratio of the market value of capital and the replacement cost of capital, q, was consistently above 1 for the analyzed period, and when the first oil shock hit, raising discount rates and reducing the current book value of assets, q fell down in 1973-74. They also point that q helped explain 40% variation in investment in the 1953-1973 period.

This view was further supported by Fischer and Merton (1984). They argue that given the forward-looking nature of stock prices they can qualify as a predictor of business cycles. They say that

> ... the change in stock prices taken by itself has predictive power for each component of the change in investment, and that it retains its power to predict (especially) business fixed investment and inventory investment ...

When stock prices go up they reflect the market's expectations of higher future earnings, which are in turn related to higher expected output. Fischer and Merton go on to claim that stock markets are the single best predictor of business fixed investment, irrespective of whether these markets are rational or not. They do point to the endogeneity of stock prices, but also state that stock prices Granger cause investment. Increases in asset prices, in this case stock prices, lead to higher investment and vice versa.

In a further analysis Blanchard, Rhee, and Summers (1993) present a second version of q, which is not based on market prices, but on the expectations of the

managers. Their argument is that managers are likely to have better information sets than markets, and are therefore in a better position to determine future investments if they see a favorable discrepancy between their own valuation of q (q^* in their paper), and the market valuation of q. They conclude that q is a good predictor of investment, an increase in q leads to higher investment; but, it is an even better predictor when combined with the expected present value of profits.

In more recent work, Abel and Eberly (2011) analytically show that investment is correlated to Tobin's q and cash flow even when there are no adjustment costs, or frictions, to take care of. As we have seen so far, multiple empirical studies have supported the claim that Tobin's q is a good predictor of investment. The predictive power of the metric may have changed over time, but there have been arguments (as mentioned above) that Tobin's q continues to be one of the best predictors of future investment. It is important to point out that marginal q is the parameter of interest, and not average q, and Hayashi (1982)'s contribution thus becomes very important. While macroeconomists in general are more concerned about what is happening in the debt market, and the market for money, these studies seem to suggest that movements in the stock market, or equivalently changes in asset prices (here, stock prices), are a good predictor of investments. Finally, it is important to point out that the stock market is not a good predictor of residential investment, but of business investment.

Asset Prices and International Capital Flows

Economies have become more integrated over the last few decades. International trade rose for every single year from the end of the Second World War till the Great Recession hit. This increased international trade has been accompanied by an even larger increase in the movement of capital across countries. The period of interest here would be the time since the collapse of the Bretton Woods system following the Nixon

shock of 1971. As was stated earlier, changes in asset prices can influence international capital flows, exchange rates, and demand. There are many channels through which this can happen. As an example, if equity prices rise in country A, investors outside country A would be inclined to invest in A, thus increasing capital flows to A. This rising capital inflow will help increase the value of country A's currency, and can help sustain a larger current account deficit. It would increase demand in country A as the currency rises in value, and hence increase consumption through the wealth effect. This higher demand can in turn increase investment in the economy. The opposite will happen with falling equity prices. The same can happen in a slightly different manner. Capital inflows can help raise equity prices in country A, and the other steps will still follow in tandem. So it is important to establish the causality. But in either case asset price changes are accompanying changes in capital flows, and changes in capital flows have been known to be associated with big changes in the state of the economy.

The literature on international capital flows primarily looks at the impact on economies if there are major changes in the rate of flow of capital. Calvo (1998) puts forward a very simple explanation of how capital flows can influence output. He argues that if there is sudden stoppage in capital inflows, it would lower demand for both tradable and non-tradable goods owing to the sticky nature of real exchange rates. As capital inflow stops, this would reduce the current account deficit, and lower imports. It would also increase the price of tradables relative to non-tradable goods. Given that this inflow change was sudden, and unexpected, it may end up making loans made to the non-tradable sector nonperforming. These nonperforming loans in turn may lead to bankruptcies. It is exactly what happened to many Asian economies during the Asian financial crisis of 1997. As capital inflows dried up, it drove many real estate firms, transport companies, and banks into bankruptcy.

Many studies have also looked at the link between capital flows, exchange rates and the current account deficit with specific focus on the US. Fratzscher, Juvenal, and Sarno (2010) use a long series of US data to conclude that the US current account developments are only temporarily affected by changes in real exchange rates, and that domestic equity and housing prices are much more important determinants. Various other studies have taken this a step further and argued that even extreme asset prices are sustainable, and that US current account deficits are not such a bad thing. Ventura (2001) argues that the high levels of US current account deficits are a result of the massive increase in US wealth in the last two decades. This in turn has been ascribed to the rapid accumulation of some intangible asset in the economy, and to the bubble in the US stocks in the late 1990s. Kraay and Ventura (2007) take this further and argue that stock markets and fiscal deficits are closely linked. They point to the presence of dynamically inefficient investments which opens up the possibility of asset bubbles to exist. Caballero, Farhi, and Hammour (2006) interpret extreme asset valuation as high valuation equilibrium that may be sustainable. They argue that speculative growth facilitates the presence of 'rational' bubbles.

What causes changes in capital flows has been analyzed by many including Hau and Rey (2006), Forbes and Warnock (2012) and Broner, Didier, Erce, and Schmukler (2013). Hau and Rey (2006) compare 17 OECD countries to conclude that exchange rate dynamics are very strongly related to equity market developments and that this relationship is more pronounced in countries that are more dependent on financial markets than banks to raise funds. For example, the US is more market dependent, while Germany is more bank dependent. Quite surprisingly, they find that higher relative returns in the home equity markets is associated with home currency depreciation. They ascribe this to a rebalancing of portfolios that investors indulge in in such scenarios to account for exchange rate risks. Forbes and Warnock (2012)

and Broner et al. (2013) both look at the causes behind changes in capital flows, but come up with contradictory results. While Forbes and Warnock (2012) find that global factors in general, and global risk in particular, is the most important factor driving capital flows, Broner et al. (2013) conclude that asymmetric shocks (that hit investors in different countries differently) are more important for capital flows. But both do agree that changes in capital flows, irrespective of what caused it, can amplify economic cycles.

On the theoretical side, two of the more important recent contributions have come from Pavlova and Rigobon (2007) and Tille and van Wincoop (2010). Pavlova and Rigobon (2007) present a two-country, two-product model where the real exchange rate, and stock and bond prices are jointly determined. In the model the foreign exchange market serves as the transmission mechanism to propagate shocks from one economy to the other. On the other hand, Tille and van Wincoop (2010) are one of the first to develop an open economy dynamic stochastic general equilibrium model of capital flows with portfolio choice. They use a two country, two good, two asset model to conclude that the time-varying portfolio shares that result from assets' time-varying expected returns and risk characteristics are a potential driver for international capital flows.

This concludes a brief review of three of the four channels through which asset prices influence the economy. In the next section we do a more detailed literature review of the channel of interest to us: the balance sheet channel that depends on the demand and supply of credit in response to changes in asset prices.

Balance Sheet Recessions: A Literature Review

Multiple studies have dealt with the role of imperfect credit markets. Models dealing with collateral are a part of this stream of literature. It has been argued

that the importance of credit stems from the imperfect substitutability of different sources of financing (Stiglitz and Weiss (1981)), which in turn is seen to arise from different information sets. These information asymmetries have been shown to lead financial intermediaries to ration credit (see for example, Stiglitz and Weiss (1981), B. Greenwald, Stiglitz, and Weiss (1984), de Meza and Webb (1992), and Fazzari and Peterson (1993)). It has also been shown that credit and output are very closely related (Blinder and Stiglitz (1983)), and the way agents interact with financial markets can help explain business cycles (B. C. Greenwald and Stiglitz (1993)).

Credit markets are marked by information asymmetries, where the problems of both adverse selection and moral hazard exist. Self-selection issues are important in these markets. Lenders issue debt in expectation of positive returns, but loan payment is contingent on the state of nature and action of borrowers. Lenders have little control over either. To reduce the risk of loan losses lenders have two alternatives: either, limit the amount of debt to the collateral that the borrower can offer; or, use a financial intermediary that is responsible for monitoring the actions of the borrower. In the former case changes in asset prices influence the value of the collateral, and hence access to credit. Fluctuations in asset prices over a business cycle will then end up causing fluctuations in available credit. These changes in credit access in turn have the potential to influence output. In the latter case it must be noted that monitoring is costly, and thus the use of financial intermediaries is bound to raise the cost of borrowing. If the costs of monitoring change over a business cycle this can help explain the changes in the size and characteristic of credit and output. While both channels offer exciting avenues of research, our focus will mainly be on the first one, the collateral channel. The second channel, that of financial intermediation, is left for future work.

The Collateral Story

Using a model where debt is completely secured by assets that play the dual role of a factor of production and collateral Kiyotaki and Moore (1997) (henceforth, KM) show that the interaction between asset prices and credit limits is an important transmission mechanism. In their model borrowers and lenders are both risk neutral, and the future is known with certainty. In the event of an unexpected technology shock that alters the productivity of both borrowers and lenders they show that the borrowers' capacity to borrow and their demand for assets change. Changing demand for assets in turn change asset prices, that subsequently reinforces the impact of the technology shock through the balance sheet channel.

A positive technology shock that raises productivity increases borrowing in the current period, increases asset prices and net worth in future periods, and thus leads to higher borrowing in future periods too. More borrowing in turn leads to borrowers holding a larger proportion of total capital which is assumed to be fixed. In the KM world borrowers are more productive than lenders and any shock that increases capital holding of borrowers leads to a more than proportionate increase in output in the current and future periods. A negative technology shock on the other hand reduces productivity and borrowing capacity in the current period, reduces asset prices and net worth in future periods, and thus leads to lower borrowing in future periods. Such a shock reduces capital holding of borrowers and leads to a more than proportionate fall in total output in the current and future periods.

In a neoclassical model the impact of an idiosyncratic shock would dissipate the same period as the shock, but in this model with credit constraints, the impact of the shock builds up over time through the balance sheet before falling and disappearing. Therefore, unlike models with instantaneous adjustments, this model can explain how

the impact of a technology shock can amplify and persist over time through changes in asset values.

While the model in KM presents a good story to explain the amplification and persistence mechanism, questions have been raised about the simple functional formulation of the model. Both borrowers and lenders have been assumed to be risk-neutral. The production function for the borrower is linear, and there is no uncertainty except for the unexpected technology shock that hits in the first period. It is therefore, natural to question whether the results presented in KM are a consequence of their stylized economy, and whether they will hold under more standard specifications of concave utility and a convex production set. An even more interesting exercise will be to look at the impact of uncertainty in the economy. While it may be argued that in the neighborhood of a steady-state the assumption of risk neutrality is not a strong assumption, the same cannot be said of uncertainty. Any uncertainty in the economy lowers asset prices by introducing a risk premium, and at the same time increases volatility. Bekaert, Engstrom, and Xing (2009) show that over the complete spectrum of choices uncertainty is an important determinant for volatility, while risk aversion plays a major role in determining risk premium. Thus introducing both risk aversion and uncertainty in KM model will be an important step in confirming, or denying, the validity of the model in a more general setting.

In an extension to KM, Nobuhiro Kiyotaki (Kiyotaki (1998)) presented a model with logarithmic utility and linear production function. The paper addressed some of the weaknesses of the RBC model in explaining business cycles within the domain of observed shocks. In particular, it addressed an issue observed in practice: most observed shocks are sector specific, or shocks of distribution of wealth, while business cycles influence a much larger part of the economy. Aggregate productivity shocks are rare, but business cycles are not. Unlike the model presented this dissertation,

which is based on the first model from KM, Kiyotaki (1998) used a model with depreciation and reproducible capital. The model presented in Kiyotaki (1998) allows agents to change from productive to unproductive through a Markov process. This is similar to the argument in KM's more elaborate model that allowed investment with a probability below 1, thus rendering some of the producers unproductive every period. Kiyotaki (1998) allow both agent types to change their type with some positive probability, but while doing so they make the assumption that this transformation does not change the proportion of agents' types in the economy. The paper presents two versions of a model similar to KM, the first without asset prices, and the second with asset prices. In the model with no asset prices, but with a credit constraint that depends on output, the paper shows that equilibrium interest rate equals the rate of return on investment of unproductive agents. Agents save a fraction β of their output, where β is the time discount factor of both agent types. This saved amount is invested for future consumption. The model shows that if the share of productive agents is higher, productivity of the economy is higher, as is the growth rate of aggregate wealth. This rate of growth of aggregate wealth though is still lower than the growth rate of aggregate wealth in an unconstrained economy with no borrowing constraint. The steady state in the model only holds if the turnover rate from productive to unproductive agents is large, and the population of productive agents is small. The model showed that if these conditions are met, a shock to the economy changes the distribution of wealth in the economy, and this redistribution of wealth changes aggregate productivity and the growth rate. While the first model in Kiyotaki (1998) explains persistence, it does not present an amplification mechanism, which is an important part of the KM model.

The second version of the model in Kiyotaki (1998) incorporates asset prices in the form of land price, where land is also an input in production. The structure of

this model is similar to KM, and to the model presented in this dissertation. The one difference here is that the production function is now set to be a constant returns to scale production function, and it collapses to the Brock and Mirman (1972) model in the absence of borrowing constraints. As stated earlier, the steady-state interest rate in the model is equal to the rate of return on investment of unproductive agents which is below the rate of return on investment of productive agents, and thus the productive agents use all their net worth to borrow. The paper showed that in case of a negative economic shock agents expect a persistent decline in the user cost of land in the future periods. This expectation of a future decline in asset values fuels a large current decline in asset value. It also reduces the net worth of productive agents more than that of unproductive agents since they have outstanding debt obligations. The fall in net worth then feeds back into further declines in asset values, and net worth. Unlike the first model presented in the paper, the second model, with the incorporation of asset prices, illustrated both persistence and amplification.

Following up on KM, Krishnamurthy (2003) has shown that in the presence of complete hedging the results of KM do not hold. But, when the availability of hedging opportunities is tied to the net worth of agents the results obtained are qualitatively similar to those in KM. In an interesting extension Paasche (2001) shows that in the presence of international linkages, shocks to one economy can be transmitted to another, seemingly unrelated, economy through the balance of payments channel. Cordoba and Ripoll (2004) introduce risk aversion in KM model and claim that the results obtained in KM are particularly sensitive to the value of parameters chosen. The results in this dissertation support this argument, and show that with more standard specification of utility and production functions the results of KM are particularly sensitive to the choice of parameters. If the parameters are not within a certain range the model may not lead to a steady state equilibrium. In a special case

with iso-elastic utility and decreasing returns to scale production function the model shows that with an exogenous positive floor on borrowers' consumption the impact of an idiosyncratic technology shock on asset prices, capital and bond holdings, and output are qualitatively similar to those obtained in KM.

The Agency Cost Story

The collateral argument presents a good description of how technology shocks can amplify and persist through the asset price channel. But, most credit transactions take place via financial intermediaries and the studies presented above completely ignore them. It is instructive to analyze the situation where intermediaries, particularly banks, are included in the model.

It is well known that commercial banks are the primary source of funds to both households and small and medium enterprises (see, for example, Gertler and Gilchrist (1994)). While larger firms have access to other, usually cheaper, forms of credit, households and SMEs rarely have any other option. The quantity and price of the funds they can obtain depends on the amount of collateral they can offer. In this lending channel source of monetary non-neutrality banks, play a special role in the economy. They issue liabilities in the form of bank deposits, hold assets in the form of bank loans, and thus provide a service which has few close substitutes. Any shock that squeezes either the asset or liability side of banking will therefore make it difficult for banks to perform their role, for consumers to finance consumption, and for firms to finance investment. This is particularly true for small banks which depend primarily on deposits as their source of funds, and small firms which depend primarily on banks as a source of funds for investment. Any shock that leads to a contraction in either the supply of deposits, or supply of funds for investment, will have a negative impact on total output. This credit channel transmission mechanism has been studied at

least since the early 1950s, though Stiglitz and Weiss (1981) can be credited with the resurrection of this loanable funds theory of banking. In an independent work Diamond (1984) presented the ideas that form the basis of most modern theories of financial intermediation. Bernanke and Blinder (1988) and Bernanke and Gertler (1989) extend the loanable funds theory further by incorporating a balance sheet channel of monetary transmission. This channel has been subsequently named the financial accelerator mechanism (Bernanke, Gertler, and Gilchrist (1996)).

Bernanke and Gertler (1989) present a dynamic stochastic general equilibrium model where a firm's net worth determines the cost of borrowing for the firm. In the presence of asymmetric information firms with higher net worth can borrow at lower rates than firms with lower net worth. Net worth of economic entities is pro-cyclical, and thus the difference in the costs of borrowing, or agency costs, also end up being pro-cyclical. Periods of relative decline are accompanied by falling net worth and rising agency costs, while periods of growth are accompanied by rising net worth and falling agency costs. They show that a purely monetary shock to the net worth of firms has the capacity to trigger real fluctuations in the economy by altering agency costs.

In a similar spirit but using Diamond's framework Holmstrom and Tirole (1997) present a model of financial intermediation where the intermediary is credit constrained. This is a big departure from the standard framework where only the firms are assumed to be constrained. The importance of the constraint on the intermediary stems from the fact that it can help capture the impact of changes on the liability as well as the asset side of banking in the same basic structure.

As in KM, Holmstrom and Tirole (henceforth HT) specify an economy where agents are risk neutral, production is linear, and there is no uncertainty. Unlike KM their model is a two period static limited liability model. In period 1 the intermediary

takes deposits from households, combines it with some of its own funds, and makes investment decisions. All contracts are signed in this period. Firms then execute the investment decision using funds from the intermediary and their own resources. In period 2 investment returns are realized and claims settled. If the investment succeeds a return of $R, R > 1$, is realized, and if the investment fails no one gets anything.

Firms are run by entrepreneurs who have an incentive to deliberately reduce the probability of success of the project and enjoy private benefits. The model specifies two levels of shirking, with more shirking leading to more private benefits, but the level of shirking has no impact on the probability of the investment succeeding. Financial intermediaries are responsible for monitoring firms and reducing the moral hazard problem that is inherent in firm behavior. The authors do not specify any particular form of monitoring but allude to a structure where the intermediary ensures that firms conform to the 'covenants of the contract.' Monitoring is assumed to be privately costly, and thus there is a second level of moral hazard built into the model. The intermediaries have an incentive to not monitor firms. This forces the intermediaries to pitch in some of their own resources in the project to be recognized as credible monitors.

The amount contributed by the intermediary has to be compensated for normal return on investment (which is assumed to be exogenous and dependent on the households), and the cost of borrowing. It is obvious that financing from the intermediary will be costlier, and hence firms try to minimize that amount. Firms would prefer to borrow directly from the households, but owing to the moral hazard issues only firms with sufficiently high net worth can manage to do this. Other firms have to go to the intermediary for financing. The intermediaries demand monitoring in return for investment, and thus monitoring acts a partial substitute for collateral.

In case there is a fall in intermediary capital (a credit crunch) the intermediary will

increase the interest rate spread and firms with lower net worth will be the first one to be squeezed out. A fall in household savings has the same impact as intermediaries escape towards the relative safety of bigger firms who have higher net worth and lower leverage. Finally, a fall in firm capital (a collateral squeeze) also reduces firms' net worth and borrowing capacity. This again hits the smallest firms the hardest. Thus in this model small firms and highly leveraged firms tend to demand more intermediary capital, submit to stricter monitoring, and are the first to be excluded from access to credit with any form of capital tightening.

The model presented in HT is one of the first that explicitly models different types of financing available to firms. By putting up different costs to capital from different sources it manages to endogenize agency costs of Bernanke and Gertler (1989). With tightening credit the difference between the costs of different types of capital rise paralleling rising agency costs in Bernanke and Gertler (1989). By changing the amount of firm capital the model also captures some aspects of KM credit constraints model. While it does incorporate a credit constraint, the model does not consider the impact of changing asset prices. Incorporating the inter-relationship between interest rates and asset prices would require the model to be changed from a static two-period model to a dynamic one. Chen (2001) performs that extension and transforms the HT model into a dynamic infinite horizon problem. The extension allows him to study the dynamic interaction between asset prices and bank lending. His results are in stark contrast to those in HT. While HT show that the intermediary's capital-asset ratio, that is the ratio of own capital to total capital that an intermediary makes available, is pro-cyclical, Chen (2001) shows that with asset prices included in the model the capital-asset ratio becomes counter-cyclical. He goes so far to claim that pro-cyclical capital adequacy requirements are ineffective in countering a credit crunch. His work shares some other aspects of HT. These include risk-neutral agents, no uncertainty,

and identical agents who differ only in their endowments.

It will be interesting to examine the case with risk aversion when the agents differ more than in just their endowments. Another aspect that needs to be looked into more closely is the role that firms' efforts play in determining the success of projects. Both HT and Chen assume that the level of shirking has no impact on the probability of project success. This seems counter-intuitive, and fails to put a convincing story for the need of monitoring if a firm's action has no impact on the success of the project. If we do endogenize project success the model will become richer, and more realistic. While the area offers exciting avenues for research we do not consider it in the present dissertation.

Before we end this part it is also important to note that any study of financial intermediation will provide some more insights into the bank regulation debate (see, for example, Minetti (2007), VanHoose (2008), Agénor and da Silva (2012), Covas and Fujita (2010), Hellwig (2010), Memmel and Raupach (2010), Repullo and Suarez (2013)) that has heated up in the aftermath of the Great Recession. Many have argued that Basel II set of regulations may in-fact have been partly responsible for the banking crisis (see, for example, Heid (2003) and Pederzoli, Torricelli, and Tsomocos (2010)). Ideally, we would like financial intermediaries to play a stabilizing role, but Goodhart (2010) argues that it might not even be an achievable goal.

The Contagion Story

Any set of events will always have repercussions over and above the direct impact, and economic events are no different. With trade leading to increasing integration of world economies the impact of events in one economy are often felt in seemingly unrelated places. In the recent period, the Asian financial crisis of 1997 began in Thailand, and soon its effects were felt as far as Latin America. The currency crisis

of 2001 began in Argentina and hit Turkey, South Africa and Russia before subsiding. The financial crisis of 2008 began in the United States and soon had the whole world in its throes. One common thread in all these was a financial crisis triggering a collapse in output. In some cases it was contained within a small group of countries (for example, the 2001 crisis), while at other times it spread over a much wider area (for example, 1997 and 2008).

There are various streams in the literature that try to explain such spillover effects (more commonly called contagion). One of these explores the possibility of financial constraints, that is the presence of imperfect credit markets, acting as a transmission medium for the crises. But the possibility of financial crisis leading to spillovers in the real economy across countries has not attracted the same kind of attention as bank contagion.

The literature that has actually looked at this interconnection between international financial flows and real economy can be broadly divided into two groups: one dealing with constraints in the developed economies, and another dealing with the same in developing economies. In case of a developed economy the argument put forward is that financial constraints, either among firms, or banks, limit a country's ability to reallocate resources and thus makes it inefficient. This inefficiency in turn makes the shock more persistent, and also leads to its amplification. On the other hand, the literature dealing with developing economies usually points to the fact that for most such economies international aggregate borrowing constraints are binding, and any negative shock will lead to real relocation of assets. This was particularly true in the aftermath of the Latin American debt default in the 1980s and the Asian financial crisis of 1997. Examples of work dealing with the developed economy argument include Bernanke and Blinder (1988), Kiyotaki and Moore (1997), and Holmstrom and Tirole (1997), while that dealing with developing countries are Bulow and Rogoff

(1989), Atkeson and Ríos-Rull (1996), Caballero and Krishnamurthy (2001) (for explicit models of international collateral constraint), and Calvo (2000) (for an implicit model). While we have discussed the former set of studies earlier, we look at the other set here.

Bulow and Rogoff (1989) presents a bargaining model of sovereign debt where borrowers cannot commit to future repayments, and in which they can sometimes successfully negotiate partial defaults or rescheduling agreements. In the model, the debtor country is assumed to be small and does not have the power to influence world prices and interest rates. It produces goods and trades with other countries. The creditors can seize the products the debtor ships in case of a default. Since the debtor always has the option of consuming its output domestically, it can never be forced to make repayments in excess of its gains from trade. Collateral plays no role in the model since debtor assets that may be accessible to creditors in the event of a default are a small fraction of outstanding debt.

In case of private debt the situation is different. When a bank issues a debt to a company in a foreign country, the debt is backed by a collateral of the same value. Assume a shock hits the debtor country and production falls. The debtor company is forced to sell assets to meet its debt obligations which increases the supply of assets in the domestic market, and asset prices fall. This reduces the value of collateral and hence the net worth of the debtor falls. Lower net worth means borrowers have to face higher interest rates (to compensate for higher risk) which in turn lead to changes in relative prices, and through the balance of payments channel influences the economic health of other countries. Thus problems in one country can propagate to another, seemingly unrelated economy, through the balance of payments channel.

Atkeson and Ríos-Rull (1996) present a discrete time model where a country faces a balance of payments crisis if constraints on its international borrowing bind. They

model the situation where a country's residents and government, given some world interest rates and the prevailing exchange rate, wish to spend in excess of national income. This excess spending is financed by borrowing from abroad and the borrowing continues till the lenders think that the borrowing country can no longer pay off the debt. When this borrowing constraint is reached the country has to either cut down spending or the central bank has to use its reserves to buy government debt while the country continues to spend above its national income. While the model analyzes international borrowing, it does so in an endowment economy with no production. Further, the limit on foreign lending is put in an ad-hoc way, and loans are not dependent on any collateral. Thus, asset prices do not play a role in their model.

Calvo (2000) endogenizes output and discusses the channels through which a balance of payments crisis can lead to an output collapse. He argues that the key difference in understanding an international financial crisis is the role that sovereign governments play. He talks about the case of vanishing credit wherein a negative shock in one sector could lead to a credit crunch in the whole economy. He further argues that these kind of spillover effects are crucial to give a full qualitative and quantitative analysis of crises in the developing world.

The models examined in both parts of the literature (developed country and developing country) can be represented by a heterogeneous agent economy with asymmetric information. But that is easier said than done. No one has been able to prove the existence of a stable equilibrium in an economy with heterogeneous agents and asymmetric information (see Kubler and Schmedders (2002) and Reiter (2009)). Models without asymmetric information, like the one in this dissertation, are solved using linearization around the steady state. That said, examining heterogeneous agent models, where agents represent different countries, with information asymmetry would be an exciting area of research for the future.

Dissertation Outline

Contributions to the Literature

This dissertation is a theoretical study of how asset prices influence economic activity through credit markets. Using a heterogeneous agent economy similar to that in Kiyotaki and Moore (1997) it shows that asset prices can act as an important transmission mechanism, and can help explain amplification and persistence of technology shocks. It first shows that with linear utility and production functions any credit constraint moves the economy away from a first-best outcome. The credit constraint amplifies the effect of the shock through the asset price channel, and increases the persistence of the shock. The final impact of any technology shock is more than proportionate to the size of the shock. The outcomes of the model are different from standard neoclassical models where the effects of a technology shock dissipate in the period they are realized. Further, unlike standard neoclassical models, the model presented here can explain how a small observed shock can lead to large changes in observed economic activity.

With more standard specifications of utility and production functions that allow for risk aversion and decreasing returns to scale production it shows that credit constraints still move the economy away from a first-best outcome. In particular, it shows that if agents in the heterogeneous agent economy are not very different from each other (in terms of their time discount factor, and in their production technologies) a steady state can be obtained where asset prices play an important role in amplifying technology shocks and making them more persistent. In the steady state thus obtained, the allocation of resources in the economy is not efficient in the Pareto sense. Further, this steady state holds only within a small range of parameter values, in other words on a 'knife-edge,' but the range of values for which the results hold are

consistent with observed differences between borrowers and lenders in practice. The above claim (about borrowers and lenders being similar) is based on the fact that real interest rates over an extended period of time have remained consistently close to 2%, which suggests that borrowers and lenders do not differ too much in terms of how they view the future. Therefore, the constraint that agents are similar to each other may not bind in practice.

