

CONSUMER DURABLES AND MONEY SUPPLY SHOCKS

By

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(Under the direction of Dr. William D. Lastrapes)

ABSTRACT

This dissertation has two goals. The first goal is to empirically estimate the response the real price of various consumer durable goods to exogenous changes in the nominal money supply. The second is to analytically solve different dynamic equilibrium models of consumer durable goods for an approximate solution for the equilibrium real price of durables and then to test the predictive power of these models concerning the dynamic response of this equilibrium price to exogenous shocks to the nominal money supply. The first goal is achieved using a VAR approach that takes advantage of a general set of restrictions that is consistent with a wide body of existing literature on VAR identification. The second goal is reached by replacing the equations of the dynamic models with linear approximations. Comparing the estimated price responses obtained from the just identified VARs to the theoretical price response to a money supply shock predicted by these models performs the aforementioned tests. This dissertation finds that both the real price of consumer durables and the real quantity of consumer durables increase in the short run in response to an exogenous shock to the money supply. Also, dynamic equilibrium models of consumer durables do a relatively effective job of matching the predictions obtained from the VAR. These results hold true whether aggregate consumer durable goods are analyzed or new automobiles.

INDEX WORDS: Consumer durable goods, VAR, Money supply shocks, Dynamic Optimization, Linear approximation

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CHAPTER 1: INTRODUCTION

Over the last few decades numerous dynamic equilibrium models of the market for consumer durables have emerged. Many of these models were spawned from the ongoing debate over the life-cycle/permanent income hypothesis. However, it is of independent interest for economists to have a coherent framework for quantifying the effects of economic policy on consumer durables markets because, as noted in Bernanke (1984), Mankiw (1985), Alessie, Devereux, and Weber (1997), and Ruiter and Smant (1999), although consumer expenditure on durables is small relative to expenditure on non-durables and services (roughly one seventh of the size) it is extremely more volatile and very pro-cyclical.

These dynamic models of consumer durables, in which forward-looking households maximize consumption subject to intertemporal resource constraints, can be used to derive both theoretical and quantitative answers to numerous questions regarding the response of the consumer durables market to exogenous shocks (a discussion of many applications of these models to answer such questions follows in the literature review). However, it should be obvious that for exercises such as these to provide truly fruitful insights into the effects of policy on consumer durables markets and consumer welfare, the dynamic framework of these models must accurately represent actual economic behavior. In this dissertation, I examine the extent to which these dynamic models fit the “facts” of actual economic behavior in the face of exogenous policy shocks, and are

therefore useful as policy simulation tools. The particular fact that I focus on is the dynamic response of the relative price of consumer durables to exogenous shocks to the nominal supply of money. I establish this fact independently of the theoretical models through the use of just identified vector autoregression (VAR) models. These models are just identified using a restriction that is very plausible, common throughout the literature on time series econometrics, and general enough to be consistent with most theoretical models of the market for consumer durables. I then compare the predicted price response implied by the theoretical models to the estimated responses obtained from the VARs by using the estimated responses of interest rates and inflation to calibrate the simulation.

Therefore, my attempt is to “test” theoretical models of the market for consumer durables along only one line. I focus on the models’ predictive power in the face of nominal money supply shocks. This method is much more tractable than attempting to test the dynamic implications of a fully specified, general equilibrium model of consumer durables and the macro economy. Additionally, it allows one to obtain precise answers regarding the ways in which various models work or do not work since the focus of the test is only one dimensional. This approach to “testing” has precedent in the literature and these works will be discussed in the following review of the literature.

The motivation behind focusing on money supply shocks is three fold. First, examining the effect of nominal money supply shocks on the market for consumer durables complements the existing literature on how money affects real economic activity. Second, there is a wide body of literature outlining the theoretical and empirical effects of money and interest rates on the market for consumer durables. And finally, money supply shocks are in many ways easier to identify than other exogenous sources of

variation. For example, the imposition of no more than long-run monetary neutrality can be used to identify money supply shocks.

Why the focus on the dynamic response of the relative price of consumer durables? The effect of monetary policy on the *price* of consumer durables has widely been neglected in previous studies of these markets in favor of analyzing the response of consumer *expenditure* on durable goods. The reason behind this is that so many of these models of consumer durable goods were spawned from the debate over the implications of the life-cycle/permanent income hypothesis which focuses primarily on how consumer expenditure responds to changes in current income. Also, focusing on the price response addresses the extent to which policy induced changes in interest rates are capitalized in the price of consumer durables, which may be viewed as one of many assets in a consumer's portfolio.