Numerical simulations of both the linear and the nonlinear models show that a 1% technology shock in the model non-linear economy leads to a 0.85% immediate change in output by moving capital from one agent type to another. Over time, the total change in output turns out to be more than the impact of the shock. Simulations also suggest that the effects of the shock can persist for up to 13 periods. With the way the parameters have been selected in the simulation, 13 periods translates to a time period of more than 3 years. There are large changes in borrowing and lending with any technology shock which is consistent with observed behavior of economic agents in practice. In a neoclassical world a 1% shock would lead to a 1% change in output, and the effects of the shock would disappear in the same period as they appear. The model presented in the dissertations shows that with credit constraints incorporated, shocks tend to amplify, and persist over time, and can potentially help explain the difference between observed shocks and the resulting impact on the economy.

The theoretical models examined in the dissertation do not lend themselves easily to empirical analysis. So a proxy, housing, has been used in the dissertation as the asset of interest to see if changes in housing prices have been accompanied by changes in the real economy. The analysis does not try to establish causation, but looks for correlation between changes in housing prices, and changes in credit and economic activity. The correlation between housing prices and credit crisis is examined using an event analysis method. Event analysis methods have been used in the financial

economics literature since the early 1970s, and are used to analyze the effect of firm or sector specific event on security returns over short horizons. They are primarily used for short horizons since they assume that the specification of expected returns does not change. The fact that securities offer higher frequency data helps in carrying out this exercise with securities data more easily. If used with low frequency data, any causal relationship indicated by regressions from event analysis will not be useful, since it is very likely that the distribution of expected returns has changed over the longer time frame.

Real estate data by its nature is less frequent, and therefore, event analysis methods cannot be used to specify a causal relationship. What can be done though is an analysis of the movement and behavior of variables of interest around some event of interest. This exercise is performed in this dissertation using housing price data from 18 rich countries. Using a modified Bry-Boschan cycle dating procedure the dissertation shows that housing price increases, when accompanied by a growth in private sector lending, are a clear sign of an impending credit and banking crisis. The peaks of real estate cycle, and financial cycle, have tended to coincide more than once. Nominal private credit growth starts falling before a housing peak is reached, and, in a worse than average drop in housing prices, nominal private credit growth actually turns negative. GDP growth follows a similar path. This is consistent with the results in the theoretical model which show that asset prices and credit move in the same direction, and credit moves more than proportionately with asset prices. The analysis also shows that inflation rates do not change with real estate prices, particularly when the real estate market is about to peak, and thus using inflation rate as the barometer of economic health may not be very useful as a warning sign of a housing led credit crisis. This fact has been recognized by policy makers across the world, and it reflects in the much wider focus on, and use of, macroprudential regula-

tion over the last few years. The steps taken in this direction are briefly summarized later in the dissertation.

The dissertation contributes to the literature on how asset prices influence economic activity by acting as a transmission and amplification mechanism using the Kiyotaki-Moore credit cycles model as a benchmark. This is done in a three step process. First, a model similar to KM with linear utility and production functions is solved. The model is solved using dynamic programming to eliminate any path dependence. Second, a non-linear version of the model is solved, again using dynamic programming. A generalized version of the model is not amenable to a closed form solution, therefore, a model with specific utility and production functions is solved. The dynamics of the specialized version are then analyzed using computer simulations. Third, the role of housing markets in determining the health of the economy is explained through an event analysis method.

While the core structure of the KM economy is retained in the theoretical analysis, the model presented here is a non-linear version of the KM economy, thus allowing the incorporation of risk aversion and decreasing returns to scale production. The use of dynamic programming as a solution method precludes the need to solve multiple non-linear optimization problems, one for each horizon, thus making the models, and the solution techniques, presented here more useful in other contexts.

Two version of the Kiyotaki-Moore credit cycles model are illustrated in the dissertation. The linear version is the closest in structure, and spirit, to KM. Unlike KM, the models in the dissertation are solved using dynamic programming. The equilibrium outcome obtained here is similar to that in KM. As stated earlier, the choice of dynamic programming as a solution method precludes path dependence of the resulting equilibrium, and the fact that the obtained equilibrium here is similar to the equilibrium obtained in KM proves the robustness of results in KM.

A non-linear version of the model that incorporates risk aversion and decreasing returns to scale production function is also solved. It shows that when agents are not very different from each other in their time discount factors and production technologies, a steady state where asset prices act as a transmission and amplification mechanism is obtained. It is not possible to obtain a steady state in a generalized version of the model, so the results obtained here may be dependent on the choice of functional forms of both utility and production functions, and on the choice of parameters. If there are large differences between borrowers and lenders in either production technologies, or time discount factors, they are less likely to agree to a market clearing price of assets, and the less likely it is to obtain a steady state equilibrium in the model. The results obtained here suggest that the conclusions in KM may depend on functional representation, and will not hold in general. There would still be scenarios where the results in KM will hold in a non-linear context, but that would require some specific choice of functional forms as well as parameters.

With the introduction of credit constraints in the economy, the allocation of resources across agent types is not efficient. This is not surprising, since any imperfection in the market will move the economy away from a first-best outcome. The cost of borrowing in the model stays constant, and hence the cost of any incremental gains from borrowing rise rapidly (since the production function is assumed to be a decreasing returns to scale function). This ensures that no agent type hogs all the capital in the economy. This also keeps the economy away from a corner solution.

There are two clear omissions in the models presented here. First, both the linear and non-linear models are deterministic. While dynamic programming allows an examination of stochastic models, no one has been able to prove the existence of an equilibrium in a stochastic heterogeneous agent economy. Any uncertainty (with the exception of a random technology shock) has therefore been avoided in the models

presented in the dissertation. The second clear omission is the lack of an explicit financial intermediary. Introducing a financial intermediary will make the dynamics of the model richer, but will simultaneously increase the complexity of the solution. That is work left for the future.

Dissertation Organization

Chapter 2 presents a description of the heterogeneous agent economy, and specifies the constraints under which the agents operate. A linear version of the economy, with linear production and linear utility functions, is then solved using dynamic programming. Keeping both functions linear gives rise to equilibrium that are not reflective of the role of asset prices, which is the main focus of this dissertation. Therefore, the assumption of linear production is relaxed for one type of agent, and a steady state in the resulting model is then obtained and analyzed. The results obtained for this model are similar to the ones obtained in KM.

Chapter 3 builds on the same economic philosophy that was introduced in Chapter 2. But the chapter uses more standard specifications of utility and production functions. It considers concave utility functions, that allow for risk aversion, and decreasing returns to scale production functions. This model does not have a closed form solution in the general case: therefore, specific function forms are assigned to both utility (a constant elasticity of substitution utility function) and production (a functional form similar to Cobb-Douglas but with decreasing returns to scale). The specific functional forms are then used to determine a closed form solution of the model. The dynamics of the resulting economy in response to a random technology shock that hits the economy is then examined. The big takeaway from this part of the dissertation is that the results in KM do seem to depend on the specification of production and utility functions. Not all utility and production functions will lead

to a steady state. Even within the small subset of functional forms that may lead to a steady state, parameter values become a prime determinant of the resulting equilibrium.

A numerical simulation of the way the economy responds to a random technology shock is then performed. With linear preferences and no uncertainty a positive 1% technology shock increases the capital being held by more productive agents by about 3.5%, and the impact of the shock persists for about 4 periods. With concave utility and convex production function the same 1% shock can raise capital holding of more productive agents by more than 4.5%, while increasing persistence to as high as 13 periods (which is equivalent to more than 3 years in the current context, given the way parameters have been specified). In either case the impact on distribution of assets, output, and prices are more than proportionate to the magnitude of the technology shock.

The simulations suggest that the impact of shocks on capital holdings are more pronounced if agents are more productive. In practice this would suggest that asset prices are a stronger transmission mechanism in developed economies. If the proportion of borrowers in the economy falls, shocks persist for longer, and impact on borrowers' capital holdings becomes larger. Asset prices also tend to change more with rising productivity and falling savings rate. These results are elaborated upon and a comparison with KM is presented at the end of the chapter.

Chapter 4 is a survey on the role of housing prices and their effect on economic activity. It examines how fluctuations in the housing market accompany changes in economic activity. There is no effort to establish a causal relationship here. An event analysis is first performed in the spirit of Fama, Fisher, Jensen, and Roll (1969). The event of interest is the peaking of a real estate cycle. The longer cycles are then filtered out from the full list. These longer cycles are then examined to see how the

peaks of these cycles are correlated with three variables of interest: growth rate of gross domestic product, growth rate of private sector credit, and growth rate of prices. A small review of the evolution of world's two largest mortgage markets, the United States and Japan, is then performed, along with a brief overview of how mortgage markets function in a larger group of rich countries. Though the markets examined here operate in different ways, sometimes markedly so, all of them have experienced at least one major real estate crash in the last four decades. A comparative study can help filter potential early warning indicators for a real estate led crisis.

The reason for choosing housing as an asset of interest in the dissertation boils down to this simple reason: the Great Recession was preceded by the bursting of the sub-prime mortgage bubble in the United States. The fall in asset values as a result of the collapse of housing prices caused problems in the banking sector, which in turn propagated the crisis to other sectors of the economy through a contraction in credit supply. This automatically puts forth a question on whether this was a black swan event, or whether there has been precedence to this, and whether there are some early warning indicators that can be searched for. While the crash of the Japanese asset price bubble immediately comes to mind, one swallow does not a summer make.

As a matter of principle, and based on past precedence, it is known that real estate bubbles may occur without banking crisis, and banking crisis may occur without real estate bubbles. The term 'bubble' is used very loosely here. Different streams recognize bubbles in different ways, but for the context of this dissertation the only point of concern is a sustained increase or fall in asset prices. For further details about how bubbles have been defined see Helbling and Terrones (2003), Shiller (2003), and Shiller (2006). What is observed though is that in a surprisingly large number of instances the two have coincided (see, for example, Herring and Wachter (2003)). Barrell, Davis, Karim, and Liadze (2010) present an empirical model that suggests

property prices can be an important early warning indicator for banking crises. These banking crises can in turn lead to changes in the larger domain of economic activity.

Data from 18 rich countries, spanning a period of 43 years, from 1971 to 2014 is then used to determine how real estate prices have fluctuated in these markets. Using a modified Bry-Boschan cycle dating procedure a total of 93 cycles in real estate prices in this group of 18 countries is counted. Some of these cycles are very short, lasting as little as 2 quarters. The average length of a cycle from peak to trough was about 6 quarters. It is possible that shorter cycles may just be showing minor corrections in real estate prices, or just reflecting reporting errors, so the dissertation focuses on the longer cycles, which are more likely to have an impact on banking and economic health. Every country in the sample had at least one long real estate cycle (lasting more than 6 quarters). There are a total of 39 long cycles in the data set. Once the cycle dates have been determined the behavior of three variables are examined around the peak of long real estate cycles: real GDP growth rate, growth rate of private sector credit, and the rate of inflation.

There is no statistically significant difference between inflation rates prior to, and post, the peak of a long real estate cycle. Rising real estate prices when accompanied by rising private sector credit do indicate problems in the economy once the real estate peak is crested. Both these factors suggest that regulators may need to look beyond just inflation rate as the sole metric of economic health. There have been moves in this direction, and the recommendations of the Bank of International Settlements (BIS) as a part of the Basel III framework try to address some of these concerns. A summary of these changes is presented. The chapter ends with a brief overview of the two largest mortgage markets in the world: the United States and Japan. Besides the size, there is little in common between the two markets. Mortgage origination, funding, regulation, and repayment, are all very different in the two markets, but

both economies have been through a major real estate induced economic crisis in the recent past, and therefore, a deeper analysis of the two may provide lessons to others.

Besides the US and Japan there is a brief survey of mortgage markets across the world, which suggests that there are wide variations in the way mortgage markets function. The availability of mortgage funds, and the choice of instruments to fund mortgages vary widely. These tend to influence the type of mortgages available in the economy, but at least superficially does not seem to influence the likelihood of a housing led crisis. Countries which rely on deposits to fund mortgages predominantly use adjustable rate mortgages, while countries where mortgages are funded by covered bonds or mortgage backed securities tend to have more fixed rate mortgages. While this is to be expected given the nature of funding, more detailed analysis would be required to test whether the source of funds has an impact on either the likelihood, or the severity, of a housing led economic crisis.

While this dissertation is primarily a theoretical study of the role of asset prices in business cycles, the models presented here are amenable to empirical analysis. There is renewed interest in how real estate may come back to haunt the engine of world growth for the last decade: China. Like banks from Japan in 1980s, today China's banks are on top of the world pile in terms of assets held. They hold five of the top ten slots by assets held, and by market capitalization. Japanese banks, at their peak in the 1980s, occupied all ten slots! Mortgages have become more important in China and the exposure of Chinese banks to Chinese infrastructure in general and real estate in particular has risen. Any major correction in real estate prices in China may prove disastrous to at least some of these banks. Some of these issues are addressed, and a path for future work is presented before conclusion in Chapter 5.

CHAPTER 2

CREDIT CYCLES

Description of the Economy

The economy consists of two types of agents, type I and type II, both infinitely lived. Both agent types can transform capital to output, and both value their own stream of consumption. They differ in two respects: one, on how they discount the future; and, two, how productive they are. These differences, as we will see below, will induce type I agents to want to borrow in net from type II agents. Thus, I will sometimes refer to type I agents as borrowers, and type II agents as lenders.

One crucial feature of the model is a constraint on lending/borrowing that can occur between the two types. This restriction will take the form of a collateral requirement, and will have the effect that capital values impact how much borrowing and lending can occur. The main interest of the model will be the extent to which a productivity shock alters lending and output levels in the economy, both immediately, and through time.

The borrowing constraint is important for various reasons. In case of a default by the borrower (who, as we shall see later, will be type I agents), the borrower cannot be forced to pay more than the existing assets that they have. The only explicit input

to production in the economy, and the only available asset, is capital used to produce output. The human effort put forth by the representative agent is inalienable to the individual (see, for example, Hart and Moore (1994)), and cannot be extracted from the borrower. Thus, the only loss that the borrower can face is lose their capital holdings. Lenders know this. Hence, they will rationally not opt for loans exceeding the value of collateral on offer, which will be the value of capital that the borrower has. This idea can only be captured if we incorporate an explicit borrowing constraint into the model.

Decision Problems

Let $c_{1,t} \in \mathbb{R}_{++}$ be the consumption of type I agent at date t; and let $\beta_1 \in (0,1)$ be their time discount factor. Let $u(c_{1,t})$ be the utility that type I agents derive from consumption. Let $k_{1,t} \in \mathbb{R}_{+}$ be the capital that type I agents hold at end of period t, and let b_t be the amount they borrow in period t. Type I agents use capital available to them at the beginning of period t, $k_{1,t-1}$ to produce output $y_{1,t}$ at the end of period t, using a production function $f(k_{1,t-1})$. There is a commodity market where one unit of capital is exchanged for $q_t \in \mathbb{R}_{++}$ units of output. We also have a credit market where one unit of output at date t is exchanged for $R_{t+1} \in \mathbb{R}_{++}$ units of output at date $t+1$.

Similarly, let $c_{2,t} \in \mathbb{R}_{++}$ be the consumption of type II agent at date t; and let $\beta_2 \in (0,1)$ be their time discount factor. Let $u(c_{2,t})$ be the utility that type II agents derive from consumption. Let $k_{2,t} \in \mathbb{R}_{+}$ be the capital that type II agents hold at end of period t, and let l_t be the amount they lend in period t. Note that if l_t is negative, type II agents become borrowers. Like type I agents, type II agents use capital available to them at the beginning of period t, $k_{2,t-1}$ to produce output $y_{2,t}$ at the end of period t using a production function $g(k_{2,t-1})$. They also access the same

commodity and capital markets as type I agents.

Type I agents choose a stream of capital holdings, $k_{1,t}$, borrowing levels, b_t, production levels, $y_{1,t}$, and consumption $c_{1,t}$ to maximize a discounted stream of utility. Specifically, at each date t, type I agents take $k_{1,t-1}$, b_{t-1} and all past and future prices $q_t, t = 0, 1, 2, \ldots$, as given, and choose $c_{1,t}$, $k_{1,t}$, b_t, and $y_{1,t}$, to maximize their lifetime discounted utility subject to budget and borrowing constraints. That is, they solve,

Maximization Problem 2.1.

$$\max_{\{k_{1,t},b_t,c_{1,t},y_{1,t}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta_1^t u(c_{1,t}) \tag{2.1}$$

subject to

$$\begin{aligned} R_{t+1}b_t &\leq q_{t+1}k_{1,t}, & (2.2)\\ q_t(k_{1,t} - k_{1,t-1}) + R_t b_{t-1} + c_{1,t} &\leq y_{1,t} + b_t, & (2.3)\\ y_{1,t} &\leq f(k_{1,t-1}) & (2.4) \end{aligned}$$

and

$$\begin{aligned} c_{1,t} &\geq 0\\ k_{1,t} &\geq 0\\ y_{1,t} &\geq 0. \end{aligned}$$

for all $t = 0, 1, 2 \ldots$

Note that, as of now, there are no restrictions on the value that b_t can take. Further, a remark is in order on constraint shown in Equation 2.2. The constraint is

used by Kiyotaki and Moore (1997) and Gertler, Kiyotaki, and Prestipino (2016). It reflects the idea that the borrower can default and lose the value of capital held, but not lose anything else.

Like type I agents, type II agents choose consumption $c_{2,t}$, lending l_t, capital holdings $k_{2,t}$, and output $y_{2,t}$ to maximize a discounted stream of utility. Specifically, at each date t, type II agents take $k_{2,t-1}$, l_{t-1} and all past and future prices $q_t, t = 0, 1, 2, \ldots$, as given, and choose $c_{2,t}$, $k_{2,t}$, l_t and $y_{2,t}$ to maximize their lifetime discounted utility subject to budget and borrowing constraints. That is, they solve,

Maximization Problem 2.2.

$$\max_{\{k_{2,t},l_t,c_{2,t},y_{2,t}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta_2^t u(c_{2,t}) \tag{2.5}$$

subject to

$$\begin{aligned} R_{t+1}(-l_t) &\leq q_{t+1}k_{2,t}, & (2.6)\\ q_t(k_{2,t} - k_{2,t-1}) + l_t + c_{2,t} &\leq y_{2,t} + R_t l_{t-1}, & (2.7)\\ y_{2,t} &\leq g(k_{2,t-1}) & (2.8) \end{aligned}$$

and

$$\begin{aligned} c_{2,t} &\geq 0\\ k_{2,t} &\geq 0\\ y_{2,t} &\geq 0. \end{aligned}$$

for all $t = 0, 1, 2, \ldots$

The collateral constraint for type II agents, Equation 2.6, is the same as that for

type I (Equation 2.2). If type II agents are lenders, as will be the case in equilibrium that follows, $l_t \geq 0$ will hold, and Equation 2.6 will not bind, and hence will not impact the equilibrium in any way. It is included here mainly to ensure that type I and type II agents differ only in their preferences and productive capacities.

Model Assumptions

I now make some specific assumption on preferences, and productivities, before defining the equilibrium. Assume that type I agents are less patient than type II agents. Type I agents are also assumed to be more productive in the domain of available capital, which is assumed to be fixed. Total population in the economy is assumed to be fixed, and of unit mass. The proportion of type I and type II agents is fixed. All available capital is distributed between the two agent types. More specifically,

Assumption 2.3. Type I agents are less patient than type II. That is, $\beta_1 < \beta_2$.

Assumption 2.4. Total amount of capital in the economy is fixed at a level $K > 0$.

Assumption 2.5. Type I agents are more productive than type II agents over the range of available capital. That is for any $k \in [0, K]$, $f(k) > g(k)$.

Assumption 2.6. Total population in the economy is fixed, and is of unit mass. The proportion of type I agents is θ, and that of type II agents is $(1 - \theta)$.

Assumption 2.7. The aggregate capital stock neither grows, nor shrinks, and is distributed between the two agent types, such that $\theta k_{1,t} + (1 - \theta)k_{2,t} = K$, for all $t \geq 0$.

Equilibrium Condition

For given values of $(k_{1,t-1}, b_{1,t-1}, k_{2,t-1}, b_{2,t-1})$, an equilibrium is a sequence of asset prices, interest rates, lending, borrowing, consumption and capital holdings $\{q_t^*, R_t^*, l_t^*, b_t^*, c_{1,t}^*, c_{2,t}^*, k_{1,t}^*, k_{2,t}^*\}_{t=0}^{\infty}$ such that

1. $\{c_{1,t}^*, b_t^*, y_{1,t}^*, k_{1,t}^*\}_{t=0}^{\infty}$ maximizes 2.1 subject to Equations 2.2, 2.3 and 2.4;
2. $\{c_{2,t}^*, l_t^*, y_{2,t}^*, k_{2,t}^*\}_{t=0}^{\infty}$ maximizes 2.5 subject to Equations 2.6, 2.7 and 2.8;
3. credit markets clear, that is $\theta b_t = (1-\theta) l_t$;
4. goods market clear, that is $\theta c_{1,t} + (1-\theta) c_{2,t} = \theta y_{1,t} + (1-\theta) y_{2,t}$; and
5. capital market clears, that is Assumption 2.7 holds, or $\theta k_{1,t} + (1-\theta) k_{2,t} = K$.

Equilibrium Behavior

The representative type I agent maximizes 2.1 subject to 2.2, 2.3 and 2.4. This can be written as a Bellman equation. For a value function V, the Bellman equation is

$$V(k_{1,t-1}, b_{t-1}) = \max_{c_{1,t}, b_t, y_{1,t}, k_{1,t}} u(c_{1,t}) + \beta_1 V(k_{1,t}, b_t), \tag{2.9}$$

subject to 2.2, 2.3 and 2.4 at t.

The behavioral conditions are given by:

$$y_{1,t} = f(k_{1,t-1}), \tag{2.10}$$

$$(c_{1,t}, b_t, k_{1,t}) = \arg\max_{c_{1,t}, b_t, k_{1,t}} u(c_{1,t}) + \beta_1 V(k_{1,t}, b_t), \tag{2.11}$$

and, the decision functions are:

$$\begin{aligned} c_{1,t} &= h_{1,c}(k_{1,t-1}, b_{t-1}) \\ b_t &= h_{1,b}(k_{1,t-1}, b_{t-1}) \\ k_{1,t} &= h_{1,k}(k_{1,t-1}, b_{t-1}). \end{aligned}$$

Similarly, the representative type II agent maximizes 2.5 subject to 2.6, 2.7 and 2.8. This can be written as a Bellman equation. For a value function W, the Bellman equation is

$$W(k_{2,t-1}, l_{t-1}) = \max_{c_{2,t}, l_t, y_{2,t}, k_{2,t}} u(c_{2,t}) + \beta_2 W(k_{2,t}, l_t), \tag{2.12}$$

subject to 2.6, 2.7 and 2.8 at t.

The behavioral conditions are given by:

$$y_{2,t} = g(k_{2,t-1}), \tag{2.13}$$

$$(c_{2,t}, l_t, k_{2,t}) = \arg\max_{c_{2,t}, l_t, k_{2,t}} u(c_{2,t}) + \beta_2 W(k_{2,t}, l_t), \tag{2.14}$$

and, the decision functions are:

$$\begin{aligned} c_{2,t} &= h_{2,c}(k_{2,t-1}, l_{t-1}) \\ l_t &= h_{2,b}(k_{2,t-1}, l_{t-1}) \\ k_{2,t} &= h_{2,k}(k_{2,t-1}, l_{t-1}). \end{aligned}$$

The functional forms of V, W, and the decision functions h, depend on the functional forms of utility and production functions. Two functional forms are analyzed in this dissertation. This chapter considers the case when utility function is linear and the production function can be both linear and non-linear. The next chapter

looks at the case where both utility and production functions are non-linear.

Linear Model

Consider the special case when both utility and production functions are linear. In particular, the production function is assumed to be additively separable. Suppose the utility and production functions of type I agents are

$$u(c_{1,t}) = c_{1,t}, \tag{2.15}$$

$$y_{1,t} = f(k_{1,t-1}) = Ak_{1,t-1}, \tag{2.16}$$

where $A > 0$. Similarly, for type II agents, the utility and production functions are

$$u(c_{2,t}) = c_{2,t}, \tag{2.17}$$

$$y_{2,t} = g(k_{2,t-1}) = Bk_{2,t-1}, \tag{2.18}$$

where $A > B > 0$. This ensures that type I agents are more productive than type II agents for any given amount of capital.

Equilibrium Interest Rate

Standard economic arguments can be used to show that type I agents will be indifferent between consuming today or in the future when

$$R^I = \frac{1}{\beta_1}, \tag{2.19}$$

while type II agents will be indifferent at

$$R^{II} = \frac{1}{\beta_2}. \tag{2.20}$$

By Assumption 2.3, we know that $\beta_1 < \beta_2$, and this means

$$R^I > R^{II}.$$

This leads to a unique situation. Any market equilibrium above R^{II} will cause type II agents to lend everything they have, and reduce their current consumption to zero. To prevent this situation market interest rate, R, has to be the rate at which type II agents are indifferent, that is

$$R = \frac{1}{\beta_2}. \tag{2.21}$$

The problem is any interest rate below R^I will induce type I agents to borrow as much as they can (and here, $R < R^I$), and since loans depend on collateral being offered they will use all their net worth to borrow. Thus, this market interest rate will induce consumption of type II agents to fall to zero. This situation can be overcome by putting an exogenous limit on the amount that type II agents can sell, and thus put a limit on their tradable output. The exact limit on this tradable output is established in the next section.

Determining the Steady State

Define the user cost of capital as

$$p_t = q_t - \frac{q_{t+1}}{R}. \tag{2.22}$$

Since type II agents are the ones lending, and have linear preferences, the user cost of capital must equal their discounted marginal product. That is,

$$\frac{1}{R}g'(k_{2,t-1}) = p_t = q_t - \frac{q_{t+1}}{R}. \tag{2.23}$$

Type I agents will buy capital if the marginal cost of capital is equal to the tradable marginal output of capital, that is

$$xf'(k_{1,t-1}) = p_t = q_t - \frac{q_{t+1}}{R}, \tag{2.24}$$

where x is the tradable part of type I agents' output. For the time being I will not use the specific functional form of type I agents' production function. The reason behind this formulation will become clear over the next few pages. Let y be the non-tradable part of type I agents' output. Thus, production function of type I agents is $(x+y)f(k_{1,t-1})$.

Denoting steady state values by an asterisk, from Equations 2.23 and 2.24 we get

$$p^* = q^* - \frac{q^*}{R} = xf'(k_1^*) = \frac{1}{R}g'(k_2^*).$$

which implies

$$\frac{R-1}{R}q^* = xf'(k_1^*) = \frac{1}{R}g'(k_2^*) = p^*. \tag{2.25}$$

We can use the principle of unimprovability to show that the above will constitute a steady state, and that type I agents will only consume the non-tradable part of their output. Consider type I agents. Suppose their tradable output in period t is $xf(k_{1,t-1})$. Total value of capital that a representative type I agent owns in period t is $q_t k_{1,t-1}$, and the agent's debt repayment for the period is Rb_{t-1}. The agent's

tradable net worth is therefore, $xf(k_{1,t}) + q_t k_{1,t-1} - Rb_{t-1}$. The agent has the option of doing two things: either, consume it, or, use it to for investment. If the agent consumes this surplus, for each unit of tradable net worth the agent's consumption in the current period will be 1, and consumption in all future periods will be zero. On the other hand, if the agent invests, then the agent gets nothing of the tradable net worth in the current period. Given that p_t is the unit cost of capital, each unit of consumption goods invested yields $1/p_t$ units of capital. In the next period each unit of investment produces $(x + y)f'(k_{1,t})$ units of goods, of which the agent can again invest $xf'(k_{1,t})$ units and consume $yf'(k_{1,t})$ units. The process continues *ad infinitum*. The two consumption paths are then given as follows

Period	t	$t+1$	$t+2$	$\cdots$
Invest	0	$\left(\frac{yf'(k_{1,t})}{p_t}\right)$	$\left(\frac{xf'(k_{1,t+1})}{p_t}\right)\left(\frac{yf'(k_{1,t+1})}{p_{t+1}}\right)$	$\cdots$
Consume	1	0	0	$\cdots$

At the steady state the user cost of capital becomes p^*, and the above array can be rewritten as

Period	t	$t+1$	$t+2$	$\cdots$
Invest	0	$\left(\frac{yf'(k_1^*)}{p^*}\right)$	$\left(\frac{xf'(k_1^*)}{p^*}\right)\left(\frac{yf'(k_1^*)}{p^*}\right)$	$\cdots$
Consume	1	0	0	$\cdots$

In any period t, if the representative type I agent decides to consume the tradable net worth, the agent's lifetime utility is 1. In case the agent decides to invest, the

discounted lifetime utility, U^B, is given as

$$\begin{aligned} U^B &= \beta_1 \left(\frac{yf'(k_1^*)}{p^*}\right) + \beta_1^2 \left(\frac{xf'(k_1^*)}{p^*}\right)\left(\frac{yf'(k_1^*)}{p^*}\right) + \beta_1^3 \left(\frac{xf'(k_1^*)}{p^*}\right)^2 \left(\frac{yf'(k_1^*)}{p^*}\right) + \dots \\ &= \sum_{s=1}^{\infty} \beta_1^s \left(\frac{xf'(k_1^*)}{p^*}\right)^{s-1} \left(\frac{yf'(k_1^*)}{p^*}\right) \\ &= \sum_{s=1}^{\infty} \beta_1^s \left(\frac{xf'(k_1^*)}{p^*}\right)^{s-1} \left(\frac{yf'(k_1^*)}{xf'(k_1^*)}\right) \end{aligned}$$

Given the value of p^* in Equation 2.25 we get

$$U^B = \left(\frac{y}{x}\right) \sum_{s=1}^{\infty} \beta_1^s,$$

which is an infinite geometric series with sum

$$\begin{aligned} U^B &= \frac{y}{x}\left[\frac{1}{1-\beta_1} - 1\right] \\ &= \frac{y}{x}\frac{\beta_1}{1-\beta_1}. \end{aligned} \tag{2.26}$$

As long as lifetime utility of investment given in Equation 2.26 is greater than utility of consuming the tradable output, the representative type I agent will invest that output. This requires

$$\frac{y}{x}\frac{\beta_1}{1-\beta_1} > 1.$$

Therefore, for investment to be the optimal decision in the neighborhood of the steady state the following must hold:

Assumption 2.8. The proportion of output that the representative type I agent can sell has to be strictly lower than their stochastic discount factor.

$$\beta_1 > \frac{x}{x+y}. \tag{2.27}$$

As β_1 is close to 1, this is not a restrictive constraint. When Assumption 2.8 holds, the representative type I agent will use all tradable output to invest, and consume just the amount that cannot be sold, or $c_1^* = yf(k_1^*)$.

The Case of Two Production Functions

So far the production function of both agent types has been assumed to be linear. In this section that assumption is relaxed for one of the agent types: type I. The reason behind this is illustrated below.

When the borrower is using a linear production function we can write it as

$$y_{1,t} = (x + y)k_{1,t-1}.$$

From Equations 2.23 and 2.24 we know that

$$p_t = \frac{1}{R}g'(k_{2,t-1}) = xf'(k_{1,t-1}).$$

With linear production function this reduces to

$$\frac{1}{R}B = x. \tag{2.28}$$

Note that $(x+y) = A$. Thus, at the steady state the productivity of the representative type II agent has to be exactly R times that of the the representative type I agent's tradable productivity. Any technology shock that alters this equilibrium can send all capital flowing in one direction: either to type I agents, or type II agents. This is a problem, for in that case asset prices are just a reflection of productivities and not of demand. This can be overcome by using a decreasing returns to scale production

function for at-least one agent type.

Suppose type I agents have a decreasing returns to scale production $y_{1,t} = (x + y)f(k_{1,t-1})$, $f'(k_1) > 0, \text{and } f''(k_1) < 0$. Also suppose that the marginal product of this function as $k_1 \to 0$ rises so that the following holds:

ASSUMPTION 2.9. The discounted marginal product of the representative type II agent lies between the marginal product of the representative type I agent with zero capital, and that of representative agent type I agent with all the capital.

$$f'(0) > \frac{1}{R}B > f'\left(\frac{K}{100 \times \theta}\right). \tag{2.29}$$

When the amount of capital held by the representative type I agent falls in this range, their marginal product rises with falling capital holdings, and thus it raises the price of capital due to increased demand. The fact that their marginal product with zero capital holding is above the marginal product of the representative type II agent ensures that the representative type II agent never ends up owning all capital. Further, the fact that the marginal product of the representative type I agent, when they own all capital, is less than the marginal product of the representative type II agent when they own nothing, means type I agents can never end up owning all capital.

This arrangement ensures both agents have some positive amount of capital to work with, and thus also ensures that their consumption will never fall to zero.

Market Behavior at the Steady State

Having established that the representative type I agent will use all available net worth to buy new capital, we can say that

$$k_{1,t} = \frac{1}{p_t}[xf(k_{1,t-1}) + q_t k_{1,t-1} - Rb_{t-1}],$$

where the left hand side is the amount of capital held by the representative type I agent at the end of period t, and the right hand side is the ratio of the agent's net-worth at the beginning of period t, and the user cost. At the steady state the credit constraint (Equation 2.2) is binding, and hence we have

$$k_1^* = \frac{1}{p^*} xf(k_1^*). \tag{2.30}$$

Using Equation 2.3, 2.25 and 2.30 we get

$$b^* = \frac{1}{R-1} xf'(k_1^*)k_1^*. \tag{2.31}$$

Using market clearing condition for capital market we get

$$l^* = \frac{\theta}{1-\theta}\frac{1}{R-1} xf'(k_1^*)k_1^*, \tag{2.32}$$

and,

$$c_2^* = Bk_2^* + \frac{\theta}{1-\theta} xf'(k_1^*). \tag{2.33}$$

The representative type I agent will consume just the amount that they are unable to sell. That is,

$$c_1^* = yf'(k_1^*). \tag{2.34}$$

PROPOSITION 2.10. For the economy described above there exists a unique steady state and the following hold:

1. the interest rate is always equal to the inverse of the discount factor of the more patient agent, the type II agent, that is $R = \frac{1}{\beta_2}$;
2. the price of capital at the steady state is proportional to the productivity of agents such that, $\frac{R-1}{R} q^* = x f'(k_1^*) = \frac{1}{R} B$;
3. the amount of debt that type I agents hold is positive, $b^* = \frac{1}{R-1} x f'(k_1^*) k_1^*$;
4. and, both agent types consume a positive amount in the steady state, and type I agents only consume the output they cannot sell.

Proof. Condition 1 follows from Equation 2.21. Condition 2 follows from Equation 2.25. Conditions 3 and 4 follow from Equations 2.31 and 2.33 respectively. □

Numerical Simulation

System dynamics of the model described above can be done by linearizing the system around the steady state. This has traditionally been done by estimating the equations that describe the behavior of variables of interest around the steady state. But more recently there has been a move to let computer programs perform these simulations. This dissertation opt for computer simulations to study how an economy at the steady state responds to an unexpected technology shock. Simulations were carried out using Dynare (a pre-processor) and MATLAB. Figure 2.1 illustrates how capital holdings, bond holdings, and capital price change in response to an unexpected 1% positive technology shock. The first point to note is that the effect of the shock persists for about 5 periods after the shock has hit. This indicates that the model does capture the role of asset prices as a transmission mechanism. In the neoclassical world

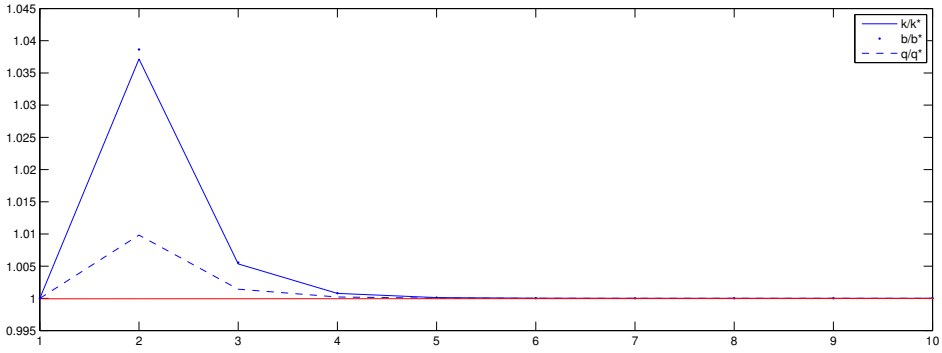

Figure 2.1 – *Impulse Response Functions: Linear Model*

the effect of the shock would have died out in the period the shock hit. Secondly, two of the three variables change by more than the quantum of the shock. While capital and bond holdings change by more than 3.5%, capital price changes by just under 1%. Though, over the life of the effect of the shock, capital price does change by more than 1%.

KM do not perform simulation of the basic model in their work, but do perform simulations of a larger model which also incorporates reproducible capital, and depreciation. Qualitatively the results presented here are similar to that in KM (see figure 3 in KM), but quantitatively they are different. Introduction of reproducible capital reduces the impact of shocks in the model they have analyzed, while at the same time increasing persistence. A more detailed comparison of the simulation results from this dissertation, and various versions of KM, are presented in the next chapter.

Summary

The linear model presented in this chapter is the closest in structure and spirit to the basic model presented in KM. The two models (the one in KM, and the one presented here) start with the same basic premise, but use different functional

specifications and solution methodology. Using a non-linear production function for one of the agent types keeps the steady state of the economy away from corners, which is a big departure from KM. The results obtained here do prove the robustness of results in KM, but still do not address the fact that in practice we are unlikely to encounter linear utility or production functions. This issue is addressed in the next chapter.

CHAPTER 3

CREDIT CYCLES REVISITED

Description of the Economy

The structure of the economy follows from the last chapter. The chapter presents the case where the utility and production functions used in the model can account for risk aversion decreasing returns to scale production. As earlier, agents of type I be borrowers, and agents of type II be lenders. Total population is normalized to a unit mass. The proportion of type I agents is θ, and that of type II agents is $1 - \theta$.

Type I Agents

Let $c_{1,t} \in \mathbb{R}_{++}$ be the consumption of the representative type I agent, the borrower, at date t; and let $\beta_1 \in (0, 1)$ be the time discount factor for the representative type I agent. Let $u(c_{1,t})$ be the utility that agents derive from consumption at time t. Agents are assumed to be infinitely lived, and maximize lifetime utility: $\sum_{t=0}^{\infty} u(c_{1,t})$, where $u(c_{1,t}) : \mathbb{R}_{++} \to \mathbb{R}_{+}$. The utility function is assumed to be strictly concave.

Let $k_{1,t-1} \in \mathbb{R}_{+}$ be the capital available to representative type I agent at the beginning of time t. The agent uses it to produce $y_t \in \mathbb{R}_{+}$ units of output at the end

of time t. The production function is $f : \mathbb{R}_+ \to \mathbb{R}_+$,

$$y_{1,t} = f(k_{1,t-1}). \tag{3.1}$$

The production function is assumed to be strictly convex. There is a commodity market where one unit of capital is exchanged for $q_t \in \mathbb{R}_{++}$ units of output. There is a credit market where one unit of output at date t is exchanged for $R_{t+1} \in \mathbb{R}_{++}$ units of output at date $t+1$. Let b_t be the amount borrowed by the representative type I agent at time t. Following the arguments from the last chapter the amount payable in period $t+1$ for the loan taken in period t has to be less than or equal to the value of the collateral on offer. Further, in the absence of uncertainty (with the exception for the random shock), both agent types know the future price of the asset on offer for collateral, capital, which is q_{t+1}. This gives the credit constraint for the representative type I agent as:

$$R_{t+1} b_t \leq q_{t+1} k_{1,t}. \tag{3.2}$$

The flow of funds constraint for the representative type I agent can be stated as

$$y_{1,t} + b_t \geq q_t(k_{1,t} - k_{1,t-1}) + R_t b_{t-1} + c_{1,t}, \tag{3.3}$$

where the left-hand side is the total income of the representative type I agent at date t (including debt), and the right-hand side is the total expenditure on purchase of new capital, on payment of old debt, and on consumption. The maximization problem of the representative type I agent can be written as:

Maximization Problem 3.1.

$$\max_{\{k_{1,t},b_t,c_{1,t},y_{1,t}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta_1^t u(c_{1,t}) \tag{3.4}$$

subject to

$$\begin{aligned} R_{t+1}b_t &\leq q_{t+1}k_{1,t}, & (3.5)\\ q_t(k_{1,t}-k_{1,t-1}) + R_t b_{t-1} + c_{1,t} &\leq y_{1,t} + b_t, & (3.6)\\ y_{1,t} &\leq f(k_{1,t-1}) & (3.7) \end{aligned}$$

and

$$c_{1,t} \geq 0, k_{1,t} \geq 0, y_{1,t} \geq 0.$$

for all $t = 0, 1, 2 \ldots$

The following simple graphical representation of the above helps us form the optimization problem later in the chapter:

Begin Time t	End Time t
Known Variables	Choice Variables
Capital, $k_{1,t-1}$	*Capital*, $k_{1,t}$
Capital Price, q_t	*Consumption*, $c_{1,t}$
Loans Outstanding, b_{t-1}	*New Loans*, b_t

Note that in case of choice variables, the choice is only between two of three variables. The third is automatically decided by the budget constraints and market clearing conditions once the other two are chosen.

Type II Agents

Let $c_{2,t} \in \mathbb{R}_{++}$ be the consumption of the representative type II agent, the lender, at date t; and let $\beta_2 \in (0,1)$ be the time discount factor for the representative type II agent. Let $u(c_{2,t})$ be the utility that agents derive from consumption at time t. Agents are assumed to be infinitely lived, and maximize lifetime utility: $\sum_{t=0}^{\infty} u(c_{2,t})$, where $u(c_{2,t}) : \mathbb{R}_{++} \to \mathbb{R}_{+}$. As earlier, the utility function is assumed to be strictly concave. Assumption 2.3 follows from Chapter 2.

Let $k_{2,t-1} \in \mathbb{R}_{+}$ be the capital available to the representative type II agent at the beginning of time t, they use it to produce $y_{2,t} \in \mathbb{R}_{+}$ units of output at the end of time t. The production function is

$$y_{2,t} = g(k_{2,t-1}). \tag{3.8}$$

The production function is assumed to be strictly convex. The representative type II agents are not credit constrained. But, for the sake of completeness, suppose they lend an amount $l_t \in \mathbb{R}_{+}$ at time t, then the borrowing/lending constraint of the representative type II agent is specified as:

$$R_{t+1}(-l_t) \leq q_{t+1}k_{2,t} \tag{3.9}$$

The flow of funds constraint for the representative type II agent is then

$$y_{2,t} + R_t l_{t-1} \geq q_t(k_{2,t} - k_{2,t-1}) + l_t + c_{2,t}, \tag{3.10}$$

where the left-hand side is the total income of the representative type II agent in period t, and the right-hand side is the expenditure on new capital, on new loans,

and on consumption. The maximization problem for the representative type II agent can then be written as:

MAXIMIZATION PROBLEM 3.2.

$$\max_{\{k_{2,t},l_t,c_{2,t},y_{2,t}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta_2^t u(c_{2,t}) \tag{3.11}$$

subject to

$$\begin{aligned} R_{t+1}(-l_t) &\leq q_{t+1}k_{2,t}, & (3.12)\\ q_t(k_{2,t}-k_{2,t-1})+l_t+c_{2,t} &\leq y_{2,t}+R_t l_{t-1}, & (3.13)\\ y_{2,t} &\leq g(k_{2,t-1}) & (3.14) \end{aligned}$$

and

$$c_{2,t} \geq 0, k_{2,t} \geq 0, y_{2,t} \geq 0.$$

for all $t = 0, 1, 2, \ldots$

As earlier, assume that the representative type I agent is more productive than the representative type II agent (see Assumption 2.5). Equilibrium concept also follows from earlier.

Equilibrium Condition

For given values of $(k_{1,t-1}, b_{1,t-1}, k_{2,t-1}, b_{2,t-1})$, an equilibrium is a sequence of asset prices, interest rates, lending, borrowing, consumption and capital holdings $\{q_t^*, R_t^*, l_t^*, b_t^*, c_{1,t}^*, c_{2,t}^*, k_{1,t}^*, k_{2,t}^*\}_{t=0}^{\infty}$ such that

1. $\{c_{1,t}^*, b_t^*, y_{1,t}^*, k_{1,t}^*\}_{t=0}^{\infty}$ maximizes 3.4 subject to Equations 3.5, 3.6 and 3.7;

2. $\{c_{2,t}^*, l_t^*, y_{2,t}^*, k_{2,t}^*\}_{t=0}^{\infty}$ maximizes 3.11 subject to Equations 3.12, 3.13 and 3.14;

3. credit markets clear, that is $\theta b_t = (1-\theta) l_t$;

4. goods market clear, that is $\theta c_{1,t} + (1-\theta) c_{2,t} = \theta y_{1,t} + (1-\theta) y_{2,t}$; and

5. capital market clears, that is Assumption 2.7 holds, or $\theta k_{1,t} + (1-\theta) k_{2,t} = K$.

Determining the Interest Rate

Optimal choice of bonds require that the marginal benefit of borrowing or lending must equal or exceed the marginal cost of doing so. This implies that the gains from every unit lent or borrowed (which is nothing but the interest rate from period t to $t+1$, R_{t+1}) must be equal to or greater than the discounted marginal utility of consuming the unit in period $t+1$. Mathematically, this implies that

$$u'(c_{i,t}) \frac{1}{R_{t+1}} \geq u'(c_{i,t+1}) \beta_i, \tag{3.15}$$

where i represents the agents, with $i = 1$ implying the representative type I agent, and $i = 2$ implying the representative type II agent.

At the steady state at least one of the agents is credit constrained, and thus equation 3.15 should hold for at least one of $i = 1, 2$. Furthermore, consumption, and hence utility and marginal utility of consumption, will not change at the steady state thus implying

$$\frac{1}{R_{t+1}} \geq \beta_i.$$

Finally, given Assumption 2.3 we know that $\beta_1 < \beta_2$, thus for the above to hold we must have

$$R_{t+1} = R = \frac{1}{\beta_2}, \tag{3.16}$$

and that

$$R < \frac{1}{\beta_1}.$$

LEMMA 3.3. The equilibrium interest rate in the above economy will always be the inverse of the discount factor of the more patient agent.

$$R = \frac{1}{\beta_2}.$$

Determining the Steady State

The optimization problem as described above is recursive in nature and lends itself to examination using dynamic programming. Both agent types are maximizing their lifetime utilities, given a set of constraints. Neither their utility functions, nor the structure of the constraints is changing in the lifetime of the agents. Capital holding, the amount of outstanding loans, and the price of capital is known to both agent types. It is also known that the total amount of capital in the economy is fixed (though this information does not become useful till we get to a later part in the chapter).

Consider the case of the representative type I agent first. The agent is trying to maximize lifetime utility given a certain set of constraints. Consider the behavior of the representative type I agent at the beginning of time t. The agent knows the amount of capital available, $k_{1,t-1}$, the amount of loans from the previous period, b_{t-1}, and the current price of capital, q_t. The agent also has access to a production technology that can produce output using capital and the agent's labor as input. Labor is assumed to be intrinsic to the agents, and does not become a part of the production function. The representative type I agent chooses how much to consume, $c_{1,t}$, how much capital to buy, $(k_{1,t-1} - k_{1,t})$, and given the constraints how much to

borrow, b_t, to finance the purchase of capital. Thus, the known variables in case of the representative type I agents are $k_{1,t-1}$, q_t, and b_{t-1}. As stated above, the agent chooses between two of three choice variables, say $k_{1,t}$ and b_t. Give the choice of $k_{1,t}$ and b_t, the budget constraint and the borrowing constraint helps determine the third variable, $c_{1,t}$.

Let $\mathbf{x_t} = \{k_{1,t-1}, b_{t-1}, q_t\}$ be the known variables vector, and $\mathbf{y_t} = \{k_{1,t}, b_t\}$ be the choice variables vector. The value function for the above system can be written as:

$$V(\mathbf{x_t}) = \max_{\{\mathbf{y_s}\}_{s=t}^{\infty}} \sum_{s=t}^{\infty} \beta_1^{s-t} u(\mathbf{x_s}, \mathbf{y_s})$$

subject to the transition constraint:

$$\mathbf{x_{s+1}} = G(\mathbf{x_s}, \mathbf{y_s}).$$

In expanded form the Bellman equation can be written as:

$$V(k_{1,t-1}, b_{t-1}, q_t) = \max_{\{k_{1,t}, b_t\}} \left[u(c_{1,t}) + \beta_1 V(k_{1,t}, b_t, q_{t+1}) \right]. \tag{3.17}$$

The budget constraint and the borrowing constraint for the representative type I agent can then be used to rewrite Equation 3.17 as

$$\begin{aligned} V(k_{1,t-1}, b_{t-1}, q_t) \quad = \quad & \max_{\{k_{1,t}, b_t\}} [u(f(k_{1,t-1}) - q_t(k_{1,t} - k_{1,t-1}) + b_t - R_t b_{t-1}) + \\ & \beta_1 V(k_{1,t}, b_t, q_{t+1})]. \end{aligned}$$

Rewrite the part inside brackets on the right hand side as

$$\tilde{V}(k_{1,t-1}, b_{t-1}, q_t, k_{1,t}, b_t) = u(f(k_{1,t-1}) - q_t(k_{1,t} - k_{1,t-1}) + b_t - R_t b_{t-1}) + \beta_1 V(k_{1,t}, b_t, q_{t+1}) \tag{3.18}$$

Thus, the Bellman equation becomes:

$$V(k_{1,t-1}, b_t, q_t) = \max_{\{k_{1,t}, b_t\}} \tilde{V}(k_{1,t-1}, b_{t-1}, q_t, k_{1,t}, b_t). \tag{3.19}$$

The first order conditions are:

$$\frac{\partial}{\partial k_{1,t}} \tilde{V}(k_{1,t-1}, b_{t-1}, q_t, k_{1,t}, b_t) = 0 \tag{3.20}$$

$$\frac{\partial}{\partial b_t} \tilde{V}(k_{1,t-1}, b_{t-1}, q_t, k_{1,t}, b_t) = 0. \tag{3.21}$$

As stated earlier, the known variables at date t are $(k_{1,t-1}, b_{t-1}, q_t)$, and the choice variables are $(k_{1,t}, b_t)$. Consumption is automatically chosen when capital stock and borrowing are chosen. The price of capital in period $t+1$ does not come into the equation since there is no optimization with respect to q_t. Given that there is no uncertainty, agents know what the price of capital in the next period will be. Therefore, with this information we can write the transition functions as:

$$k_{1,t} = k_{1,t}(k_{1,t-1}, b_{t-1}, q_t) \tag{3.22}$$

$$b_t = b_t(k_{1,t-1}, b_{t-1}, q_t). \tag{3.23}$$

With the first order conditions holding, we can state that:

$$V(k_{1,t-1}, b_t, q_t) = \tilde{V}(k_{1,t-1}, b_{t-1}, q_t, k_{1,t}(k_{1,t-1}, b_{t-1}, q_t), b_t(k_{1,t-1}, b_{t-1}, q_t)). \tag{3.24}$$

The Benveniste-Schienkman conditions are then obtained by taking the derivative with respect to known variables. Consider $k_{1,t-1}$ first.

$$\begin{aligned}\frac{\partial}{\partial k_{1,t-1}}V(k_{1,t-1},b_{t-1},q_t) &= \frac{\partial\tilde{V}(t)}{\partial k_{1,t}}\frac{\partial k_{1,t}}{\partial k_{1,t-1}}+\frac{\partial\tilde{V}(t)}{\partial b_t}\frac{\partial b_t}{\partial k_{1,t-1}}+\frac{\partial\tilde{V}(t)}{\partial k_{1,t-1}}\\ &= (0)\frac{\partial k_{1,t}}{\partial k_{1,t-1}}+(0)\frac{\partial b_t}{\partial k_{1,t-1}}+\frac{\partial\tilde{V}(t)}{\partial k_{1,t-1}}\\ &= \frac{\partial\tilde{V}(t)}{\partial k_{1,t-1}}\end{aligned}$$

where the second line uses Equation 3.20. With respect to the other known variable b_{t-1}, the Benveniste-Schiekman condition is:

$$\begin{aligned}\frac{\partial}{\partial b_{t-1}}V(k_{1,t-1},b_{t-1},q_t) &= \frac{\partial\tilde{V}(t)}{\partial b_t}\frac{\partial b_t}{\partial b_{t-1}}+\frac{\partial\tilde{V}(t)}{\partial b_t}\frac{\partial b_t}{\partial b_{t-1}}+\frac{\partial\tilde{V}(t)}{\partial b_{t-1}}\\ &= (0)\frac{\partial k_{1,t}}{\partial b_{t-1}}+(0)\frac{\partial b_t}{\partial b_{t-1}}+\frac{\partial\tilde{V}(t)}{\partial b_{t-1}}\\ &= \frac{\partial\tilde{V}(t)}{\partial b_{t-1}}\end{aligned}$$

where the second line uses Equation 3.21. To summarize the Benveniste-Schienkman conditions for the representative type I agent are:

$$\frac{\partial}{\partial k_{1,t-1}}V(k_{1,t-1},b_{t-1},q_t) = \frac{\partial\tilde{V}(t)}{\partial k_{1,t-1}} \tag{3.25}$$

$$\frac{\partial}{\partial b_{t-1}}V(k_{1,t-1},b_{t-1},q_t) = \frac{\partial\tilde{V}(t)}{\partial b_{t-1}} \tag{3.26}$$

The symmetry of the choices and utility functions means that the representative type II agent faces similar optimizing choices. Let W be the value function for the representative type II agent. At date t, the known variables are $(k_{2,t-1},l_{t-1},q_t)$, and the choice variables are $(k_{2,t},l_t)$. As earlier choosing $k_{2,t}$ and l_t, will automatically decide $c_{2,t}$ from the budget and borrowing constraints. The Bellman equation for the

representative type II agent can then be written as:

$$W(k_{2,t-1}, l_{t-1}, q_t) = \max_{\{k_{2,t}, l_t\}} \left[u(c_{2,t}) + \beta_2 W(k_{2,t}, l_t, q_{t+1})\right]. \tag{3.27}$$

The budget and borrowing constraints for the representative type II agent determine the agent's consumption path, and Equation 3.27 can be rewritten as

$$\begin{aligned} W(k_{2,t-1}, l_{t-1}, q_t) &= \max_{\{k_{2,t}, l_t\}} [u(g(k_{2,t-1}) - q_t(k_{2,t} - k_{2,t-1}) - l_t + R_t l_{t-1}) + \\ &\quad \beta_2 W(k_{2,t}, l_t, q_{t+1})]. \end{aligned}$$

Rewrite the part within brackets on the right hand side as

$$\tilde{W}(k_{2,t-1}, l_{t-1}, q_t, k_{2,t}, l_t) = u(g(k_{2,t-1}) - q_t(k_{2,t} - k_{2,t-1}) - l_t + R_t l_{t-1}) + \beta_2 W(k_{2,t}, l_t, q_{t+1}) \tag{3.28}$$

Thus, the Bellman equation becomes:

$$W(k_{2,t-1}, l_t, q_t) = \max_{k_{2,t}, l_t} \tilde{W}(k_{2,t-1}, l_{t-1}, q_t, k_{2,t}, l_t). \tag{3.29}$$

The first order conditions are:

$$\frac{\partial}{\partial k_{2,t}} \tilde{W}(k_{2,t-1}, l_{t-1}, q_t, k_{2,t}, l_t) = 0 \tag{3.30}$$

$$\frac{\partial}{\partial l_t} \tilde{W}(k_{2,t-1}, l_{t-1}, q_t, k_{2,t}, l_t) = 0. \tag{3.31}$$

The transition functions can be written as:

$$k_{2,t} = k_{2,t}(k_{2,t-1}, l_{t-1}, q_t) \tag{3.32}$$

$$l_t = l_t(k_{2,t-1}, l_{t-1}, q_t). \tag{3.33}$$

With the first order conditions holding, we can state that:

$$W(k_{2,t-1}, l_t, q_t) = \tilde{W}(k_{2,t-1}, l_{t-1}, q_t, k_{2,t}(k_{2,t-1}, l_{t-1}, q_t), l_t(k_{2,t-1}, l_{t-1}, q_t)). \quad (3.34)$$

The Benveniste-Schienkman conditions are then obtained by taking the derivative with respect to known variables. Consider $k_{2,t-1}$ first.

$$\begin{aligned}
\frac{\partial}{\partial k_{1,t-1}} W(k_{2,t-1}, l_{t-1}, q_t) &= \frac{\partial \tilde{W}(t)}{\partial k_{2,t}} \frac{\partial k_{2,t}}{\partial k_{2,t-1}} + \frac{\partial \tilde{W}(t)}{\partial l_t} \frac{\partial l_t}{\partial k_{2,t-1}} + \frac{\partial \tilde{W}(t)}{\partial l_{1,t-1}} \\
&= (0) \frac{\partial k_{2,t}}{\partial k_{2,t-1}} + (0) \frac{\partial l_t}{\partial k_{2,t-1}} + \frac{\partial \tilde{W}(t)}{\partial k_{2,t-1}} \\
&= \frac{\partial \tilde{W}(t)}{\partial k_{2,t-1}}
\end{aligned}$$

where the second line uses Equation 3.30. With respect to the other known variable l_{t-1}, the Benveniste-Schiekman condition is:

$$\begin{aligned}
\frac{\partial}{\partial l_{t-1}} W(k_{2,t-1}, l_{t-1}, q_t) &= \frac{\partial \tilde{W}(t)}{\partial l_t} \frac{\partial l_t}{\partial l_{t-1}} + \frac{\partial \tilde{W}(t)}{\partial l_t} \frac{\partial l_t}{\partial l_{t-1}} + \frac{\partial \tilde{W}(t)}{\partial l_{t-1}} \\
&= (0) \frac{\partial k_{2,t}}{\partial l_{t-1}} + (0) \frac{\partial l_t}{\partial l_{t-1}} + \frac{\partial \tilde{W}(t)}{\partial l_{t-1}} \\
&= \frac{\partial \tilde{W}(t)}{\partial l_{t-1}}
\end{aligned}$$

where the second line uses Equation 3.31. To summarize the Benveniste-Schienkman conditions for the representative type II agent are:

$$\frac{\partial}{\partial k_{2,t-1}} W(k_{2,t-1}, l_{t-1}, q_t) = \frac{\partial \tilde{W}(t)}{\partial k_{2,t-1}} \quad (3.35)$$

$$\frac{\partial}{\partial l_{t-1}} W(k_{2,t-1}, l_{t-1}, q_t) = \frac{\partial \tilde{W}(t)}{\partial l_{t-1}} \quad (3.36)$$

The above set of optimizing conditions (Equations 3.20, 3.21, 3.25, 3.26, 3.30, 3.31, 3.35

and 3.36) do not lead to a closed form solution. To analyze the behavior of this economy there is, therefore, a need to specify functional forms to both utility and production functions. In general, analytic solutions tend to focus on estimating the policy function by seeking convergence in the state space. But, the main concern of this dissertation is the dynamics of the system post a shock. The next section uses specific utility and production functions, and obtains a closed form solution of the resulting economy. The response of various variables of interest to a random, unexpected, 1% technology shock, once the economy has reached a steady state, are then presented in the subsequent section.

Special Case

The economy's basic structure remains as above. This section specifies functional forms for utility and production functions, and the resulting economy is analytically solved to determine the steady state. The system's response to a random, unexpected, 1% technology shock is then analyzed using numerical simulations.

Type I Agents

Let $c_{1,t}$ be the consumption of the representative type I agent at date t; and let β_1 be the time discount factor. Agents maximize utility $u(c_{1,t}) = (c_{1,t}^{1-\sigma} - 1)/(1-\sigma)$, subject to a set of constraints. $1/\sigma$ is the inter-temporal elasticity of substitution.

Let $k_{1,t-1}$ be the capital available to the representative type I agent at the beginning of time t. They use it to produce $y_{1,t}$ units of output at the end of date t using a production function $f(k_{1,t-1}) = ak_{1,t-1}^{\alpha}$ where $a, \alpha \in R_{++}$ and $\alpha < 1$. The productivity parameter, α, with a value less than one ensures decreasing returns to scale. Type I agents are assumed to be credit constrained, and the borrowing constraint for

the representative type I agent is

$$R_{t+1}b_t \leq q_{t+1}k_{1,t}. \tag{3.37}$$

The flow of funds constraint is

$$ak_{1,t-1}^{\alpha} + b_t \geq q_t(k_{1,t} - k_{1,t-1}) + R_t b_{t-1} + c_{1,t}, \tag{3.38}$$

where the left-hand side is the total income of the representative type I agent at date t (including debt), and the right-hand side is the total expenditure on purchase of new capital, on payment of old debt, and on consumption. The maximization problem that the representative type I agent solves is:

Maximization Problem 3.4.

$$\max_{\{k_{1,t},b_t,c_{1,t},y_{1,t}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta_1^t \left(\frac{c_{1,t}^{1-\sigma} - 1}{1-\sigma} \right) \tag{3.39}$$

subject to

$$\begin{aligned} R_{t+1}b_t &\leq q_{t+1}k_{1,t}, && (3.40)\\ q_t(k_{1,t} - k_{1,t-1}) + R_t b_{t-1} + c_{1,t} &\leq y_{1,t} + b_t, && (3.41)\\ y_{1,t} &\leq ak_{1,t-1}^{\alpha} && (3.42) \end{aligned}$$

and

$$c_{1,t} \geq 0, k_{1,t} \geq 0, ak_{1,t-1}^{\alpha} \geq 0.$$

for all $t = 0, 1, 2 \ldots$

Type II Agents

Let $c_{2,t}$ be the consumption of the representative type II agent, the lender, at date t; and let β_2 be the time discount factor. Agents maximize utility $u(c_{2,t}) = (c_{2,t}^{1-\sigma} - 1)/(1-\sigma)$ subject to a set of constraints. $1/\sigma$ is the inter-temporal elasticity of substitution.

Let $k_{2,t-1}$ be the capital available to the representative type II agent at the beginning of time t. They use it to produce $y_{2,t}$ units of output at the end of time t using a production function $g(k_{2,t-1}) = zk_{2,t-1}^{\delta}$ where $z, \delta \in R_{++}$ and $\delta < 1$.

$$y_{2,t} = zk_{2,t-1}^{\delta}. \tag{3.43}$$

The representative type II agent is not credit constrained. Suppose they lend an amount l_t at time t. For the sake of completeness specify the borrowing/lending constraint for the representative type II agent as:

$$R_{t+1}(-l_t) \leq q_{t+1}k_{2,t} \tag{3.44}$$

The flow of funds constraint for the representative type II agent is then

$$zk_{2,t-1}^{\delta} + R_t l_{t-1} \geq q_t(k_{2,t} - k_{2,t-1}) + l_t + c_{2,t}, \tag{3.45}$$

where the left-hand side is the total income of the representative type II agent in period t, and the right-hand side is the expenditure on new capital, on new loans, and on consumption. The maximization problem for the representative type II agent is then

Maximization Problem 3.5.

$$\max_{\{k_{2,t},l_t,c_{2,t},y_{2,t}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta_2^t \left(\frac{c_{2,t}^{1-\sigma} - 1}{1-\sigma} \right) \tag{3.46}$$

subject to

$$\begin{aligned} R_{t+1}(-l_t) &\leq q_{t+1}k_{2,t}, & (3.47)\\ q_t(k_{2,t} - k_{2,t-1}) + l_t + c_{2,t} &\leq y_{2,t} + R_t l_{t-1}, & (3.48)\\ y_{2,t} &\leq z k_{2,t-1}^{\delta} & (3.49) \end{aligned}$$

and

$$c_{2,t} \geq 0, k_{2,t} \geq 0, z k_{2,t-1}^{\delta} \geq 0.$$

for all $t = 0, 1, 2, \ldots$

Determining the Steady State

Following Lemma 3.1 we can say that at the steady state the equilibrium interest rate would be the inverse of the time discount factor of the more patient agent: the representative type II agent. Thus,

$$R^* = R = \frac{1}{\beta_2}, \tag{3.50}$$

where R^* represents the steady state value of the cost of borrowing.

Consider any time t. Both agent types have two choices for every unit of available consumption good: consume it during that period, or invest it for future use. If agents consume during the current period, they get utility today. If they invest it in purchasing new capital they get utility in the future through higher production.

Economic theory suggests that the choice should boil down to which one of the above choices gives the users higher marginal benefit. They will be indifferent between the two choices when the marginal benefit of holding capital is the same as the marginal cost of doing so.

Define p_t as the user cost of capital, or the downpayment to purchase capital. This will be the difference of the current price of capital and the discounted future price of capital:

$$p_t = q_t - \frac{q_{t+1}}{R}. \tag{3.51}$$

Standard economic theory suggests that optimal choice would require that the amount spent on purchasing capital that increases future consumption must be sufficient to offset utility loss of giving up present consumption. Consider periods t and $t+1$. The above would imply that the extra output due to the purchase of capital is the marginal product of that additional unit of capital purchased at price p_t. Thus the extra output of giving up one unit of present consumption is the ratio of the marginal product of capital and the user cost of capital. This must be equal to the ratio of extra utility gained in the future period (properly discounted) and the utility given up in the current period. Thus, for the borrower the following must hold:

$$\frac{f'(k_{1,t})}{p_t} = \frac{u'(c_{1,t})}{u'(c_{1,t+1})}. \tag{3.52}$$

Similarly, for the representative type II agent,

$$\frac{g'(k_{2,t})}{p_t} = \frac{u'(c_{2,t})}{u'(c_{2,t+1})}. \tag{3.53}$$

Equations 3.52 and 3.53 both equate the marginal cost of holding capital, and the marginal benefit from doing so. At the steady state consumption, utility, marginal

utility, and capital holdings do not change, and the above two equations (Equations 3.52 and 3.53) become:

$$\begin{aligned} u'(c_1^*)p^* &= \beta_1 f'(k_1^*)u'(c_1^*), \\ u'(c_2^*)p^* &= \beta_2 g'(k_2^*)u'(c_2^*). \end{aligned}$$

Canceling out common terms

$$p^* = \beta_1 f'(k_1^*) = \beta_2 g'(k_2^*). \tag{3.54}$$

Equation 3.54 shows that the user cost at the steady state depends on the productivity of agents, and their discount factors. The equation can be rewritten as

$$\frac{g'(k_2^*)}{f'(k_1^*)} = \frac{\beta_1}{\beta_2} > 1, \tag{3.55}$$

which shows that the difference between the time discount factors of the two agents determines the equilibrium difference between their productivities. In a perfectly competitive economy with no credit constraints the marginal product of both agent types must be equal. This is not the case here, and at the steady state the difference in marginal products of agents depends on the difference in their discount factors.

If the agents are very different from one another in terms of their time preference, then the more patient agents will hold a lot more capital than they should, and vice versa. It also suggests that the equilibrium in this economy is not a first best outcome. This is shown graphically in Figure 3.1.

The above results about equilibrium asset price and equilibrium interest rate, the credit constraint of the representative type I agent, the budget constraints of both agent types, and the market clearing conditions for capital and debt can be used to

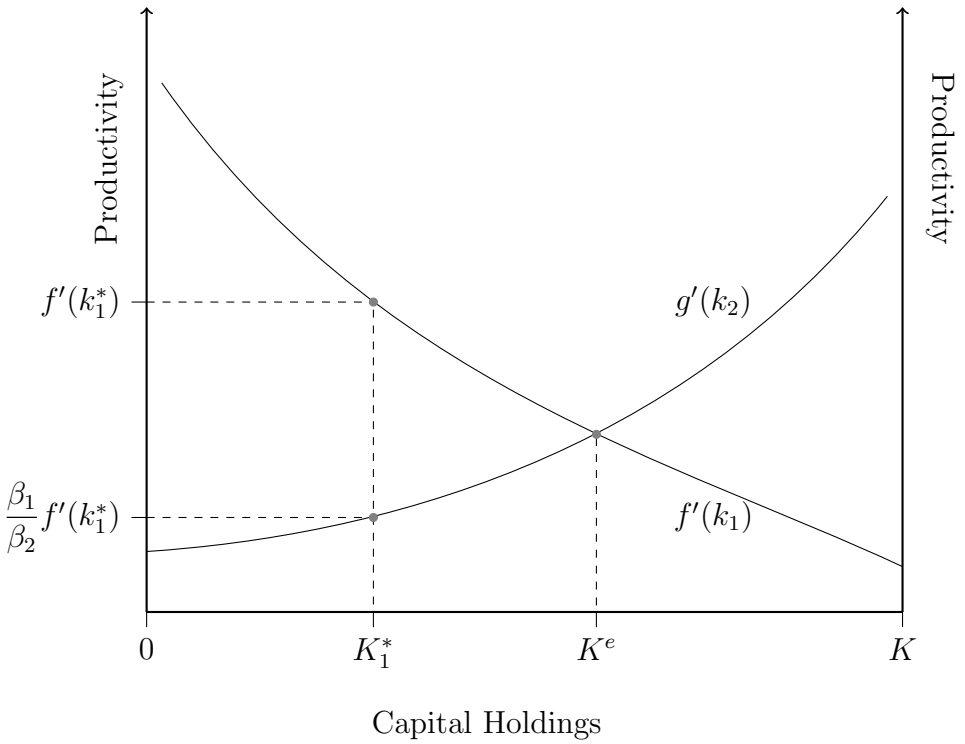

Figure 3.1 – *Inefficiency Gap in the Economy: Note that the representative type I agent has higher productivity than the representative type II agent for most of the range. The representative type II agent has higher productivity than representative type I agent when the agent's capital holdings falls close to zero. This prevents either agent type from holding all capital.*

determine the steady state values for asset price (q^*), borrowing (b^*) and lending (l^*), which are as follows:

$$q^* = \frac{R}{R-1}p^* = \frac{R}{R-1}\beta_1 f'(k_1^*) \tag{3.56}$$

$$b^* = \frac{q^* k_1^*}{R} = \frac{1}{R-1}\beta_1 f'(k_1^*)k_1^* \tag{3.57}$$

$$l^* = \frac{\theta}{1-\theta}b^* = \frac{1}{R-1}\beta_2 g'(k_2^*)\left[\frac{K}{1-\theta} - k_2^*\right] \tag{3.58}$$

PROPOSITION 3.6. For the economy described above there exists a unique steady state and the following hold:

1. the price of capital at the steady state is proportional to the productivity of the agents such that, $q^* = \frac{R}{R-1}\beta_1 f'(k_1^*) = \frac{R}{R-1}\beta_2 g'(k_2^*)$;

2. the amount of capital held by agents is not efficient: the less productive agents hold more capital than they should;

3. and, the efficiency gap in the economy is determined by the difference between the agents' discount factors.

Proof. The first claim follows from Equation 3.51 and Equation 3.54. Equation 3.55 proves the second and third claims. □

The response of this economy to a random, unexpected, 1% technology shock that hits when the economy is at steady state is presented in the next section.

System Dynamics: Special Case

This section presents the impact of a 1% technology shock to an economy at the steady state using simulations conducted on Dynare and MATLAB. A summary of the simulation results is presented in Table 3.2. The set of graphs associated with the

simulation are in Appendix A. A steady state is obtained in the model only if the parameters are within a certain range. If the parameter values exceed that range (which depends on the functional forms of utility and production functions), the simulation program returns an error. The simulations focus on changing three parameter values: productivity of both agent types, proportion of type I agents (and by symmetry, type II agents), and the proportion of saleable output of the representative type I agent. The behavior of the following variables is examined around the steady state: capital holdings of both agent types, bonds issued by representative type I agents, the price of capital, and the persistence of shocks. In a neoclassical setup any technology shock will change output, consumption and price of capital in the period that the shock hits, and there would be no change in future periods as the economy gets back to the steady state in the same period. In the current setup shocks persist through time, and amplify, before the economy gets back to the steady state.

The three parameters that are changed can each proxy for an economic variable. The proportion of type I agents (and by symmetry, type II agents) can proxy as the savings rate in the economy. The level of productivity can represent the development status of the economy. Finally, the proportion of output that representative type I agents can sell can proxy for production and distribution losses. One of the three variables in each set of simulations is changed, while keeping the other two constant. The parameters used for the simulation are in Table 3.1. The choice of parameter values was largely driven by what has been used earlier in the literature. At equilibrium, the interest rate in the economy is assumed to be 4% per annum (as in KM), and that translates to a discount factor of 0.96 for the representative type II agent. We have assumed that the representative type I agent has a lower discount factor, and the choice of 0.90 was inspired by the value used by Cordoba and Ripoll (2004). The productivity coefficient with the two production functions, α and δ, were both

Parameter	Symbol	Value
Discount Factors		
Type I agents	β_1	0.90
Type II agents	β_2	0.96
Productivity Parameter		
Type I agents	α	0.70 - 0.90
Type II agents	δ	0.70 - 0.90
Proportion of Type I agents	θ	0.10 - 0.40
Proportion of Saleable Output (Type I agents)	x	0.65 - 0.85
Inter-temporal Elasticity of Substitution	$1/\sigma$	10

Table 3.1 – *Parameter Values*

chosen to be less than 1 to ensure decreasing returns to scale. While various values were tried in the simulation, the reported results are for values between 0.7 and 0.9, which is again inspired by Cordoba and Ripoll (2004) who use a value of 0.8. The proportion of type I agents (θ) is inspired by KM. KM also use a savings rate of at most 50%, and so the simulations in the dissertation use the proportion of saleable output to be above 50% (which is equivalent to saying a savings rate of less than 50%). The results are reported for values between 65% to 85%. Cordoba and Ripoll (2004) use a value of 10 and 15 for inter-temporal elasticity of substitution in different numerical simulations. The simulations in this dissertation use a value of 10. A higher value of inter-temporal elasticity of substitution would imply lower sensitivity of consumption to changes in real interest rate, and vice versa.

Impact of Changes in Agents' Productivity

The productivity of agents is changed by changing the coefficient of productivity in the production function. This part presents the case where the coefficient α rises from 0.6 to 0.7 to 0.8. The other two parameters of interest, the proportion of type I agents (θ), and the percentage of output that can be sold by the representative

Simulation Summary	Changed Variable	k_1	k_2	b	q	Persistence
Change Productivity						
Proportion of Type I Agents, θ, at 30%						
Proportion of Saleable Output, x, at 75%						
	$\alpha = 0.6$	3.5%	-1.4%	40%	1.5%	8 Periods
	$\alpha = 0.7$	3.8%	-1.6%	55%	1.6%	10 Periods
	$\alpha = 0.8$	4.5%	-1.8%	70%	1.8%	13 Periods
Change Proportion of Type I Agents						
Productivity Parameter $\alpha = 0.6$						
Proportion of Saleable Output, x, at 75%						
	$\theta = 0.1$	4.1%	-0.5%	45%	0.7%	10 Periods
	$\theta = 0.2$	3.8%	-0.9%	42%	1.1%	9 Periods
	$\theta = 0.3$	3.5%	-1.5%	40%	1.5%	8 Periods
	$\theta = 0.4$	3.5%	-2.5%	52%	2.2%	7 Periods
Change Saleable Output						
Of Representative Type I Agent						
Proportion of Type I Agents, θ, at 30%						
Productivity Parameter $\alpha = 0.7$						
	$x = 0.65$	3.9%	-1.6%	46%	1.4%	11 Periods
	$x = 0.75$	3.8%	-1.5%	55%	1.6%	10 Periods
	$x = 0.85$	3.7%	-1.4%	62%	1.8%	9 Periods

Table 3.2 – *Summary of Simulation Results*

type I agent (x), are both kept constant at 30% and 75% respectively. The impulse response functions are in Figures A.1, A.2, and A.3 respectively. Five parameters are examined in response to a change in α: persistence (as measured by how long it takes for the economy to get back to the steady state), capital holding of representative type I and type II agents, bonds issued by representative type I agents, and the price of capital.

As productivity rises shocks becomes more persistent. The effects of the shock take 8 periods to disappear when $\alpha = 0.6$, and that time frame rises to 13 periods when α rises to 0.8. Given that type I agents are constructed to be more efficient, we would expect that rising productivity should raise their demand for capital more than proportionately, and this is what is observed. As α rises from 0.6 to 0.8, the change in capital demanded by representative type I agents in response to the shock rises from 3.5% to 4.5%. That is, when α is 0.6, a 1% technology shock increases the demand for capital from the representative type I agent by 3.5%, and the same shock increases capital demand by 4.5% when α is 0.8. This is simultaneously accompanied by a fall in capital holdings of representative type II agents, from a fall in capital demand of 1.4% when $\alpha = 0.6$, to a fall in capital demand of 1.8% when $\alpha = 0.8$. Given that representative type I agents would be more interested in buying capital when productivity is higher, we would expect capital price to rise more in case of higher productivity, and this is exactly what is observed in the simulations. Capital price rises by 1.4% in case $\alpha = 0.6$, and this change rises to 1.8% when $\alpha = 0.8$. Bond issuance also rises as productivity increases. Changes in bond issuance are an order of magnitude higher than the changes observed in the other variables. This is understandable, since assets are being purchased with the help of credit, and the leverage that the representative type I agent utilizes should reflect in the volume of bonds issued.

Impact of Changes in Proportion of Type I Agents

The next variable changed is the proportion of representative type I agents. Four values of this parameter, θ, are examined, and it rises from 0.1 to 0.4 in equal increments. The other two parameters, productivity coefficient, $\alpha = 0.6$, and the proportion of saleable output, $x = 0.75$, are kept constant. Simulation results are shown in Figures A.4, A.5, A.6 and A.7.

The percentage change in capital holdings of the representative type I agent becomes smaller with rising aggregate percentage of type I agents. In particular, capital holdings of a representative type I agent rises by 4.1% in response to a 1% positive technology shock when the aggregate percentage of type I agents is 10%, and it rises by 3.5% when the aggregate percentage of type I agents is 40%. Shock persistence also falls from 10 periods to 7 periods as the aggregate percentage of type I agents rises. Capital holdings of representative type II agents sees an even bigger fall as the aggregate percentage of type I agents rises. When the aggregate percentage of type I agents is 10%, a 1% positive technology shock reduces capital holding of representative type II agents by 0.5%, but when the aggregate percentage of type I agents rises to 40%, the same 1% positive technology shock reduces the capital holding of representative type II agents by 2.5%.

Capital price rises with rising aggregate percentage of type I agents. When the proportion of type I agents is 10%, a 1% positive technology shock raises capital price by 0.7%, but capital price rises by 2.2% when the proportion of type I agents is 40%. This is natural, as a rising proportion of type I agents would imply that there is more competition for the same amount of capital (which is assumed to be fixed), and more competition is bound to increase the price of capital. The impact on bond issuance by representative type I agents is ambiguous. It falls at first, and then rises.

Impact of Changes in Type I Agent's Capacity to Sell Output

The last variable changed is the proportion of saleable output of the representative type I agent. It is raised from 65% to 85%, while keeping the productivity and the proportion of type I agents fixed with $\alpha = 0.7$ and $\theta = 30\%$. As the proportion of output that can be sold rises, the increase in capital holdings of representative type I agent falls from 3.9% in case the proportion of output sold is 65%, to 3.7% in case the proportion of output sold is 85%. At the same time the capital holding of representative type II agent sees a smaller fall, from 1.6% in case the proportion of output sold is 65%, to 1.4% in case the proportion of output sold is 85%.

Capital price rises more with the same given shock as the proportion of output that can be sold by the representative type I agent rises. A 1% positive technology shock raises capital price by 1.4% when the proportion of output that can be sold is 65%, while the same shock raises capital price by 1.8% when the proportion of output that can be sold rises to 85%. The amount of bonds issued by representative type I agents also rises with the rising proportion of output sold.

Last, but not the least, the persistence of shock falls as the proportion of output sold by the representative type I agent rises. Shocks persist for 11 periods when 65% of the output can be sold, and it falls to 9 periods when 85% of output can be sold. Results of the simulation are presented in Figures A.8, A.9 and A.10.

Comparison with Linear Model

The last chapter presented simulation results for the linear model. The impulse response functions were in Figure 2.1. One of the first things to note with simulations in the current context is that the transitions are smoother, and that would be expected with non-linear production and utility functions. There are three important

Parameter	Linear Model	Non-Linear Model
Change in Capital Holdings		
Representative Type I Agents	3.6%	3.5-4.1%
Representative Type II Agents	(-)2.4%	(-)0.5-2.5%
Change in Capital Price	0.9%	0.7-1.8%
Persistence of Shocks	6 Periods	7-13 Periods

Table 3.3 – *Linear vs Non-Linear Model*

differences between the linear and non linear simulations. First, the change in capital holdings in case of non-linear version is larger than in the linear one. Secondly, asset prices change by more in most non-linear simulations compared to linear simulations. This is on expected lines. Using concave utility introduces risk aversion, and that shows up in the form of larger asset price changes. And finally, higher persistence is observed in the non-linear case. This is again on expected lines. Quantitative differences between the two versions are summarized in Table 3.3. Do note that the quantitative effects will depend on the choice of functional form of both production and utility functions, as well as the choice of parameter values.

Explaining Simulation Results

The chapter started with the argument that asset prices can help act as a transmission and amplification mechanism, and can help explain the differences between observed shocks and their economic impact. Traditionally, transmission mechanism refers to the process through which monetary policy influences the economy in general, and the price level in particular. It would, therefore, by definition involve change in either the stock of nominal money supply, or some short-term nominal interest rate, to obtain a change in some real economic variable. The channels through which this effect can pass through from the point at which the decision is taken to the final

outcome is usually seen to be one of the following: the interest rate, the exchange rate, asset prices, bank lending, firm balance sheets, and expectations.

The model presented in this chapter shows a slightly different way in which the transmission mechanism can operate. First, money is not included in the model. Credit though is a part of the model, as are asset prices. Second, expectations do not play a role in this model since the only uncertainty is the random technology shock that hits the economy. Third, interest rates do not change in the model. The shock that hits the economy is a random technology shock, not a policy shock that changes money supply or interest rates (that would be expected in the traditional definition of a transmission mechanism). This technology shock changes asset prices and credit constraints, and the impact on the economy is similar to that induced by a monetary policy shock.

A positive technology shock increases output in the current period, increases the demand for assets in the current and future periods, and increases the price of assets in the current and future periods. As the price of assets increase, it increases the net worth of representative type I agents, and thus increases their capacity to borrow. This increased borrowing will in turn increase the demand for assets, and hence, increase the price even further. Thus, the impact of the shock persists across periods, and amplifies with time. This is unlike neoclassical models where the effects of the shock dissipates over the same period that the shock is realized.

In terms of actual output from the simulations a 1% technology shock, which would have led to a 1% change in output in a neoclassical model, leads to a 0.85% immediate change in total output, and a larger change in output over time in the current model with credit constraints. Capital holdings change by as much as 4.5% for the constrained agent, while capital price changes by more than 2%. The effects of the shock persist for as much as 13 periods, or more than 3 years (since each period

in the model corresponds to a quarter). None of this would be possible in a perfectly competitive economy with no uncertainty: the effects of the shock will be realized in the same period, and disappear in the same period. The impact on individual variables will be of the same order of magnitude as the shock. Thus, the model, with active credit constraints helps explain how shocks can amplify. The numbers reported here, and in Table 3.2, only note the peak effect (except for the persistence column). The combined effect over the entire time frame while the effects of the technology shock are still being felt is much larger. Thus, the model can partly explain the difference between observed shocks and observed economic changes.

Intuitively also the above results make sense. Consider a classical competitive economy. Two of the defining features of the economy would be instantaneous price changes in response to any shock, and the equivalence of all forms of funding. Thus, if a positive shock hits the economy we would expect asset prices to rise instantaneously in response to the shock. representative type I agents can borrow as much as they want since everyone knows everything, and thus there would be no borrowing constraint. In the current context both these assumptions break down. Debt depends on the amount of collateral on offer, which in turn depends on the price of assets. There is a feedback loop between asset prices and debt, and thus the effects of the shock do not disappear in the period they are realized, but rather amplify with time.

Further, the simulations seem to suggest that, *ceteris paribus*, this effect on asset prices and output rises as economic productivity rises. Shocks also become more persistent. In practice we would expect this to hold. History suggests that asset price changes have a bigger impact on developed economies where the relationship between asset prices and banking sector helps in sustaining a feedback mechanism. Asset prices cannot act as a major transmission mechanism when most asset purchases do not involve the banking sector. This is true for most of the developing world. Thus, if

there are any changes in asset prices it would not influence banks and financial sector in a large way, and would not affect the representative type I agents' borrowing, or lenders' capacity to lend. The 2008 financial crisis did not hurt most developing countries banks' as they were not exposed to asset prices in the same way as banks in developed countries. Though the poorer countries did see their output growth shrink, and some went into outright recession, but that was primarily an after effect of the impact of the sub-prime crisis on international trade.

The second and third sets of simulations reported in Table 3.2 explain the impact of changes in savings rate. A higher proportion of type I agents translates to lower savings rate. Simulations suggest that a lower savings rate implies a lower output change, and lower persistence. Asset price change becomes larger with falling savings rate. This may be because the demand effect of a larger number of representative type I agents in the economy outstrips the availability of assets, and thus leads to a higher price increase.

Change in proportion of saleable output captures a similar idea. Given the structure of the economy, representative type I agents would spend all their net worth as collateral, and can starve themselves to death (that is, reduce current consumption to zero). This is so because the interest rate in the economy is below their rate of indifference to borrow or not borrow. They would be indifferent between borrowing and not borrowing at a higher interest rate. Since their loan depends on their capacity to raise collateral, they would use all their current output to fund new investment to maximize lifetime utility. If we do not put an exogenous limit on how much representative type I agents can utilize as collateral, their consumption in every period will fall to zero, and they will use all their net worth to borrow. The exogenous investment limit (which depends on usable net worth of the representative type I agent) forces the representative type I agent to consume a positive amount each period. One example

may shed some light on this issue. The 1997 Asian financial crisis was characterized by large scale cross border borrowings which had become too attractive to potential borrowers in South East Asia. This was a result of the interest differential that existed between those countries and the funding countries in the West. Firms, and households, borrowed more than they could afford, and when asset prices collapsed, these economies all came crashing down. A similar idea is being captured here. To prevent representative type I agents from using all their current worth to borrow, the model is forcing them to consume some part of their output, and use the rest as collateral. In terms of simulation, without this exogenous limit the model will not converge to an equilibrium since the consumption of the representative type I agent will always be zero.

Comparison with Kiyotaki-Moore

KM present two versions of the credit cycles model in their paper, but provide simulations for only one of them. The first version of the KM model is concerned with establishing the relationship between asset prices and economic activity. In the second model they make two major changes: they allow the use of reproducible capital, in the form of trees, and they limit the ability of borrowers to invest by reducing the probability of investment opportunity. The model in this dissertation is based on the first version of KM model, while their simulations are for the the second version. Thus, the simulation results presented earlier in this chapter, and those in KM are not strictly comparable. With this disclaimer in place, it will still be instructive to present a comparison of the two results.

KM present only one simulation graph in their JPE paper. The simulation presented is based on the assumption of 4% annual rate of interest, 10% annual rate of depreciation, and a given price of reproducible capital. In this setup a 1% posi-

tive technology shock increases both land (capital) holdings (0.10%), and debt held (0.13%) by the more productive agents by one order of magnitude less than the shock. Capital price increases by less than 0.4%. While this may not seem like a lot, it is important to note that in the neoclassical world the change in asset price in response to any technology shock would have been zero, and thus, any positive value for change in asset price is a step in the right direction. The impact of the technology shock in this version decays at a slow rate, and the effects of the shock disappear in about 10 years.

The authors also present two other simulation results in a working paper version of the final paper (Kiyotaki and Moore (1995)). The first set of these simulations assumes that the more productive agent always has the ability to invest. This is similar to the setup in this dissertation. The simulation results in the working paper show that a 1% positive technology shock (with other parameters as above) raises capital price by 0.43%, raises land holdings (capital holdings) of the more productive agents by 0.90%, while at the same time increasing their debt by 1.25%. These values are similar to simulation results in the dissertation. The persistence of shocks in this version is about 3 years, which is what is obtained in simulations in the dissertation.

The last set of simulations in Kiyotaki and Moore (1995) limits the probability of investment in every period to 10% (as is the case reported in KM), and reduce the price of reproducible capital by half, while sticking to other parameter values as above. This change leads to a larger initial impact on both asset prices, and debt holdings. Shocks are relatively less persistent compared to the model presented in KM, but more persistent than the version where investment happens every period, at about 6 years. Asset price movements also become less volatile, while at the same time the initial impact on the variables of interest (quantity of capital, debt, and capital price) is larger in this case.

All three simulations above show that the impact of the 1% positive technology shock in KM simulations are in general at least one order of magnitude lower than the estimates presented in this dissertation. One exception is persistence, which tends to be higher in KM models. The difference can be attributed to the damping effect of both reproducible capital, and the inability to invest in every period. As the probability of investment increases, or the price of reproducible capital decreases, large part of the effect of the shock tends to be recognized early, and thus, the initial impact on variables of interest are higher. The damping also reduces the convergence in KM, and this makes the effects of the shock last longer in KM.

The model in this dissertation does not include either of these factors, and this is reflected in the simulation results. The longest persistence observed in the model in the dissertation is about 13 periods, or slightly more than 3 years. This is close to the smallest persistence that KM observe. When the observed persistence is about 3 years in KM, the change in asset prices and capital holdings of the productive agent are similar to the values obtained in the dissertation. When comparing with KM, current values (in the dissertation) are about an order of magnitude higher than what is reported in KM. This can be attributed to the fact that simulations in KM only allow investment once in about 2.5 years, thus spreading out the effects of any technology shock over a longer time period.

Summary

The chapter used a simple deterministic heterogeneous agent economy to show that collateral constraints can act as important transmission mechanism, and can help amplify shocks in the economy. The use of credit constraints and different time discount factors helps isolate the role of collateral constraints as the transmission and amplification mechanism. This confirms the results in KM, but unlike KM, the

results do not hold for all possible parameter values. For a steady state to exist in an economy with risk averse utility and decreasing returns to scale production function, the range of parameters that can lead to a steady state, and that can help explain the amplification of shocks, is very small. Unless agents differ a lot in their time discount factors (which is unlikely) the results in KM may not hold for a large variety of possible capital allocations. Whether the same argument applies to the case where there is reproducible capital is an open question to be addressed in future work.

The next chapter looks at the role of real estate in the economy. An event analysis is performed to examine if real estate cycles have been consistently associated with larger economic malaise, or was the Great Recession of 2008 a random event. There is no attempt to establish causality. It is only an effort to establish whether real estate needs to be dealt with in a slightly different manner, and whether the recent spate of changes in bank regulation are a step in that direction.

CHAPTER 4

BANK REGULATION AND MORTGAGE FINANCE

The last two chapters used a heterogeneous agent model to show that asset prices can act as an important transmission mechanism that can help transmit and amplify technology shocks in the economy. It is widely agreed that the crisis of 2008 was triggered by the collapse of the sub-prime mortgage bubble in the United States. But was it true of other major changes in real estate prices across the world? One question that has been doing rounds ever since the 2008 crisis is whether regulators could have done anything to prevent the crisis? What can be learned from the crisis to be used in the future? Is it time to go beyond traditional monetary policy regime of using a single policy (inflation control) and a single tool (the policy rate), and look for policy measures that go beyond these? This is particularly so when central banks today have to address issues going beyond inflation, and onto output growth and macroeconomic stability. This chapter looks at some of these questions and the experience of various countries in this context, both prior to, and post the financial crisis of 2008.

The chapter is organized as follows. First, data from a group of 18 rich countries spanning the last four and half decades is analyzed to see if real estate cycles had

an impact on their economic health. Subsequently, the current state of affairs with regards to monetary policy regime and bank regulation is discussed. In terms of monetary policy, most major economies today practice some form of explicit or implied inflation targeting, following Tinbergen's idea that a single tool should be used to target a single policy measure. While this policy has served well for an extended period of time, the recent economic crisis has made policy makers look at other possible metrics of economic health.

In terms of bank regulation, most central banks today follow the recommendations of the Basel committee to determine local regulation requirements. There have been arguments that Basel II recommendations may have in part contributed to the crisis in 2008 (see Heid (2003), Pederzoli et al. (2010), and Bair (2014)), and some of those shortcomings have been addressed in Basel III. Some of these changes are discussed. The inter-relationship between mortgages and the banking sector is examined. Macroprudential regulation is examined in slightly more detail given the role played by the real estate sector in the recent crisis. The chapter ends with a discussion on how mortgage markets differ in terms of organization, funding, and other features across the world, with particular focus on the two largest mortgage markets in the world: the United States and Japan.

Asset Prices & Economic Activity: Empirical Evidence

In the aftermath of the sub-prime mortgage bubble collapse in the United States, economies across the world were engulfed in the longest, and the deepest, recession since the Great Depression. While policy makers across the world tried every trick in the book, and then some, at the time of writing this (August 2014) the economy was still not completely out of the woods. Unemployment rate in the US was at 6.2%, still above the generally agreed upon natural rate of unemployment, almost 7 years

after the recession began and 5 years after it ended. The loss in output from peak to trough was the largest since the Second World War. Equity prices collapsed almost 50%, and housing prices in many states collapsed more than this. Remarkably, it was also the first time since the 1970s that the US housing market saw a sustained contraction in terms of both prices and new construction. This indicates that housing prices can have a substantial impact on the state of the economy. But one instance cannot be used to form a rule. There is need for more empirical support. The problem is that housing price data is difficult to get for most countries, particularly for longer time frames. The longest credible data set for housing prices is available from the Bank of International Settlements. The data set has quarterly housing price index for the following 18 countries going back to the first quarter of 1971: Australia, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, the United Kingdom and the United States. More recently, the BIS data has been updated with a few more countries being added to the list. The price indices for the new countries on the list is not as long as the ones used in this dissertation, and hence they are not included here.

This data set is used to determine changes in housing price index, and then event analysis is used to determine the correlation between housing price changes and other aspects of the economy. A modified Bry-Boschon cycle dating procedure is used to estimate the peaks and troughs in the house price index of the above 18 countries (see Bry and Boschan (1971) for the original procedure, and Harding and Pagan (2002) for a version that deals with quarterly data that is used here). Details of the cycles are included in Table B.1. Summary statistics for the data are in Table 4.1.

With the dates of the peak and troughs determined we can then look at the changes in the parameters of interest around these dates. While a number of variables can

Parameter	Notes
Number of Contractions	93
Longest Contraction	Japan (91+ quarters, from 1990:4)
Average Length of Contraction (Quarters)	6.6 (With Japan) 5.7 (Without Japan)
Longest Expansion	Spain (84 quarters, 1971:1 to 1991:4)
Double Dip Contractions	Canada (1981-1984) Denmark (1979-1982) Germany (2005-2007) Netherlands (2008-Continuing) Norway (1988-1993)
Triple Dip Contractions	Switzerland (1990-1998)
Most Cycles	Germany, Norway (9 each)
Least Cycles	Japan, Spain (2 each)

Table 4.1 – *Real Estate Cycles Summarized*

Sources: National sources, BIS Residential Property Price database, `http://www.bis.org/statistics/pp.htm`, and author's calculations.

be studied, this dissertation focuses on two variables: real GDP growth and private sector lending. Before getting into the details of that analysis it will be instructive to note why these variables were chosen. As we have seen earlier, asset prices can influence the economy through four main channels. Changes in asset prices can influence household wealth that affects consumption. It can influence the price of capital relative to its replacement cost which influences investment (as in Tobin's q-theory). It can influence capital flows which affect demand through real exchange rate changes. Lastly, it can also influence the balance sheet of banks, households, and firms that can influence both investment, and government debt, as governments try to recapitalize firms and financial intermediaries. Further, as stated earlier, the main focus of this dissertation is the balance sheet effect, whereby changes in asset prices influence borrowing and lending in the market through change in the balance sheets of households and financial intermediaries.

Asset price busts can damage balance sheets of households, firms and financial intermediaries. This in turn would limit their capacity to borrow (through a fall in value of collateral) and lend (through a reduction in the intermediary's capital position). Real estate happens to be the biggest component of household's wealth, and any fall in housing prices would influence their net worth. A similar analysis would work for firms, but the problem is the lack of data on commercial real estate prices. Researchers are therefore forced to use housing price index as a proxy for commercial real estate. As housing prices fall they can reduce the value of assets that financial intermediaries have on their books, thus reducing their capacity to make new loans. This claim can be tested empirically to see what happens post a real estate peak. In the data set analyzed here there were a total of 93 cycles in housing price index over this period of 43 years. Not all of these were equivalent. Some were much longer and deeper than others, while some contractions lasted just 2-3 quarters. A longer contraction was generally deeper too, and can proxy a bust, rather than just a minor correction in real estate prices. There are two ways in which these contractions can be analyzed to determine which of these constitute a bust: either, through the price changes from the peak to the trough; or, through the length of the contractions. The former has been done in Helbling and Terrones (2003), while the latter method is adopted here. The analysis focuses only on those contractions that are equal to, or longer than, the average length of contractions which was 6.6 quarters. This reduces the number of cycles to be analyzed to 39 cycles (out of 93). Denmark has had the most of these (with 6 contractions lasting 6 or more quarters), while every other country has had at-least one such cycle.

Changes in median real GDP growth rates around the peak of the cycles are given in Figure 4.1. GDP growth contracts substantially soon after housing prices peak, with the trough being reached around 4 quarters after a real estate peak. Over the

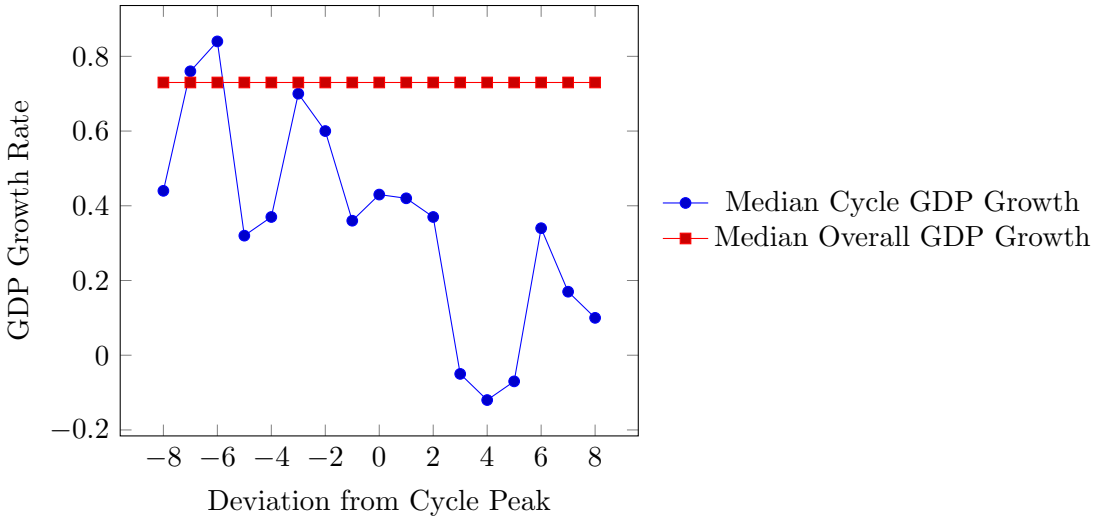

Figure 4.1 – *Median GDP Growth Around Real Estate Peak*

The graph represents median growth rate across 18 countries 8 quarters prior to and post the peak of a long real estate recession. Housing price data are from the Bank for International Settlements (BIS). Sources: National sources, BIS Residential Property Price database, `http://www.bis.org/statistics/pp.htm`. GDP data are from the Organization of Economic Cooperation and Development (OECD). OECD, "Main Economic Indicators - complete database," Main Economic Indicators (database), `http://dx.doi.org/10.1787/data-00052-en` (Accessed on August 24, 2014). Copyright, 2014, OECD. Reprinted with permission.

entire length of the study the median quarterly growth rate of real GDP was 0.73, while it reached −0.12 one year after housing prices peaked. This translates into a 3.44% annualized fall in median GDP growth rate: a number larger than the 2.95% median annual growth rate experienced by these countries during the period analyzed in the study.

Over the same period private sector lending experienced an even larger change. The median growth rate of nominal private sector lending during the period was 2.15% quarter-on-quarter. The median growth rate rose above this number (2.15%) leading to a real estate peak, and crashed substantially thereafter. Figure 4.2 plots the changes in median growth rate of nominal private sector lending 8 quarters prior to, and post a long real estate peak. Mean growth in private sector lending is above the overall mean almost till the peak (not shown on this graph) while the median

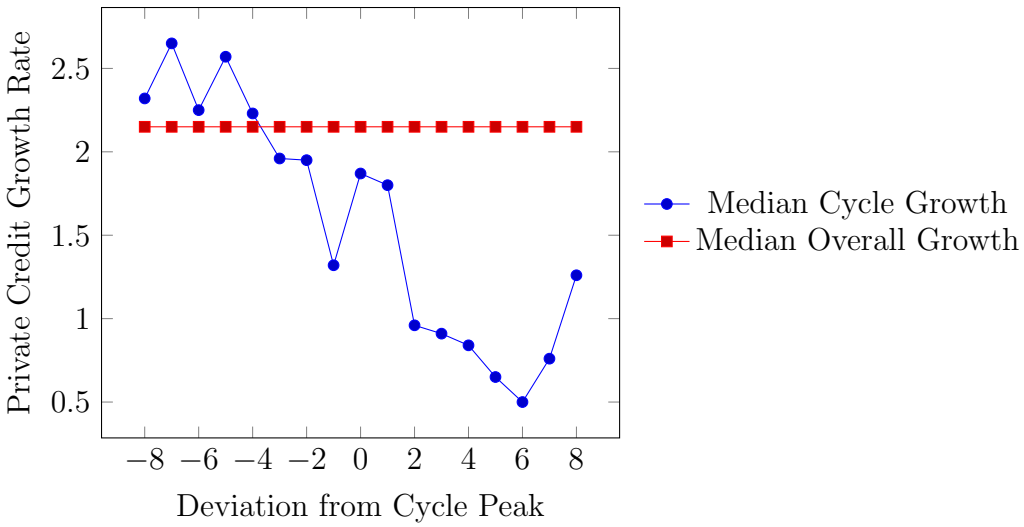

Figure 4.2 – *Median Private Credit Growth Around Real Estate Peaks*

The graph represents median private credit growth across 18 countries 8 quarters prior to and post the peak of a long real estate recession. Housing price data are from the Bank for International Settlements (BIS). Sources: National sources, BIS Residential Property Price database, `http://www.bis.org/statistics/pp.htm` Private sector credit growth data from the Bank for International Settlements (BIS) and the Reserve Bank of New Zealand. Sources: National sources, BIS Private Credit database, `http://www.bis.org/statistics/credtopriv.htm` and RBNZ.

growth rate starts falling below the overall median about 3 quarters before a real estate peak. Median nominal quarterly growth rate of private credit does not fall below zero, but it does go down to 0.5% about 6 quarters after a real estate peak. The lower quartile of median nominal quarterly growth rate of private credit does go down to −0.26% about 6 quarters post the real estate peak, thus suggesting that in a worse-than-average contraction, nominal credit may actually shrink. On the annualized scale, the fall from the overall median growth rate of private credit is even larger than one observed with real GDP at 6.76%.

Taking into account the rate of inflation it would mean an even larger fall in real credit growth. A fall in credit growth will have long term consequences on goods and labor markets, and the empirical evidence above suggests that a sustained fall in real estate prices does have a major impact on the state of the economy. But until

recently real estate prices were not considered seriously enough. Inflation rate was, and continues to be, the most preferred metric to analyze the health of the economy. The question is whether that approach is right? In particular, can inflation predict economic cycles that are led by real estate price movements. This, and some other aspects of bank regulation, are considered in the next section.

Structure of Regulatory Policy

Inflation Targeting

Most major economies across the world today practice some form of explicit or implied inflation targeting. While many central banks did this unofficially for a long time, New Zealand was the first country to officially adopt an inflation target in 1989 that came into force in 1990. While the Fed, the European Central Bank (ECB) and the Swiss National Bank do not have official inflation targets, they do follow regimes which have similar features. This has been a result of a long debate starting in the 1940s about the role and conduct of monetary policy. The consensus that emerged involved the central bank looking at one policy, that of inflation control, and use of a single tool, the policy rate, to influence that measure. The policy has on average been a very successful one. There are multiple studies that show countries following some form of inflation targeting have had better economic outcomes compared to those that did not (see Walsh (2009), Svensson (2011), and Thornton (2012)). Other methods of price level targeting have been used. For a survey on an alternative type of price level targeting see Ambler (2009). Inflation targeting has been so popular that no country has voluntarily moved away from inflation targeting after adopting it, while many have joined or are seriously considering doing so. Some European countries, most notably Spain, did abandon inflation targeting after joining the European Monetary

Union, but that was because the European Central Bank does not have an explicit inflation targeting policy.

Inflation targeting as a tool seems to work well in normal times, but if there has been any shortcoming it has been an inflation targeting regime's inability to ensure financial stability (Roger (2010)). While inflation targeting has helped keep inflation under control, it has not been able to maintain financial stability. This was clearly in evidence in 2008 across the world, and in other countries prior to that. Whether this was a result of inability, or unwillingness, on part of the central banks is an open question. Given the dominance of the Fed, and the clout of one of its longest serving chairmen Alan Greenspan's views on bubbles, it may have been a bit of both.

Monetary policy, based on inflation targeting, seemed so successful in the late 1990s and early 2000s that many started believing in its infallibility. The experience of the world economy in general, and the American economy in particular, was one of rapid growth, low unemployment, low inflation, and more importantly lower volatility in all these variables. Economists called it the great moderation. The confidence that this built in professional as well as academic economists about monetary policy's efficacy in dealing with business cycles was remarkable. This was ironically captured in a famous remark by Robert Lucas (Lucas (2003)) who argued that

> ... central problem of depression prevention has been solved, for all practical purposes, and has in fact been solved for many decades.

As late as 2007, when the US economy was already in a recession an analysis from the Federal Reserve Bank of Chicago (Mojon (2007)) argued that US monetary policy had succeeded in reducing fluctuations in US output, and in decoupling household investment from business cycles.

Though this was the dominant discourse there were some who questioned this

complacence. One of the most prominent critics of this view was Richard Koo (Koo (2003) and Koo (2008)), who used the Japanese experience to point out that one needed to look beyond inflation rates. He opined that regulators needed to pay special attention to real estate prices, and argued that the collapse in the real estate sector was the main driver of Japanese economic troubles that began in early 1990s. Japan's experience post its asset bubble burst in 1990 has been anything but a great moderation. What started as a recession has prolonged into lost decades of the Japanese economy. In real terms Japan's GDP grew at 1.433% quarter-on-quarter in the 24 years prior to the collapse of the Japanese asset bubble, and at 0.247% quarter-on-quarter in the 24 years post the crash. This meant that if Japan had grown at the same rate post the asset bubble burst as it did prior to it, its economy today would be more than three times larger than what it actually is. The obvious question then is the following: why did the Japanese economy not recover from the crisis even when all conventional tools were utilized? The Bank of Japan gradually reduced interest rates to 0%, and the government went from a budget surplus to a massive budget deficit, but none of this could take Japan out of the slow growth - deflation period. Conventional policy tools have all been exhausted in Japan to no perceptible effect on the economy. More recently, the Bank of Japan did something unthinkable in January 2016. They reduced the policy rate to -0.10% in an effort to break the deflationary cycle in the country. Koo claimed that the fact that asset prices fell so much meant that Japanese firms and households were more interested in repairing their balance sheets than in profits, and as a result of this change in behavior what started off as a regular recession turned into something much bigger. He called this a 'balance sheet recession.' Koo's argument has been that this is possible in every economy where there is a major asset price correction, particularly one that deals with real estate and hence policy makers have to be more careful when dealing

with real estate bubbles. Opponents of the view argued that Japan's case was unique (with regards to its demographics and economic structure) and that such a scenario was unlikely in other major economies, particularly so in the United States. The great recession laid rest to any such complacence.

One common thread between the Japanese lost decades and the sub-prime mortgage crisis was the rapid and massive fall in asset prices, particularly real estate. The prolonged nature of these crisis suggests that there was something unique about a fall in real estate prices. The argument also finds support in data from other economies. What is also instructive is the fact that the conventional monetary policy tool to measure the health of the economy, the inflation rate, was well under control before the real estate prices peaked and started collapsing. The conventional measure of health of the economy didn't indicate any problems, when trouble was brewing all along (see Figure 4.3). Appendix C shows details of quarterly inflation rates for the 18 countries in our sample from 1971 to 2014 (except Ireland, whose data is from 1976 to 2014). When comparing the median quarterly inflation rate during the overall period, and eight quarters preceding a real estate peak, there is no statistically significant difference (at 99% confidence) between the inflation rates in the overall time frame (Mean 1.0892, SD 0.3124), and that just before a long real estate cycle peaked (Mean 1.0202, SD 0.6564). If there is no statistically significant difference between the inflation rates before a real estate peak and its normal level, policy makers and market participants are likely to think that everything is fine, and that the economy is running normally. This also suggests that we need to look beyond inflation rate as the only metric of economic health.

Rising asset values can make market participants (including regulators) complacent, particularly when inflation is in the comfort zone. This in turn pushes households, firms and banks to move to higher leverage, which can then make any cleanup

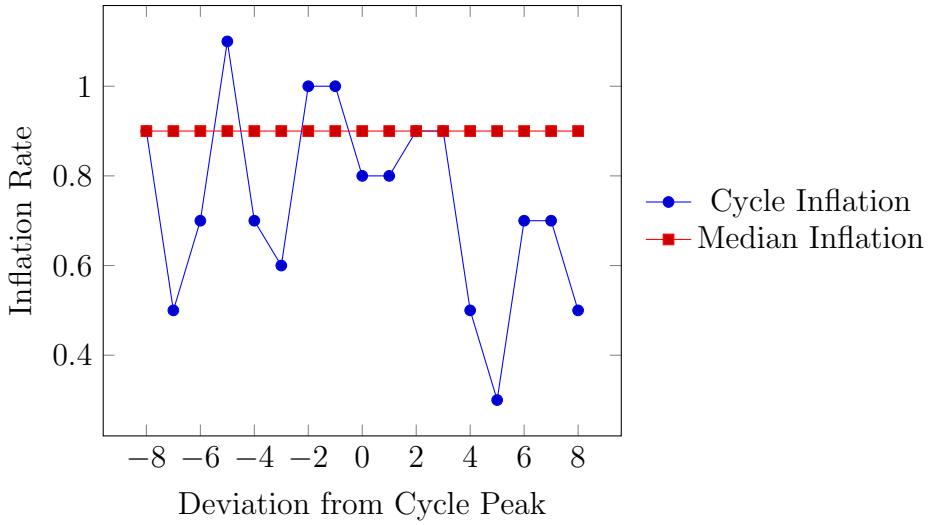

Figure 4.3 – *Median Inflation Rates Around Real Estate Peaks*

The graph represents median inflation rate across 18 countries 8 quarters prior to and post the peak of a long real estate recession. Housing price data are from the Bank for International Settlements (BIS). Sources: National sources, BIS Residential Property Price database, `http://www.bis.org/statistics/pp.htm` Inflation data is from the OECD.

after a crash very expensive. Financial stability will come under major stress if a large part of the economy deleverages simultaneously, which is very likely, if not inevitable, with a major asset price correction. This is an aspect that cannot be addressed by inflation targeting.

When looking at real estate cycles there are two major actors in the field: mortgage lenders and borrowers. The reason for only looking at real estate cycles for now boils down to this: real estate purchases tend to be funded by credit, and hence problems in the real estate sector turn lead to problems in the banking and financial sectors, while other assets tend to be cash purchases, and hence the impact on the economy is not as large. Both have garnered more than ample attention post 2008.

In most countries banks tend to be the biggest mortgage lenders, so looking at their regulatory structures becomes important. There are two points to consider here: one, to look at the individual health of the financial institution which corresponds to

the classical bank regulation debate, and one that the BIS recommendations focus on; and two, look at their role in providing financial stability. Their inter-connectivity is a major factor contributing towards financial stability, and it brings us to the domain of macroprudential policy. Macroprudential combines two words: macroeconomy, and prudential which means with foresight. A history of the origins and evolution of the term 'macroprudential' is presented in Clement (2010). A wider literature survey is available in Galati and Moessner (2013). While there are no internationally agreed frameworks yet on macroprudential regulation, most major economies are experimenting with some form of this framework.

The second pillar, the borrowers, also need to be dealt with. There is a need to look at the borrowers' ability to actually purchase a property, and their own stake in the investment. Two parameters come in focus here: the loan-to-value (LTV) ratio, and the debt-to-income (DTI) ratio. The loan-to-value (LTV) ratio determines what part of any real estate purchase can be financed by a financial intermediary. The debt-to-income (DTI) ratio determines a borrower's ability to pay off the debt. To illustrate how far both lenders and borrowers had gone during the sub-prime crisis look at the so called NINJA loans (NINJA stands for No Income, No Jobs or Assets). People ended up getting mortgages without putting a single penny down, without any asset (except the house itself) as collateral, and with no prospect of actually paying off the debt. On the other hand most Asian banks, outside Japan, require at least 20% down from the borrower, and the monthly mortgage payment is usually capped at 40% of the borrowers' monthly gross income. Income requirements are higher if there is some other existing debt. This makes the borrower more responsible for the mortgage with his skin in the game, and avoids over-stretching the borrower. This may be a template for the future.

Changes to Bank Regulation: The Basel Framework

It was just shown that inflation as the sole metric of measuring the health of the economy has not been very useful in foretelling a crisis in real estate, or a real estate induced banking or financial crisis, over the last four decades, or virtually the whole period where inflation targeting has acquired the central position in monetary policy framework across economies. Most earlier downturns in real estate cycles, including major ones that caused banking crisis and major downturns in economic activity, were primarily limited to a single country (as in Japan in 1990), or a single region (as in Scandinavia in the late 1980s and early 1990s). The sub-prime mortgage crisis that began in the US in 2006-07 was different in the sense that it spread further than any earlier crisis in the sample.

Partly in response to the problems caused by collapsing banks and financial institutions post the sub-prime mortgage crisis the Basel committee in its latest set of recommendations has tried to address two important issues: making banks more responsible for their actions by increasing capital requirements; and, indirectly looking at the inter-linkages by putting more attention on systemically important financial institutions. There have been arguments that Basel II may have been partly responsible for the extent of the crisis of 2008. The prime channel was the way risk weighted assets were defined in the capital adequacy requirements. For example, debt to a company like IBM, was considered to be riskier than that to any bank or financial institution (see Bair (2014)). Thus transactions between banks, by definition, were considered less risky than virtually any other transaction involving any other type of firm, even when it was known that banks may all be hit by a common shock. Some of these provisions, that were under the scanner, have been modified in Basel III recommendations that are coming into force across countries. The full set of recom-

mendations is likely to be in force by 2019. Table 4.2 compares some of the major changes between Basel II and Basel III.

The two biggest changes from Basel II to Basel III have been an increase in the amount of capital banks would be required to hold, and in the amount of leverage they can take on. In terms of capital requirements, there has been an increase in not only the amount of capital that banks would hold, but also in the composition of that base. Thus, core equity requirement in Basel III has been raised to a level higher than total Tier I capital requirement in Basel II. Similarly there have been changes in the risk weights assigned to various types of assets, and a counter-cyclical capital buffer has been introduced. Banks would thus be required to hold more capital in an economic downturn, making them more likely to survive the crisis. The quantum of leverage that banks can undertake has also been defined, and a leverage ratio of 3%, implying a leverage of 33, has been introduced. The US Fed has used the leverage ratio earlier than Basel III recommendations, but it failed to prevent the collapse of Lehman Brothers whose leverage peaked at a value above 40 in 2007 for one simple reason: Lehman was regulated by the Securities and Exchange Commission (SEC), and the SEC did not have any such requirement. This also hints that there is a need for more coordinated action, and more synchronized regulatory tools, between various regulators. Further, in a nod to the role of interconnectedness of the financial system, measures have been proposed to tackle financial institutions that are too big to fail. Systemically important financial institutions (SIFI) would be required to hold more capital than other financial institutions.

Basel III recommendations can be said to be a response to the increased use of securitization, both within and outside financial institutions, and that of growing inter-dependence of financial institutions across national boundaries. It addresses the problem of bank solvency, and how to deal with it, but does not address the problem of

large asset price fluctuations and whether policy makers should do something about it. This is quite natural since Basel recommendations are not looking at aspects beyond the narrower domain of bank regulation. The bigger question is can we do anything to prevent banks and financial institutions from getting into trouble, rather than looking at ways to get them out of it once the crisis has hit? Basel III recommendations will help banks be better prepared to deal with a crisis, but can we do anything to prevent the crisis from happening in the first place?

Macroprudential Policy

One underlying principle of modern economics has been the belief that financial markets are efficient in a pricing sense: that is, prices are a true reflection of all available information, and that the joint hypothesis problem that markets are efficient cannot be disproved. An implication of this belief is that we cannot have asset price bubbles, and if we do have these bubbles we cannot recognize them in time to do something about it. In other words, we cannot recognize a bubble till after it has burst. A concern for central banks leaning against a bubble has been that while there may be problems in one asset market, the policy rate is too blunt a tool to act against one specific sector. For example, if housing prices are rising rapidly, and the central bank increases interest rate to counter it, the rise in interest rate will also influence other investments where there may not be a bubble. We therefore need something more granular to counter problems in specific sectors of the economy. As a result of this consensus, central banks across the world were hesitant to explicitly target any asset price increase till it was too late.

The recent crisis has shown that the cost of clean up is way too high to ignore asset price bubbles, particularly those fueled by an expansion in credit. Blanchard, Dell'Ariccia, and Mauro (2014) have captured this in a very simple framework. They

Parameter	Basel II	Basel III
Quality of Capital	Tier II capital could be 100% of Tier I capital. Common equity is 50% of Tier I capital.	Tier I capital to be the dominant part of capital of banks. Tier II capital can only be 25% of core capital requirements. Common equity also rises to more than 50% of total capital requirement (4.5% of Risk Weighted Assets).
Quantity of Capital	Total capital requirement is 8% of Risk Weighted Assets.	Total capital requirement raised to 13% of Risk Weighted Assets, with additional supplements for systemically important financial institutions. The 5% increase consists of 2.5% as counter-cyclical capital buffer and 2.5% as capital conservation buffer.
Leverage	No explicit leverage ratio.	Leverage ratio set at 3%, implying a leverage of slightly more than 33 for both on- and off-balance sheet assets.
Short Term Liquidity Coverage	No explicit regulation.	Introduction of liquidity coverage ratio that requires banks to hold enough high quality liquid assets that cover for liquidity outflows over a 30 day period of stress.
Long Term Funding	No explicit regulation.	Introduction of a Net Stable Funding Ratio (NSFR) that requires firms to maintain stable long term funding that is firm specific.
Counter-party Risk Exposure	No provision.	A counter-party risk buffer has been introduced. Methods to determine risks modified.

Table 4.2 – *Basel II to Basel III Changes*

argue that the choice between pricking a bubble, and not pricking it is like a trade-off between Type I and Type II errors. While it is difficult to decipher in real time whether a particular phase of increase in asset prices is a bubble or not, the argument seems to be veering towards central bankers acting against these increases without worrying about the nature of its increase. That would mean opting for higher Type I error, that is acting against an asset price increase even when it is not a bubble, than higher Type II error, that is not acting against an asset price increase assuming it is not a bubble. This change in attitude has been primarily driven by the rising cost of cleaning up after a bubble has burst.

One big component of this change in attitude has been the increasing focus on macroprudential regulation. The term literally means interaction between prudential policy (that is, policy that acts with foresight) and the macroeconomy (Haldane (2014)). While regulation thus far, including that in banking, dealt with regulation of individual firms and institutions there is a need to look at the feedback loops, and the interaction between various firms. These feedback loops make most conventional tools on a firm level less relevant during a crisis (Borio, Drehmann, and Tsatsaronis (2012)), and give a wrong sense of calmness. Towards this, there is a need to search for the appropriate set of instruments that can act as the go-to tool, like inflation rate does for monetary policy. But the definition of instruments requires specifying the objective of these tools: are we trying to protect the financial system from changes in the real economy, or vice-versa (Haldane (2014)).

Some of the choice we have for these instruments are price based measures (as in taxing certain types of transactions) or quantity based measures (as in reducing loan-to-value and debt-to-income ratios). Both have been tried by various countries, but it is too early to judge either for their efficacy. For example, Singapore imposed an additional buyer's stamp duty (ABSD) on purchase of residential real estate in

late 2011 at the rate of 10% for foreigners and 3% for permanent residents who are not citizens. In early 2013 it was raised to 15% for foreigners, 10% for permanent residents, and a new 5% ABSD was introduced for citizens. The Singaporean residential real estate market which rose more than 50% in the 5 years prior to the higher ABSD imposed in January 2013, has fallen in every quarter since then. What can be said with more certainty though is that some of these measures can act as early warning systems (see Borio and Lowe (2002) and Borio and Drehmann (2009)). They are also better suited to act in a more precise manner and target one particular sector or area, unlike monetary policy which is a blunter tool. For example, China restricted home ownership in Beijing and Shanghai in 2013 (see Barboza (2013)). They also increased capital gains tax, reduced loan disbursements, and imposed additional duties to discourage speculative purchase of real estate. These regulations did not apply to other cities in the country, thus making them very region specific. South Korea has actually gone ahead to do so for certain regions within Seoul (see Kim (2014)), thus indicating how precisely the tools can be applied.

Both price and quantity based measures mentioned above deal with the real estate market. The question that naturally arises is why should real estate prices play such an important role in the process? One answer to this would be that both property cycles and financial cycles are of a much lower frequency than traditional business cycles (and consequently equity cycles), and the peak of the property and the financial cycles tend to coincide with systemic banking crises, or serious strains, in the banking sector(see Figure 6.1 in Borio (2014)). It has also been shown that positive deviations from the long term mean of ratio of private credit to GDP, and property prices, if both happen simultaneously, usually indicate financial imbalances. Thus, any such comovement of these variables can act as an early warning indicator for policy makers. The growing acceptance of this hypothesis can be seen from the string of measures

adopted by policymakers across the world over the last few years to cool down the real estate market. Table 4.3 lists some of these measures. Countries with names in small capital letters in the table are a part of the earlier sample of countries analyzed in the dissertation. Nearly all of these measures are attempting to cool down real estate markets to some degree, and help prevent a repeat of 2007-09. While the measures being adopted across the world are very similar, as it should be given the fact that the fundamental economic problem is the same, the nature of mortgages and mortgage markets across the world are anything but similar. These issues are addressed in the next section.

International Mortgage Markets

Mortgage markets have grown quite dramatically over the last few decades. The growth has been particularly rapid in the US and the UK in terms of the type of financing available, and the type of institutions that supply these funds. Markets in rest of the rich world have also become large, but are still dominated by bank financing, which in turn is sourced from consumer deposits or bond sales(International Monetary Fund (2011a)). Markets in Asia (outside Japan), Latin America and Africa are still in their relative infancy, with higher borrowing costs, lower maturities, and lower market depth (see for example, Kobayashi (2013) for a brief survey of Asian markets; Cubeddu, Tovar, and Tsounta (2012) for Latin American markets; and the Housing Finance Information Network for African market). Table 4.4 gives a brief comparison of mortgage market characteristics for our sample of countries. It shows that the use of deposits to fund mortgages is widespread. Germany, the Scandinavian countries and Spain rely primarily on bonds to fund these mortgages, while the use of mortgage backed securities or other derivatives has become the primary source of funding in the US residential mortgage market. Ireland and the United Kingdom get

Country	Measure	Notes
Australia	APRA to pay attention to Loan-to-Value (LTV) and debt-to-income (DTI).	RBA and APRA not too keen for across the board restrictions.
Canada	Reduced amortization period. Increased down payment. Remove government insurance for home equity lines of credit.	More skin-in-the-game for borrowers.
China	Increase capital gains tax. Reduce loan disbursements.	Reduce speculation, particularly in large cities.
Finland	Recommend reduced amortization of mortgages to 25 yrs. LTV at 90%.	Reduce risk taking.
Israel	LTV limited to 75% for first time home buyers, and 50% for investors. Increased provision for housing loans with higher LTV ratios.	Reduce leverage, and reduce the rate of property price increase.
Netherlands	Stricter DTI regulation. LTV limited to 110%.	Stricter loan origination.
New Zealand	LTV reduced to 80% for most loans.	Loans with higher LTV possible, but limited to 10% of a bank's loan book.
Norway	LTV limited to 85%. Stringent checks on ability to pay.	Stricter loan origination.
South Korea	LTV in Seoul area lowered to 50%. DTI limit of 40% for younger borrowers.	Reduce speculation.
Sweden	LTV limited to 85%.	Less risk taking.
United Kingdom	Established Financial Policy Committee.	
United States	Established Financial Stability Oversight Council.	

Table 4.3 – *Macroprudential Measures, 2008-2014*

Sources: Fischer (2014), Kim (2014), International Monetary Fund (2011a), International Monetary Fund (2011b), Barboza (2013), Rogers (2014), Australian Prudential Regulation Authority (APRA).

just over half of all their mortgages funded through deposits: the other funds coming through derivatives or bonds. The tenure of mortgages is 20 years or longer in all cases, except France, where the mortgages may be of a shorter maturity. Mortgage debt-to-GDP ratios tend to be higher in English speaking countries and in Scandinavia, perhaps indicating a higher encouragement to home ownership. Going forward these maturer markets may provide lessons to developing economies on how to house millions who are leaving their ancestral homes in search for greener pastures. Of particular interest is the way the two largest mortgage markets, the United States and Japan, have evolved over the last few decades. The two countries also happen to be the ones hit most strongly by real estate led banking and economic crisis. There are some fundamental differences in the structure of the two mortgages markets (summarized in Table 4.5), but over the last few years there has been convergence with regards to the way they function, particularly in the secondary market.

Mortgages in the United States

Home ownership has always been a part of the American dream. For a long time the volume of mortgage debt has grown faster than output. In 1949, mortgage debt was about 20% of US GDP, a number that rose to 50% in the 1980s, and peaked at just above 86% in 2008 (Green and Wachter (2005), Isgrò and Johnson (2014)). In the same period mortgage debt as a percentage of disposable income rose from less than 20% in 1949, to just above 100% in 2007, before falling (Mishel, Bivens, Gould, and Shierholz (2012)). Along with the volume of debt the regulatory framework and source of funding has also changed dramatically.

The US mortgage market was small prior to the Great Depression. Mortgages were short term, and needed frequent refinancing. The debt was non-amortizing and required a large bullet payment on maturity. But that did not prevent a housing boom

Country	Mortgage Funding Lenders	Term	LTV Max	M Debt to GDP Latest	M Debt to GDP Max	Interest	Tax Benefits Principal	Tax Benefits Interest
Australia	Banks, Mortgage Inst	25	90-100	-	-	Variable	No	No
Belgium	Banks	20	100	49.5	49.5	Fixed	Yes	Yes
Canada	Banks, Mortgage Inst	25-35	95	-	-	Mixed	No	No
Denmark	Banks	30	80	93.8	96.9	Mixed	No	Yes
Finland	Banks	20	75	45.7	45.7	Variable	No	Yes
France	Banks	15-20	100	43.8	43.8	Fixed	No	Yes
Germany	Banks, Savings Banks	20-30	80	44.2	53.5	Fixed	No	No
Ireland	Banks, Mortgage Inst	21-35	100+	57.8	91.2	Variable	No	No
Italy	Banks	20	80	23.2	23.3	Mixed	No	Yes
Japan	Banks, Mortgage Inst	20-30	70-80	-	-	Mixed	Yes	Yes
Netherlands	Banks, Mortgage Inst	30	125	104.9	108.9	Fixed	No	Yes
New Zealand	Banks	25	80+	-	-	Mixed	No	No
Norway	Banks	25	90	64.1	69.6	Mixed	No	Yes
Spain	Banks, Mortgage Inst	30	100	59.9	65.1	Variable	No	No
Sweden	Banks, Mortgage Inst	30-45	85	80.9	83.5	Variable	No	Yes
Switzerland	Banks	50-100	80	-	-	Mixed	No	Yes
United Kingdom	Banks, Mortgage Inst	25	110	80.6	87.5	Mixed	No	No
United States	Banks, Mortgage Inst	30	100+	62.1	86.2	Fixed	No	Yes

Table 4.4 – *Comparison of International Mortgage Markets*

Sources: National sources, International Monetary Fund, European Mortgage Federation and the Housing Finance Information Network.

in the roaring twenties. In 1925 more than 900 thousand new houses were built, but soon after the market dovetailed, and that volume of new housing construction was not achieved in the US till the end of the Second World War. But this housing boom happened despite the frictions in the mortgage market. The situation worsened post the Great Depression. Mortgage loans which were hard to come by became even more scarce as housing prices fell more than 50%. As a part of the New Deal, the Roosevelt administration established the Home Owner's Loan Corporation (HOLC) in 1933 which brought the US government in the market for the largest purchase most households ever make. The idea behind establishing the corporation was to prevent mortgage loans that were in default to go in foreclosure, which could cause more distress in an already fragile market. It did so by purchasing loans in default and changed them to a fixed rate 15 year fully amortizing loans. The rate of interest was 5% to begin with, and was later lowered. The HOLC would finance 80% of the value of the house, with the borrower paying the rest. These loan purchases were financed by issuing bonds, which had the full credit of the United States government behind it. This role of providing liquidity in the secondary mortgage market by government linked institutions continues to this day. The HOLC refinanced more than a million mortgages, a vast majority of which were paid off before maturity. Once out of the depths of depression the HOLC stopped any new refinancing and finally wound down operations in 1951. At the time of its closure the HOLC generated a small profit for the US government.

In the meanwhile the Federal Housing Administration (FHA) was established in 1936 under the National Housing Act. FHA's role was to insure home mortgages, whereby it insured up to 80% of the appraised value of the house. The other 20% had to be insured by private insurers. Like the HOLC, the FHA generated funds through issue of bonds. The FHA was performing its assigned role but the success of

HOLC didn't go unnoticed. To bank on this success the Federal National Mortgage Association (Fannie Mae) was established in 1938. Fannie bought mortgages from banks, thus freeing up their capital to generate new loans, and then sold off those loans to private investors. This activity generated the much needed liquidity in the market for mortgages. For the next two decades Fannie Mae had a monopoly over the secondary mortgage market. Post the Second World War they even purchased mortgages insured by the veteran affairs loan guarantee program.

The next major change in the US mortgage market came in 1956 when the loan-to-value ratio was raised from 80% to 95% for new construction, and 90% for existing homes. Home ownership rates rose rapidly through the period reaching more than 60% in 1960s. Fannie's and the FHA's role in this transformation cannot be understated.

In 1968 Fannie Mae was privatized, thus becoming the first government sponsored enterprise (GSE). Given the sensitivity of Fannie's veteran affairs loans and other government lending programs, the company was split into two, with the government related loan portfolio becoming a part of the Government National Mortgage Association (Ginnie Mae), and the other assets remaining with the new Fannie Mae. Two years later, in 1970, Fannie was again split when the savings and loan mortgages were hived off into a new company, the Federal Home Loan Mortgage Corporation (Freddie Mac).

1970 is also important for a different reason. It was when Ginnie Mae issued the first mortgage backed security (MBS). The issuance of a residential mortgage backed security (RMBS) changed the way the American mortgage markets functioned. Ginnie Mae insured that investors who purchased these mortgage backed securities would receive the mortgage payments as a "pass through" amount every month. This was a first step in a series of innovations that were designed to increase home ownership

in the country. Some of these included buy-downs, graduated payment mortgages, negative amortization loans, and collateralized mortgage obligations. With a negative amortization loan, the borrower paid a part of the interest payment, and the remaining interest was added to the principal. Thus the principal of the loan increased: the borrower was not paying down but paying up the loan! The introduction of pass-through securities improved liquidity in the mortgage markets, and the housing price index kept rising. The securities were also sold off to foreign investors who were more than happy to buy into the US housing market.

1970s was also a period of rapid inflation across the world. With the collapse of the Bretton Woods system and the two oil shocks, inflation was rollicking in the US and elsewhere. To counter this inflation, the Volcker Fed increased the federal funds rate to 20% in 1981. That interest rate hike did manage to bring inflation under control, but in the process it made life difficult for savings and loans (S & L) whose cost of funds went up without increasing their returns on investment. S & L had historically held deposits, and used these to make mortgages. As a group they were the largest mortgage originator in the country at the time. The increase in the federal funds rate introduced a wedge between the return on their investments and the cost of funds, pushing many of them over the line. The resulting S & L crisis cost the American taxpayers more than $500 billion! It also illustrated the problem in funding fixed rate mortgages using deposits as the source of funds.

Given the trouble the savings and loans associations were in, the government allowed them to expand their business to other activities. At the same time the government also allowed other financial institutions to enter the mortgage market. This increased the type of institutions that were into mortgage origination and lending, and also increased the type and complexity of instruments used to fund the mortgages. Securitization increased, as did the number of layers between the eventual

borrowers and lenders. The incentive system also went through rapid changes, and more information asymmetry was introduced into the system. Mortgage originators lost the incentive to do due diligence of the borrowers since they rarely held those mortgages on their book, and investors who bought the securities hardly knew which mortgages were a part of the pool they were buying into. The investors did know the general characteristics of the mortgages in the pool, but they had no way of knowing which individual mortgages were a part of the pool, and what was the credit worthiness of a specific borrower. What market participants hoped was that the gains from securitization would be more than sufficient to offset potential losses from increased asymmetry.

Post 9/11 a renewed push to increase home ownership accompanied by historically low interest rates meant that mortgage originators were essentially searching for borrowers from the bottom of the credit pool to generate new mortgages. The percentage of people whose score is below what is classified as prime (a FICO (Fair Isaac Corporation) score of 640 or higher) has historically been more than 30% of the total population. Home ownership had tapered off in the high 60% range in the 1960s, and any push towards more home ownership meant you had to go into the sub-prime part of the market. Many of these borrowers were not in a position to meet the traditional requirements for a mortgage, and had to be brought in using some other lending standards. This included a loan-to-value ratio of 100%, no income verification, adjustable rate mortgages with options, and other innovations. The fact that many of these loans did not stay on the books of the originators meant there was a rush to issue the mortgage as soon as possible, and then sell it off to investors across the world. The share of GSEs in the mortgage market kept falling through this period. At the peak of the sub-prime bubble the share of GSEs in the mortgage market fell to less than a third. After the bubble burst in 2007 many of these mortgage

originators rapidly went out of business. This included Countrywide, the then largest private mortgage lender in the country, which was bought over by Bank of America in a $4 billion all-stock deal. With many private lenders and originators shutting their doors the share of GSEs in the mortgage market again went up, and by 2008 they accounted for more than 75% of all American mortgages. The problem with this growth in the share of GSEs was that it was not backed by a proportionate increase in capital of these companies, and they had to be brought under direct government control in September 2008.

Government conservatorship of Fannie and Freddie came with a string of measures to counter future problems. Many bills were introduced in the US Congress post the crisis to deal with the issues raised during the crisis. Of particular focus was increasing the accountability of Fannie and Freddie, reducing the cost to the government, and changing the charter of the GSEs if, and when, they leave government conservatorship (Weiss (2013)). The Covered Bond Act of 2011 was introduced to encourage the issue of covered bonds in the US.

Two other important legislations have also tried to change the functioning of the US mortgage markets. The Bowles-Simpson act has proposed reducing tax deduction for mortgage interest paid on principal and on second mortgages. The idea is to reduce the demand for mortgages and home ownership, as well as reduce the price and overall size of housing units. The Dodd-Frank Act in its section on the Consumer Finance Protection Board (CFPB) directs implementation of financial regulation to implement "qualified mortgages" which would affect risk retention, underwriting, pooling, and selling mortgages as a part of an MBS. This is to protect both the customers, who may be gulled into signing something they cannot afford; and financial institutions who may underestimate risk. The CFPB is also developing procedures to review mortgages servicing process and establish standard rules for record keeping and the process

to change interest rates. Further, the Federal Housing Finance Agency (FHFA), the Fed and the Federal Deposit Insurance Corporation (FDIC) have proposed regulations affecting capital that insured depositories must hold against mortgages. These measures are all aimed at reducing the likelihood of the sub-prime mortgage crisis repeating itself in the future.

To summarize, we can say that while American regulators have been successful in increasing the rates of home ownership in the US to one of the highest levels in the world, the journey has not been without incidents. The transparency, and the liquidity, on offer in the US mortgage market is admirable. But, in the push towards higher ownership the government may have put undue strain on the economy. Home ownership rates were above 60% in the late 1950s, and is currently about 65%. Over the last fifty years it has fluctuated around the 64-65% mark, with the only major deviation occurring when the sub-prime market boomed in the late 1990s. We all know what happened once that market crashed. Maybe this is an indication that pushing for higher home ownership rates may not be justified. If the concern is to house the poor, and the vulnerable, the policy makers may take a leaf out of what some other governments have done across the world: provide low cost housing in high density areas. For example, home ownership rates in Singapore in the resident population is over 90%, but more than 80% of the resident population lives in government subsidized high rise complexes with the average size of about 1000 square feet. Co-ops in the US do something similar, and maybe they are a better way to support the needy. Further, it is evident that deposits cannot be used to fund fixed rate mortgages, so a major secondary market for mortgages is required. The question then is what instrument to use to fund these mortgages in the secondary market. Mortgage backed securities are the preferred choice in the US, but as we have just seen they may lead to massive moral hazard problems. An alternative is to use covered bonds

which provide long term fixed rate funding like mortgage backed securities, but do so with a smaller problem of moral hazard. This is discussed later in the chapter.

Mortgages in Japan

The Second World War left Japan devastated. By some estimates Japan lost more than 40% of its fixed capital stock in American bombing (Ferguson (2009)). Post War Japan spent substantial resources to rebuild its capital stock. Towards this effect the government established the Government Housing Loan Corporation (GHLC) in 1950 with the stated goal of providing stable housing finance and improving the stock of the Japanese housing. This was done through low-fixed-rate mortgages and preferential treatment for mortgages on housing stock that was energy efficient, or was handicap/elderly friendly. It financed about a third of housing stock constructed between its establishment in 1950, and its reorganization to the Japanese Housing Finance Agency (JHF) in 2007. GHLC's role in terms of providing stable long term funding for mortgages was similar to that of the FHA and Fannie, but the structure was different. Unlike FHA and Fannie, the GHLC was involved in loan origination, and at one point of time was the largest mortgage lender in the world. The GHLC received funds from the Japanese treasury, which in turn were funded through postal savings schemes, and the Government of Japan, and used them to offer fixed rate mortgages. The GHLC imposed no pre-payment penalties, though they did pay these penalties to the treasury in case of pre-payment. These penalties were in turn subsidized by the Japanese government. Private lenders were unable to compete with this arrangement, given that they funded their mortgages through short term deposits, which by their very nature make provisioning for fixed rate mortgages difficult. This also meant that Japanese mortgage market was clearly demarcated between GHLC with its fixed rate mortgages, and private lenders with their adjustable rate mortgages

(Kobayashi (2009)). The structure has remained similar post the reorganization of the GHLC, with the only difference being that private lenders now also originate fixed rate mortgages.

In 2007 the GHLC ceased to exist and its existing assets were transferred to the Japan Housing Finance Agency (JHF). The transformation was much more than a mere change in nomenclature. The JHF is much closer to Fannie and Freddie in both purpose and structure. JHF does not originate home loans. Private lenders now issue both fixed and adjustable rate mortgages, but sell the fixed rate mortgages to the JHF while retaining the adjustable rate mortgages on their books. The JHF only buys fixed rate mortgages from banks, with the underlying idea being that the government supported agencies should only provide products that are not available through the private sector. The private sector was happy providing adjustable rate mortgages, and that continues to be the case today. The JHF on purchasing fixed rate mortgages from private lenders securitizes them, and then sells them to investors in the form of mortgage backed securities. It also provides mortgage insurance and provides loans for urban development projects. As a part of its social obligations, it also funds the construction of rental housing for the elderly, and housing for those with small children. Thus, JHF has moved from providing loan origination services of commercial banks or mortgage banks, to that of providing liquidity to the mortgage market through secondary market operations. This is very similar to the roles performed by GSEs in the US. One difference between the institutions is that the the residential mortgage backed securities issued by JHF have features that make them similar to covered bonds. Assets included in the mortgage backed securities are parked separately in a special purpose vehicle (like in all mortgage backed securities), but they stay on the books of JHF. In case there is a problem (a trigger event), these assets will not be available to JHF. Further, in case there are problems with the pool

of assets itself the investors can go after other assets of JHF to recover their losses. Thus, JHF has an incentive to monitor these loans very carefully. This reduces the disconnect which exists between parties in the US mortgage market, where mortgage backed securities are the main source of funds.

The similarity with the US mortgage market ends with the role and functioning of the JHF. On virtually every other parameter Japanese mortgage market is very different from that in the US, in both organization and functioning. The differences are summarized in Table 4.5. Some of the most prominent differences in the two markets arise from the difference in the structure of the economy and the banking sector. Unlike US mortgages, most Japanese mortgages tend to be adjustable rate mortgages (ARM). This happens for two main reasons. Firstly, most Japanese mortgages are funded by deposits which can be fickle, and banks try to minimize their exposure to interest rate risks by offering adjustable rate mortgages. Secondly, Japanese consumers today expect the low interest rate regime to continue, and thus are more likely to seek adjustable rate mortgages which tend to have lower interest rates than fixed rate mortgages (ARMs today have interest rates closer to 1%, while the fixed rate mortgages are more than twice as expensive). While interest rates in Japan were on the higher side in the 1970s and 1980s, they have tended to stay very low since the early 1990s thus feeding back into the demand for adjustable rate mortgages.

According to the Japan Housing Finance Agency, about 80% of all Japanese mortgages are still funded through deposits, while in the US that number is less than 40%. At the same time agency mortgage backed securities (residential mortgage backed securities issued by Freddie and Fannie in the US, and JHF in Japan) constitute less than 10% of Japanese mortgage funding, but close to 50% in the US. Residential mortgage backed security (RMBS) market in Japan is still very small compared to that in the US (the US market is more than 100 times larger). Annual issuance of

Parameter	United States	Japan
Mortgage Type	Fixed Rate (Mainly)	Adjustable Rate (Mainly)
Mortgage Term	30 years	35 years or longer
Funding Source	Deposits and MBS	Mainly Deposits
Mortgage Decision	Mainly Objective	Largely Dependent on Loan Officer
Pricing & Valuation	Transparent	Largely Opaque
Credit Information	Easily Available	Underdeveloped

Table 4.5 – *Comparison of US and Japanese Mortgage Markets*

residential mortgage backed securities in Japan is about ¥2 trillion, and almost all of that is through JHF. Till about 2007, almost half of RMBS issued in Japan were by the private sector, but private players have virtually disappeared from the market since then. Further, Japanese RMBS tend to be similar to covered bonds like the Pfandbriefe in Germany and other European countries (for a survey of the covered bond market in Europe and elsewhere see Mastroeni (2005) and Avesani, Pascual, and Ribakova (2007)) and the JHF continues to hold the mortgages it purchases on its balance sheet. Similar to the sovereign guarantees that Fannie and Freddie enjoy, the securities issued by JHF are guaranteed by the Government of Japan. Like other Zaito agencies (a Zaito agency is a government agency that carries out public policies by receiving loans, investments, and/or loan guarantees from the Fiscal Investment and Loan Program of the Ministry of Finance, Government of Japan) it performs a specified role in the economy, that of providing liquidity to the mortgage market, and gets government guarantees in return for the services it provides.

A further difference between the two markets arises from the the way mortgages originate, and the way they are repaid. While the US housing market is very transparent, the same is not the case in Japan. Owing to the long periods of deflation, limited availability of sales data, and the underdeveloped nature of credit reporting

measures, Japanese mortgage originators are skeptical to issue mortgages with assets as collateral. They look more at the income of the borrower, and the history of the borrower before deciding on the loan application. The decision taken is largely dependent on the loan officer, so introductions and connections become very important. The loan repayment methodology is also very different. Unlike most other markets where monthly installments of the loan are fixed, Japan tends to have a setup where the borrower pays 10 or 11 relatively small payments every year, and one or two large payments in June and/or December when most Japanese employees get their annual or semi-annual bonuses. Further, unlike the US, and various other countries, mortgages are recourse loans in Japan. If on foreclosure, or default, the value of the property mortgaged is not enough to recover the loan, the lender can go after the borrower's other assets for the remaining amount. Even after these issues the rates of default on Japanese mortgages remain very low.

The Japanese policymakers have been trying to move the country towards more fixed rate mortgages, like in the US and most other developed markets. They believe that the low interest rate regime cannot continue forever. But, long-term low-fixed-rate financing requires a liquid secondary market of funds where investors are willing to provide funding. It cannot happen within the current structure of the Japanese mortgage markets. That was one of the reasons to reorganize GHLC as JHF, and focus more on providing liquidity in the secondary market. The bigger problem though is to move the consumers away from adjustable rate mortgages, which will be very difficult in a low interest regime. What Japanese policy makers do to overcome this problem would be interesting to watch.

Mortgage Funding

Mortgage markets have grown leaps and bounds over the last 50 years. Home ownership has gained traction across the world, but the source of funding and availability of mortgage products varies widely across countries. While many developing countries have relatively underdeveloped mortgage markets, the richer countries tend to have a wider spectrum of products available for customers to choose from. As is evident from earlier discussion, the source of mortgage funding can vary widely, and can influence the type of mortgages available in any market. The three most common sources of funding are deposits, mortgage backed securities (MBS) and covered bonds (CB). While deposits have some presence almost across the board, mortgage backed securities are more common in the English speaking world (the US, and the UK in particular), and covered bonds are more common in continental Europe. Markets where deposits are the main source of funding tend to have predominantly adjustable rate mortgages, while markets with MBS or covered bonds as the main source of funding tend to have predominantly fixed rate mortgages.

Deposits tend to be short-term, and any mortgage funded by short term deposits is exposed to interest rate risk. When interest rates rise banks cannot fund low-rate long-term loans since the short term cost of borrowing rises. Thus, they have no other option but to offer adjustable rate mortgages whose rate varies with changes in the cost of funding. Not adjusting to this change can lead to massive problems, as many savings and loan associations found out during the 1980s S & L crisis. In most Asian markets, including Japan, deposits tend to be the biggest source of funding for mortgages, and therefore, these markets tend to see mainly adjustable rate mortgages. Some banks in these markets do provide fixed rate mortgages, but they tend to be much more expensive than adjustable rate mortgages to counter the interest risk that

banks are exposed to.

Covered bonds and mortgage backed securities allow long-term funding at lower rates, but these sources are not available in every market. Then tend to be more common in richer countries with deeper debt markets. The two operate in similar ways in the sense that both are backed by mortgages, but the structure of the instruments differ (Murphy (2009)). A mortgage backed security represents a pool of mortgages which allows the owner a claim on the cash flow from the mortgage pool, but if the pool does not perform there is no recourse for the owner. On the other hand a covered bond is almost always overcollateralized, that is, the value of the bonds issued against a pool of mortgages is lower than the value of the pool itself. With a covered bond the issuer stands ready to cover losses if the pool does not perform, and bond owners retain claims against loan originators. Unlike a mortgage backed security a covered bond stays on the balance sheet of the issuer. Covered bond originators do not sell their mortgages, and hence the servicing relationship with the mortgagee does not change. In case of a MBS the servicing of mortgages will be contracted out to a third party. Given this structure, covered bonds provide incentives to ensure that originators perform due diligence before issuing mortgages, thus reducing asymmetric information, while simultaneously getting the benefit of cheaper long term funding. What is remarkable is that there has never been a covered bond default in the nearly 300 year history of these bonds. The same cannot be said about mortgage backed securities which are not even 50 years old.

Most covered bonds in the market today are based on the German Pfandbriefe. They also tend to be much more common in continental Europe than elsewhere. Given the problems encountered in the aftermath of the sub-prime mortgage crisis there have been suggestions that covered bonds may be a substitute for mortgage backed securities. As stated earlier they are able to provide long term funding but with the

added advantage of security owners having a recourse to recover investments in case of problems. This encourages transparency and due diligence on the part of the loan originator. One other difference between the two securities is that mortgage backed securities tend to be static instruments. Once the mortgages are pooled in an special purpose vehicle they do not change. This allows for mortgage backed securities to be tranched, while covered bonds have a more dynamic pool of mortgages to maintain their value, and as such are not open to tranching. For this reason MBS investors usually have more information about mortgages in the pool than do investors in covered bonds.

Post the sub-prime mortgage crisis covered bonds have garnered more interest. There have been arguments that covered bonds may be a better source of funding for mortgages than mortgage backed securities. But Carbó-Valverde, Rosen, and Rodríguez-Fernández (2011) have argued that it may not be the case. They argue that covered bonds and mortgage-backed securities serve different purposes, with covered bonds being used to increase liquidity in the market, while mortgage backed securities tend to exploit some agency problems in the market, and that firms use it more as a tool of risk management than liquidity provisioning. Their conclusion may be a result of the sample they chose: banks in 6 countries that had a certain minimum size, and issued either an MBS, or a CB, or both. They ignored the role played by government sponsored enterprises, which happen to be some of the largest issuers of MBS, and they looked at a relatively short period of time (2003-2007), which in many ways was one of the best periods for most banks and financial institutions. They however do indicate that banks which issued MBS during the period seeked out more government bailouts than comparable institutions which issued covered bonds. That is reason enough to seriously consider covered bonds as a tool to raise funds for mortgages.

Summary

Over the last few pages we have seen that real estate markets are an important part of economies across the world. People may have an emotional connect with a house, but the bigger issue is that for most households it is the single largest purchase made in their lifetime. Coupled with the fact that in most rich economies this purchase is funded by loans brings banks and other financial institutions into the picture. Their interaction plays a major role in financial stability of the economy, and hence keeping a good eye on them will help in maintaining the overall well being of the economy.

Large fluctuations in real estate markets have almost always led to comparable changes in financial markets, and real estate cycles tend to coincide with financial cycles. An above average increase in real estate prices does not always lead to a crisis, but when that increase in price is accompanied by an increase in private sector credit that may be a lead indicator of a banking and/or financial crisis. It may be instructive to construct an index that combines these variables to come up with an indicative tool like the inflation rate, but that is work left for the future.

The nature of funding varies across markets, and the nature of funding plays a role in determining the extent of, and the impact of, information asymmetry in the market. Economies where deposits are the main source of funds for mortgages tend to rely heavily on adjustable rate mortgages, while economies where covered bonds or mortgage backed securities are more commonly used tend to rely more on fixed rate mortgages. Fixed rate mortgages tend to be better for the end consumer with the certainty that it provides, but that would require markets with adjustable rate mortgages to look at alternate sources of funding. The nature of funding in itself does not say anything about the likelihood of a real estate bubble, or a banking or financial crisis. The US, which uses mortgage backed securities as the primary

source of funding, and where mortgages are non-recourse loans, just went through a massive economic crisis; as did Japan which uses deposits as the main source of mortgage finance, and where mortgages happen to be recourse loans. Even markets where covered bonds are used much more frequently are not immune from real estate bubbles, but what has been different is that they have not faced a comparable banking crisis when a real estate bubble burst. That would suggest further exploration of the use of covered bonds to generate funds for mortgages.

One aspect of mortgage finance that was not touched in this chapter is the use of real estate investment trusts. They were first introduced in the US in 1960, but were not very common outside the country till about 10-15 years ago. Over the last decade many countries, including Germany, Japan and the UK, have introduced enabling legislation that allows the setting of these companies with the primary aim of purchasing or constructing commercial real estate, and other income generating property. They can increase liquidity in the commercial real estate market, and make transactions more transparent. Whether they will have an impact similar to the introduction of mortgage backed securities is an open question.

CHAPTER 5

CONCLUSIONS AND FUTURE WORK

This dissertation examined the role of asset prices as a transmission mechanism. Using a heterogeneous agent economy it showed that asset prices are a credible transmission and amplification mechanism. Numerical simulations suggest that the effectiveness of asset prices to act as a transmission mechanism rises with rising productivity. That would suggest richer countries are likely to suffer from consequences of asset price crashes more severely than poorer countries. This may be a result of the rising importance of banking as countries get richer. Asset price fluctuations influence the health of the banking sector, and in turn influence overall economic activity.

On the empirical side the dissertation examined the role of housing prices in the economy. It illustrated that when there is a large increase in housing prices, that is also accompanied by an increase in private sector credit, the peak of the housing crisis is usually accompanied by the start of a banking crisis. Inflation rates do not show any measurable changes around housing peaks, and hence cannot act as an early warning system in case of crisis that are led by exuberance in the real estate sector. While there was a long time consensus that central bankers should not intervene in asset price bubbles, that consensus seems to be breaking down. As of this writing there

is a very active debate on whether central banks should lean against an asset price bubble (see, for example, Agur and Demertzis (2013), Hellwig (2014), Smets (2014), and Svensson (2014)). Some prominent central bankers have argued about at least considering the impact that massive asset price increases can have on the economy. The biggest driver for this change has been the rising cost of cleanup after an asset price bubble has burst. As Blanchard et al. (2014) suggests: we may be better off pricking some asset price expansions even when they are supported by fundamentals, than cleaning up after a bubble has burst. There has been an increase in the use of macroprudential tools. The Bank of International Settlements has been advocating a counter-cyclical banking regulation framework with special emphasis on counter-cyclical buffers and higher capital requirements for systemically important financial institutions. Stress tests of banks have become regular features across major markets.

An important aspect not addressed in the theoretical part of the dissertation is the role of financial intermediaries. Most transactions between borrowers and lenders involve a financial intermediary, so a richer model of their interaction must bring intermediaries into picture. The model presented here does not have one, and the transactions are direct. Introducing an intermediary would lead to a richer system dynamics, and more importantly would allow the study of the impact of different types of shocks. Of particular interest would be to study the impact of changes in the availability of credit, changes in the value of assets and collateral, and the arguments they provide in the bank regulation debate.

A place to start such a study would be Holmstrom and Tirole (1997). They extend the standard Diamond model of banking to examine both the asset and liability side of banking by making the intermediary credit constrained. They show that in case of a credit crunch the intermediary would increase the interest rate spread and squeeze out firms with lower net worth. The same thing would happen with falling savings

rate or falling net worth of firms. In the model, monitoring can partly substitute for collateral. The paper shows that smaller firms, and highly leveraged firms, who are more dependent on bank financing, also submit to stricter monitoring, and are the first ones to be excluded from credit markets in case of any crisis. In some ways the work endogenizes the agency cost story in Bernanke and Gertler (1989) by arguing that as agency costs change over a business cycle, firms with the highest agency costs tend to be the first to be excluded from credit markets.

In a subsequent study, Chen (2001) extends HT to a dynamic infinite horizon model and comes up with some contradictory results. While Holmstrom and Tirole (1997) show that the capital asset ratio for intermediaries is pro-cyclical, Chen (2001) shows that with asset prices included it turns out to be counter-cyclical. Both these studies incorporate two levels of shirking by the intermediary, but do not consider the possibility that monitoring of firms may increase the probability of success of a project. In practice, one argument for monitoring is that it prevents shirking by the borrower, and hence monitoring should have an impact on the probability of success. Incorporating this idea into their models will be an exciting project for the future.

Another possible extension of the work presented here would be to use it as a model of contagion. It is conceptually easy to accept the two agents in the model as two countries, or two different parties. We can then allow the technology shock to hit just one of the two agents. That will initially alter the behavior of just one agent type, and through their trade interactions, can influence behavior of other agents over time. One way to incorporate this system would be to assign some probability of a shock hitting an economy at any given point of time, and then examining the behavior of agents as they digest this information.

The empirical part of the dissertation offers even more avenues for future research. The first thing that jumps out of the empirical chapter is that the rate of inflation

is unable to foretell the arrival of a banking or economic crisis led by a real estate cycle. With increased exposure of the banking sector to the real estate sector this is a uncomfortable situation to be in. While it is obvious that housing price data is very localized, and infrequent, there is a need to find some proxy that can act as an early warning signal. One potential candidate may be some combination of the number of housing units sold, or built, along with the changes in the amount of loans to the sector. Both these data points are available more readily, and can potentially act as an early warning indicator.

Different regions use different sources to fund mortgages. But, there seems to be no systemic relationship between the source of funding and the possibility of facing a major real estate led crisis. Japan, which uses deposits as the main source of mortgage funding saw a massive real estate bubble, as did the United States, where mortgage backed securities are much more important. Continental Europe which relies more on covered bonds was also hit by multiple real estate crashes. In fact, Switzerland was the only country in the sample analyzed in the dissertation which faced a triple dip contraction in housing prices. What has not been examined is whether all crises were equally severe, and whether a particular funding method offers less volatile cycles. Theoretical considerations will suggest that covered bonds should offer the best of both worlds: lower moral hazard problems, and long term fixed rate mortgages. But the fact that countries with covered bonds as the main source of mortgage funds have had more frequent real estate cycles dampens the excitement in them. A more intensive analysis of the relationship between funding source, home ownership, and the frequency and depth of real estate contractions will provide us with more answers in this regard.

There is a need to examine the role of government policies in general, and tax policies in particular. Most countries provide tax deduction on mortgage interest,

but over the last two years there has been a move in multiple countries to reduce or eliminate this tax deduction, and at the same time reduce the leverage in the banking sector by limiting the loan-to-value ratio as well as the debt-to-income ratio. There have been arguments that Japanese land laws were the prime driver of the real estate bubble in Japan (see, for example, Noguchi (1994), and Seko (1994)), and land values rose higher in Japan than virtually anywhere else in the world. Laws that distort markets are not unique to Japan, and a future study may look at common features of laws that distort real estate markets and can potentially lead to financial instability. The Bowles-Simpson Act has recommended reducing tax incentives for housing, and similar measures have been adopted elsewhere. Only time will tell whether these work, or we land up again in a scenario so aptly captured by Carmen Reinhart and Kenneth Rogoff (Reinhart and Rogoff (2009)) in the title of their seminal work: *This Time is Different*!

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APPENDICES

APPENDIX A

DETAILS OF SIMULATION

This appendix includes the complete set of simulation graphs. The first set of graphs (Figures A.1, A.2, A.3) shows the impact of a change in productivity. The second set, Figures A.4, A.5, A.6 and A.7 shows the impact of a change in the proportion of borrowers. The final set, Figures A.8, A.9 and A.10 shows the impact of a change in the proportion of saleable output.

Impact of Changes in Productivity

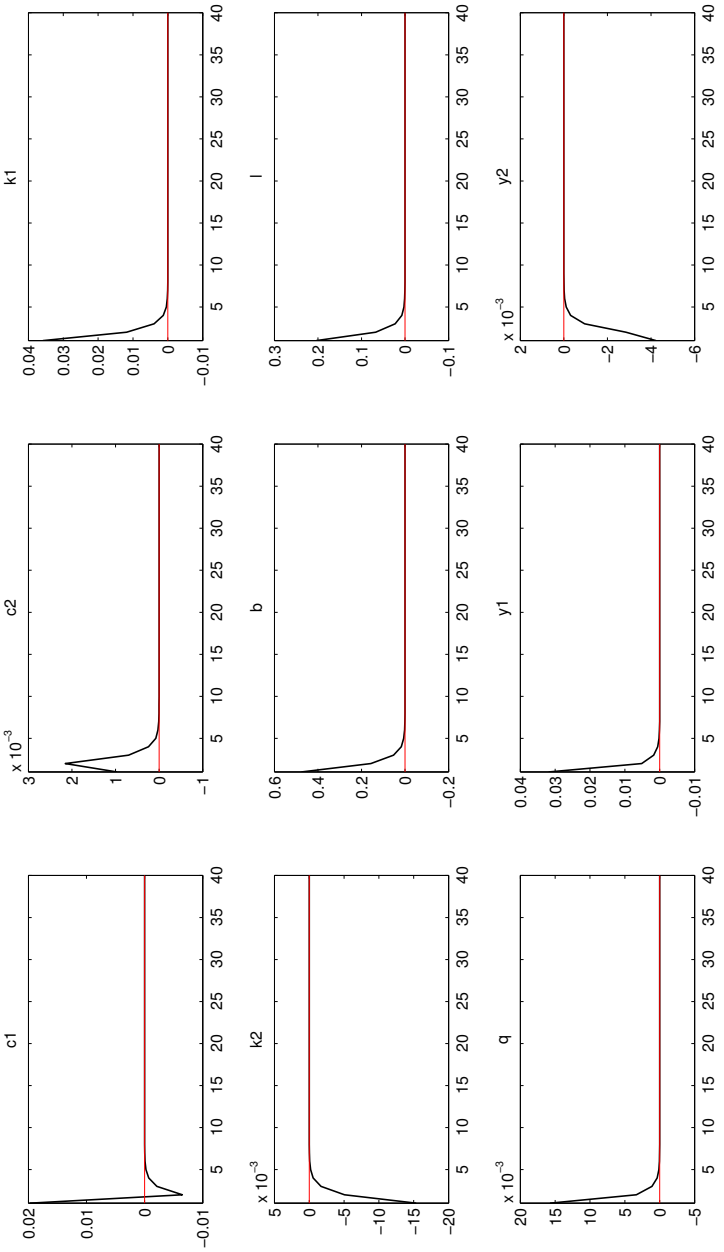

Figure A.1 – *Impulse Response Function with* $\alpha = 0.6, \theta = 0.3, x = 0.75$

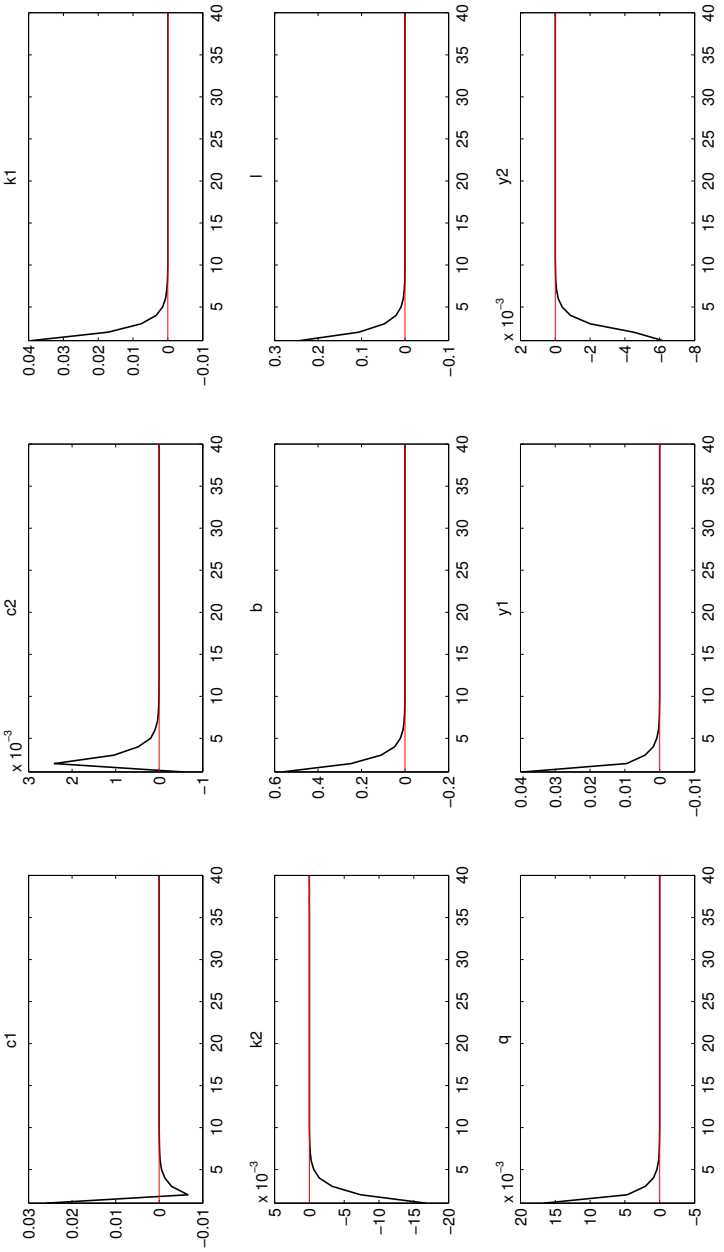

Figure A.2 – *Impulse Response Function with* $\alpha = 0.7, \theta = 0.3, x = 0.75$

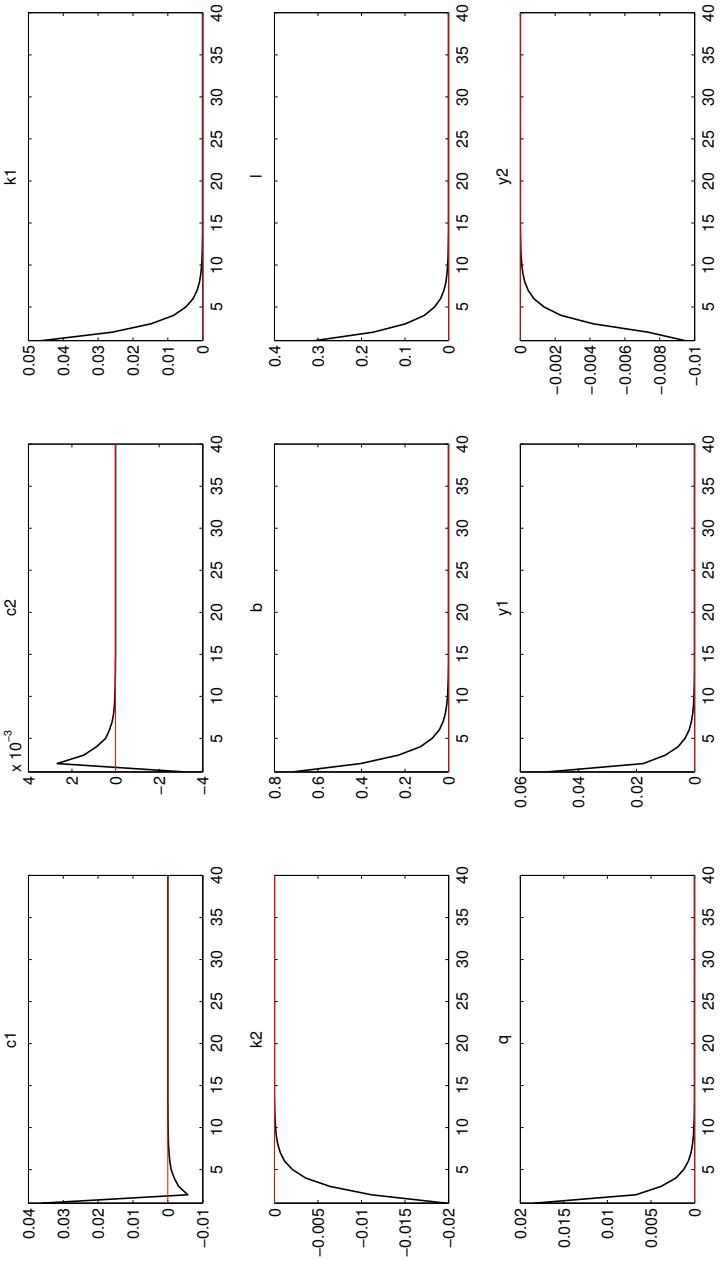

Figure A.3 – *Impulse Response Function with* $\alpha = 0.8, \theta = 0.3, x = 0.75$

Impact of Changes in Proportion of Borrowers

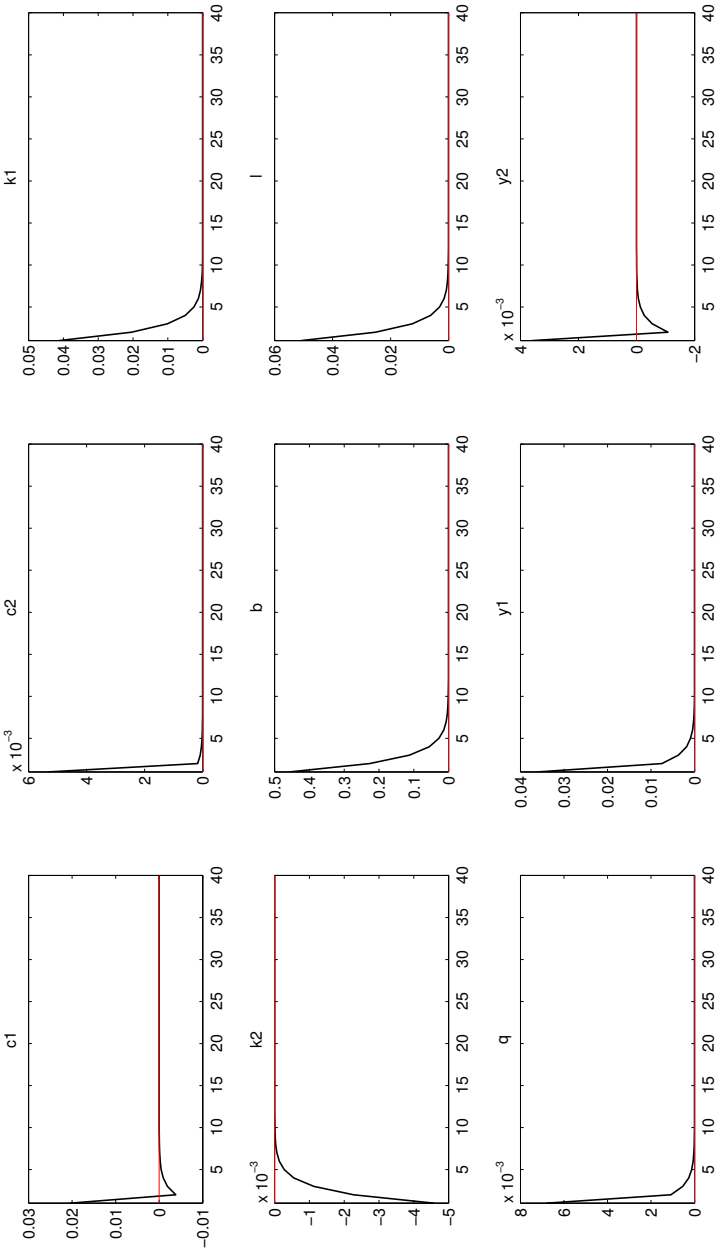

Figure A.4 – *Impulse Response Function with* $\alpha = 0.6, \theta = 0.1, x = 0.75$

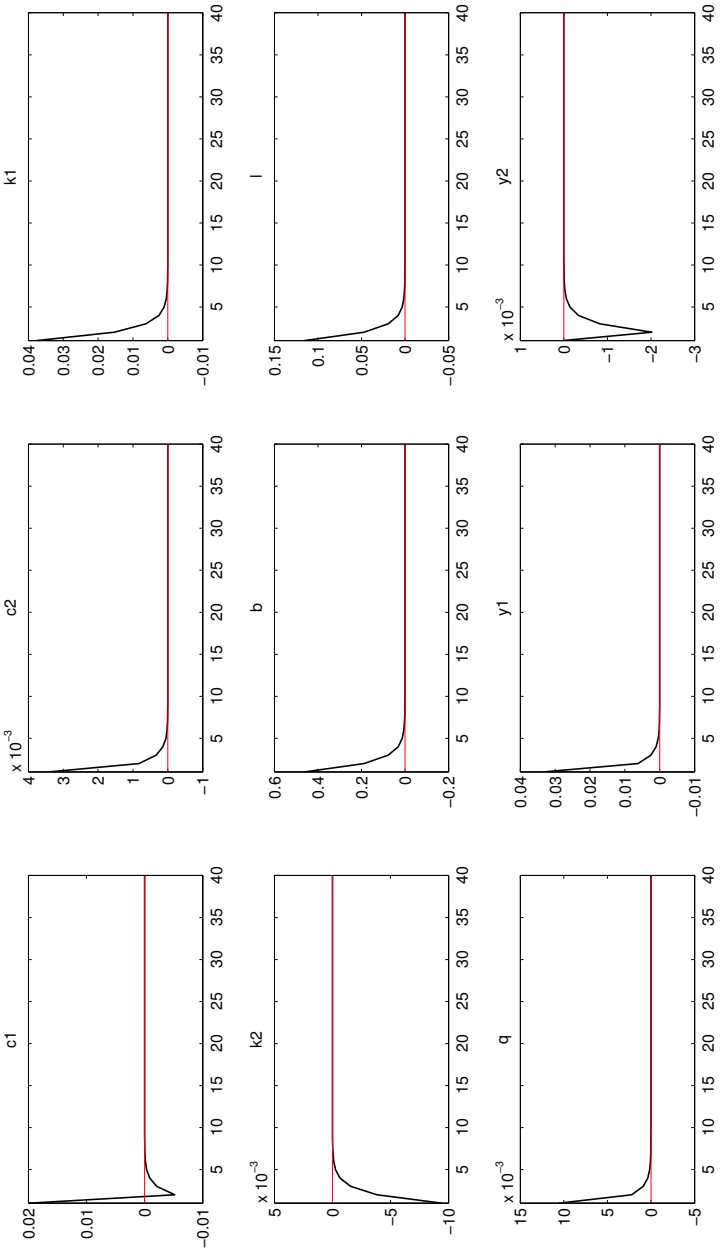

Figure A.5 – *Impulse Response Function with* $\alpha = 0.6, \theta = 0.2, x = 0.75$

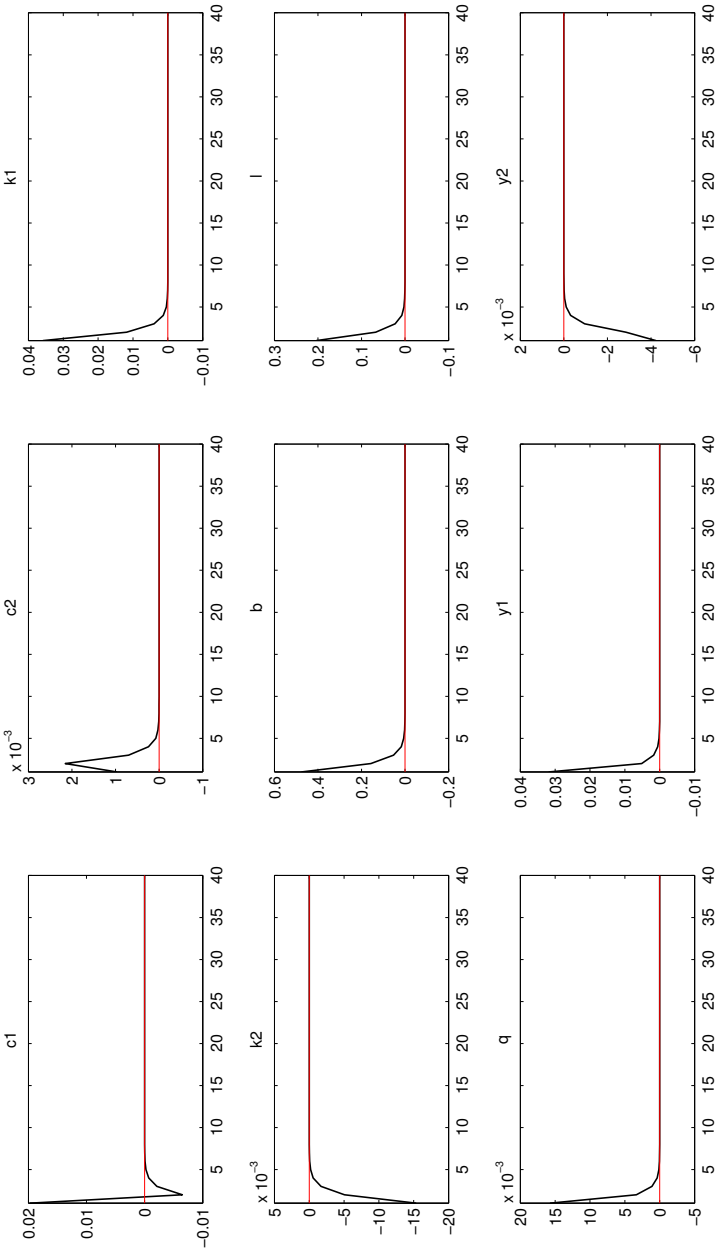

Figure A.6 – *Impulse Response Function with* $\alpha = 0.6, \theta = 0.3, x = 0.75$

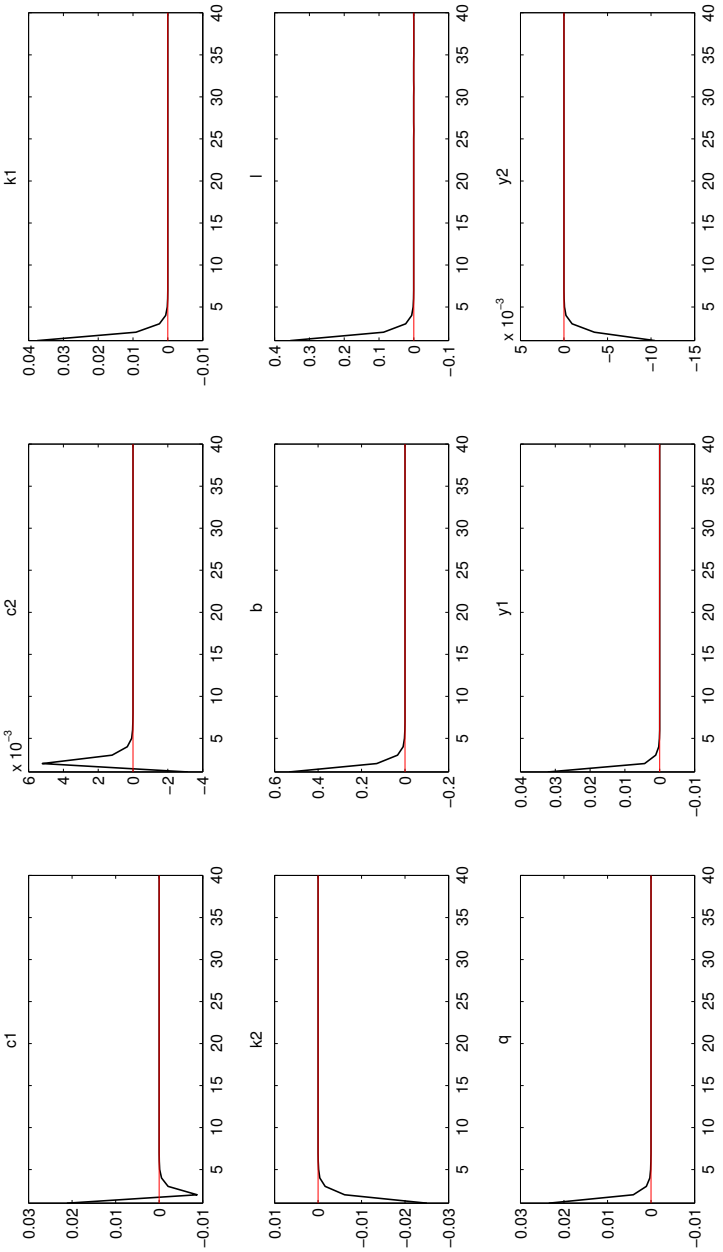

Figure A.7 – *Impulse Response Function with* $\alpha = 0.6, \theta = 0.4, x = 0.75$

Impact of Changes in Proportion of Saleable Output

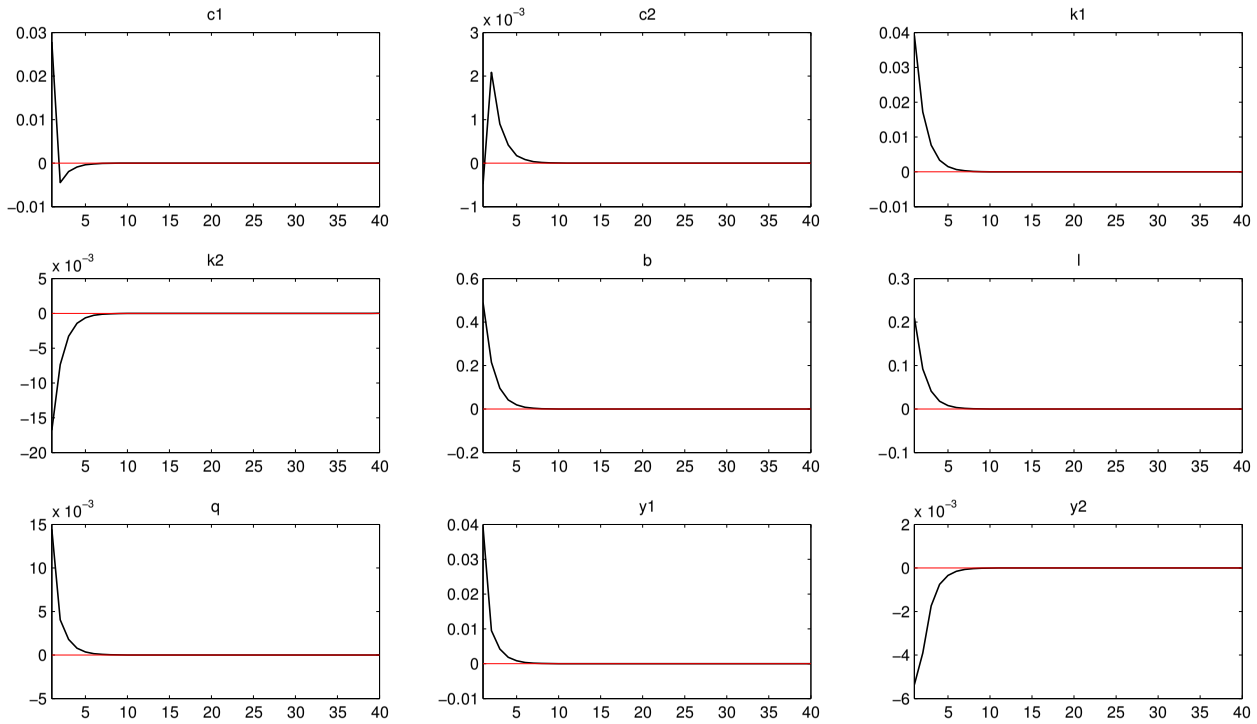

Figure A.8 – *Impulse Response Function with* $\alpha = 0.7, \theta = 0.3, x = 0.65$

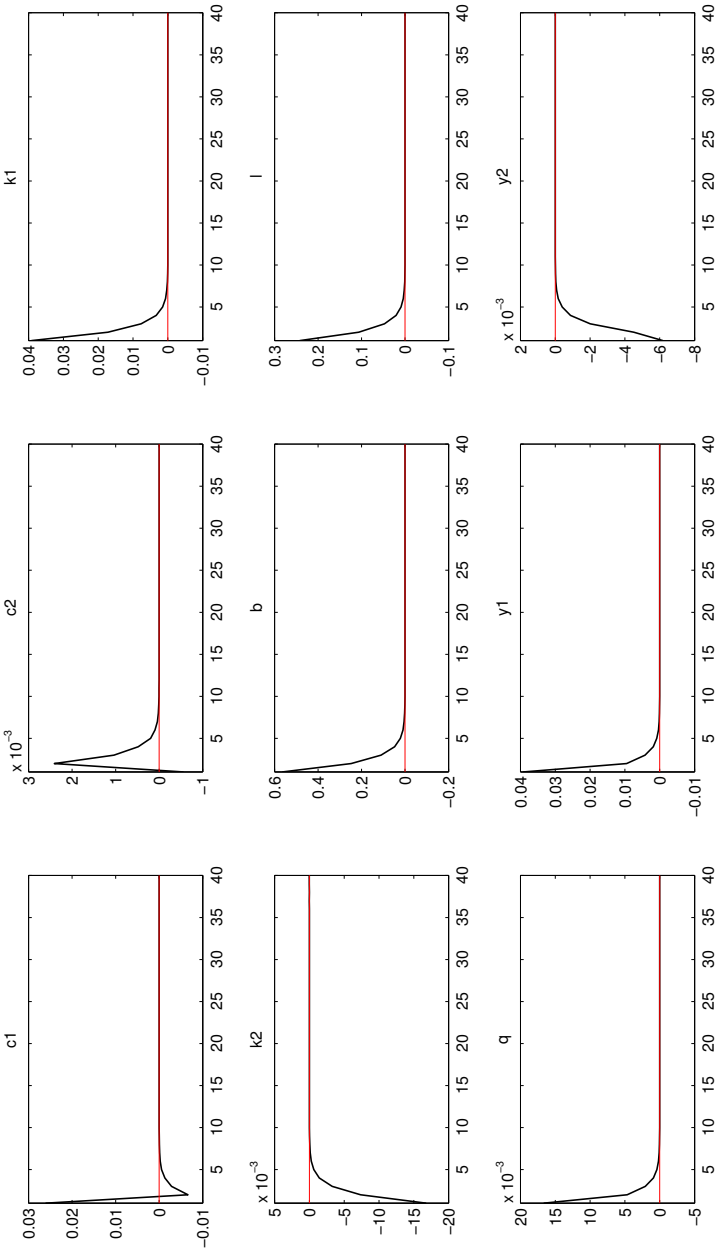

Figure A.9 – *Impulse Response Function with* $\alpha = 0.7, \theta = 0.3, x = 0.75$

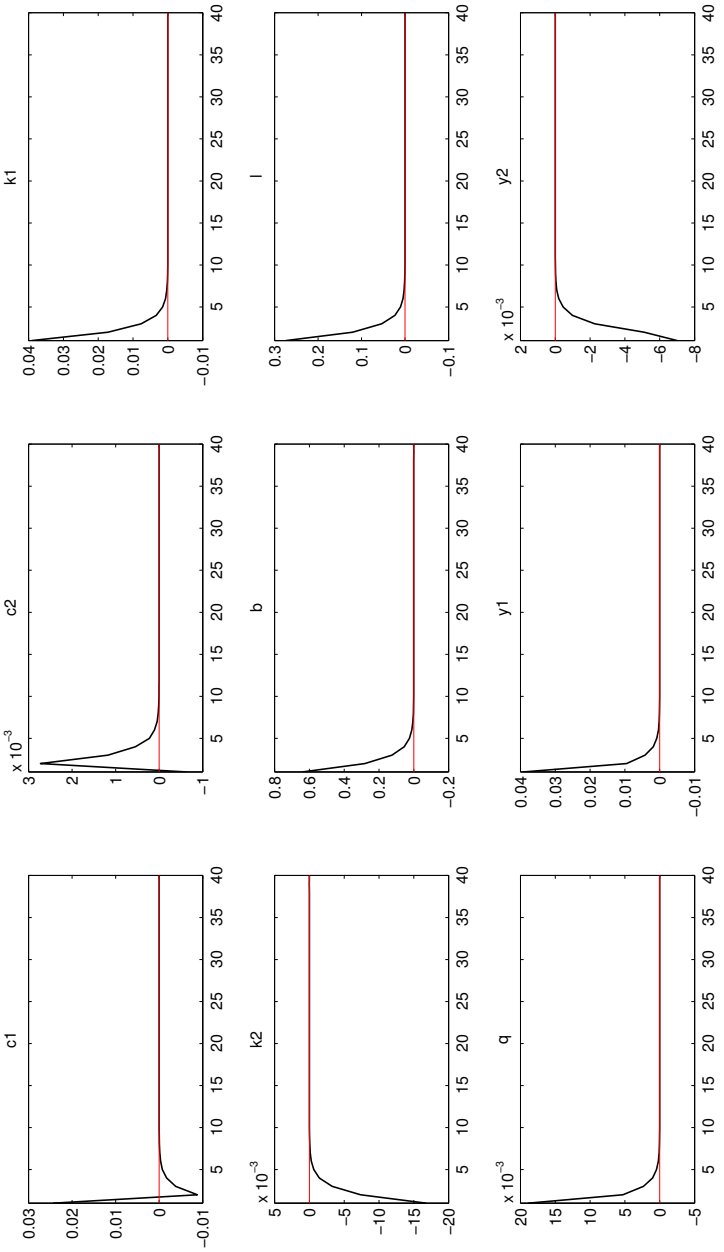

Figure A.10 – *Impulse Response Function with* $\alpha = 0.7, \theta = 0.3, x = 0.85$

APPENDIX B

DETAILS OF REAL ESTATE CYCLES

The real estate index was obtained from data compiled by the Bank of International Settlement (BIS) from national and private sources. The data can be obtained from `http://www.bis.org/statistics/pp.htm` (Last Accessed: August 28, 2014). To this index was applied the modified Bry-Boschon algorithm (Harding and Pagan (2002)) and changes in the time series were detected. A total of 93 cycle changes were observed (including incomplete cycles, most notably Japan's that began in the last quarter of 1990 but is yet to end). The average length of the cycles was observed to be slightly more than 6 quarters. Few countries had double dip contractions (meaning an expansion turned into a contraction in just 2 quarters), while Switzerland was the only country that had a triple-dip contraction that began in the second quarter of 1990. As a result the Swiss real estate index did not attain its 1990 peak till 2008.

Country	Peak	Trough
Australia	1982:2	1982:4
	1995:1	1996:1
	2003:4	2004:3
	2008:1	2009:1
	2010:2	2012:1
Belgium	1980:1	1983:1
	1990:4	1991:2
	1994:3	1995:1
	2008:3	2009:2
Canada	1981:4	1982:3
	1983:1	1984:3
	1987:1	1987:3
	1989:1	1990:2
	1994:1	1996:1
	1997:2	1998:3
	2008:2	2008:4
	2011:2	2012:3
Denmark	1979:3	1980:2
	1980:4	1982:3
	1986:2	1987:4
	1988:4	1990:4
	1991:4	1993:2
	2007:3	2009:1
	2010:3	2012:1
Finland	1985:1	1985:3
	1989:2	1993:1
	1994:2	1995:4
	2000:2	2000:4
	2008:2	2009:1
France	1985:3	1986:1
	1991:3	1995:1
	1996:3	1997:1
	2007:4	2009:2
	2011:3	
Germany	1974:3	1975:1
	1983:2	1984:4
	1986:2	1988:1
	1989:3	1990:1
	1995:2	1998:1
	2002:3	2003:3
	2005:1	2006:1
	2006:3	2007:2
	2008:4	2010:1
Ireland	1971:4	1972:2
	1984:3	1985:2
	1986:3	1987:2
Ireland	1990:3	1991:2
	2007:3	2013:1
Italy	1984:2	1984:4
	1993:3	1995:1
	1997:4	1999:1
	2008:3	2010:1
	2011:3	
Japan	1973:4	1975:2
	1990:4	
Netherlands	1978:2	1982:4
	1990:2	1990:4
	2008:3	2010:1
	2010:3	
New Zealand	1990:3	1992:1
	1997:4	1998:1
	1999:3	2000:4
	2007:4	2009:1
	2010:1	2010:4
Norway	1973:2	1974:1
	1975:2	1976:1
	1979:2	1980:1
	1984:3	1985:1
	1988:1	1989:4
	1990:2	1993:1
	2002:2	2002:4
	2008:2	2008:4
	2010:2	2010:4
Spain	1991:4	1993:1
	2008:1	
Sweden	1980:3	1981:4
	1982:3	1983:1
	1991:3	1995:4
	2008:3	2009:1
	2011:2	2012:1
Switzerland	1973:3	1976:3
	1977:3	1978:1
	1990:2	1991:1
	1991:3	1993:3
	1994:1	1998:4
United Kingdom	1981:3	1982:1
	1989:3	1992:4
	2007:3	2009:2
	2010:3	2011:2
	2012:3	2013:1
United States	1990:1	1991:1
	2006:1	2009:1
	2010:1	2011:4

Table B.1 – *List of Real Estate Cycles*

APPENDIX C

QUARTERLY INFLATION RATES

The following table lists the quarterly inflation rates of all countries in the sample from 1971 to 2014, with the exception of Ireland whose data runs from 1976 to 2014. Overall mean and median show the mean and median quarterly inflation rates for the whole range of dates that we have data for. The Pre-Peak mean and median inflation rates refer to the mean and median inflation rates 8 quarters prior to a long real estate contraction, whose peak date is mentioned in the second column. The table is based on data obtained from OECD, national sources, and author's calculations.

Country	Peak	Mean	Median	Mean	Median
		Overall		Pre-Peak	
Australia	2010Q2	1.37	1.0	0.66	0.75
Belgium	1980Q1	0.94	0.7	1.10	1.15
Canada	1983Q1	1.05	0.9	2.65	2.75
	1994Q1	1.05	0.9	0.44	0.40
Denmark	1980Q4	1.13	0.9	2.81	2.75
	1986Q2	1.13	0.9	0.95	1.15
	1988Q4	1.13	0.9	1.00	1.10
	1991Q4	1.13	0.9	0.59	0.75
	2007Q3	1.13	0.9	0.45	0.30
	2010Q3	1.13	0.9	0.43	0.30
Finland	1989Q2	1.22	0.9	1.28	1.20
	1994Q2	1.22	0.9	0.39	0.35
France	1991Q3	1.10	0.7	0.78	0.75
	2007Q4	1.10	0.7	0.35	0.20
	2011Q3	1.10	0.7	0.45	0.45
Germany	1983Q2	0.69	0.6	1.23	1.30
	1986Q2	0.69	0.6	0.39	0.40
	1995Q2	0.69	0.6	0.64	0.70
Ireland	2007Q3	1.26	0.8	1.10	1.00
Italy	1993Q3	1.65	1.1	1.23	1.20
	2008Q3	1.65	1.1	0.63	0.60
	2011Q3	1.65	1.1	0.51	0.45
Japan	1973Q4	0.66	0.3	2.13	1.80
	1990Q4	0.66	0.3	0.65	0.50
Netherlands	1978Q2	0.83	0.7	1.47	1.00
	2008Q3	0.83	0.7	0.51	0.45
	2010Q3	0.83	0.7	0.33	0.40
New Zealand	1990Q3	1.55	1.0	1.48	1.20
Norway	1988Q1	1.16	1.0	1.96	1.80
	1990Q2	1.16	1.0	1.13	1.05
Spain	2008Q1	1.74	1.3	0.83	0.35
Sweden	1991Q3	1.16	0.9	2.44	1.85
Switzerland	1973Q3	0.61	0.4	1.78	1.75
	1991Q3	0.61	0.4	1.38	1.55
	1994Q1	0.61	0.4	0.75	0.90
United Kingdom	1989Q3	1.40	1.0	1.10	1.00
	2007Q3	1.40	1.0	0.60	0.60
United States	2006Q1	1.03	0.9	0.86	0.75
	2010Q1	1.03	0.9	0.40	0.90

Table C.1 – *Quarterly Inflation Rates*