In summary, I test the ability of dynamic models of consumer durable goods to accurately predict the dynamic response of the relative price of these goods in the face of an exogenous shock to the nominal money supply. I determine the accuracy of the models by comparing the predicted theoretical responses to the actual empirical price responses obtained from just identified VAR models. This procedure has precedent in the literature but is predominately applied to real business cycle theories. The work in this dissertation is of economic significance because it is important for economists to have theoretical models of consumer durables that fairly represent dynamic economic behavior for the analysis of policy effects. Also, the chapters contained in this dissertation contribute to the body of research concerning the impact of nominal money on the real economy and the transmission of monetary policy to changes in aggregate

demand. Furthermore, this dissertation provides evidence to the extent that policy induced changes in interest rates are capitalized in the price of physical consumer assets that yield a flow of services over time.

This dissertation fills a void in the existing literature because the theoretical and empirical effects of shocks to the money supply on the market for consumer durables has previously only focused on the response of expenditure on these goods. Also, the particular method I undertake in solving the dynamic models and subsequently “testing” them has as of yet not been applied to the market for consumer durables. The proposed dissertation therefore is a worthwhile undertaking.

In the next chapter I present an extensive review of the pertinent literature. First I review the literature regarding the method for solving and testing various dynamic optimization models. Second, I discuss the literature on various dynamic optimizing models of consumer durables and their features. Next, I address the literature pertaining to the theoretical and empirical impact of money and interest rates on consumer durables. And finally I discuss the literature that rationalizes the VAR identification scheme I employ. In chapter three I estimate a number of vector autoregressions identified by imposing long-run monetary neutrality. The goal of this chapter is to analyze to what extent nominal money supply shocks affect both the relative price of consumer durable goods as well as real expenditure on these goods. It is found that increases in the supply of nominal money cause both the relative price of consumer durables and real expenditure on these goods to increase in the short run. Both aggregate consumer durables and new automobiles are examined in this chapter. In chapter 4, I solve both a simple dynamic optimization model of consumer durables as well as a model

incorporating liquidity constraints. I then compare the ability of these models to accurately predict the dynamic response of the real equilibrium price of consumer durables to a nominal money supply shock, using the estimated results obtained in chapter 3 as a benchmark. Finally, Chapter 5 gives concluding remarks.

CHAPTER 2: A REVIEW OF THE LITERATURE

I. Linear approximations of Euler equations

In a seminal article, Kydland and Prescott (1982) develop a competitive equilibrium model and use it to explain the autocovariances of real output and the covariances of cyclical output with aggregate economic time series. Kydland and Prescott propose taking a linear quadratic approximation to the true model around a steady state growth path to generate linear equilibrium decision rules. In equilibrium, the approximate economy in their model is a system of stochastic difference equations for which covariances are easily determined.

Kydland and Prescott then test whether the model's co-movements for the series in question are quantitatively consistent with the observed behavior of the corresponding series for the U.S. post war economy. The authors calibrate the model by choosing certain relevant benchmark parameter values to achieve this goal. The result that Kydland and Prescott obtain is that their competitive equilibrium model fits the observed empirical data very well.

Later, Christiano (1988) substitutes all of the budget constraints of his dynamic model into the objective function and then takes second order Taylor approximations in logs of all the variables in order to approximate a solution. Hansen and Singleton (1988) employ this method in their article, "Straight Time and Overtime in Equilibrium". In this paper, Hansen and Singleton formulate an equilibrium model of wages, both overtime and

straight time, and extract time series implications for these wages. They extract these implications from a linear quadratic approximation to the model evaluated at particular benchmark parameter values.

In another important contribution to the literature regarding real business cycle theories, Campbell (1994) suggests a way of attaining an approximate analytic solution to the stochastic growth model. Campbell proposes replacing the true Euler equations and budget constraints of the model with loglinear approximations. The model then becomes a system of loglinear stochastic difference equations that he solves by a method of undetermined coefficients.¹ Campbell obtains these stochastic difference equations by taking first order Taylor series expansions of the logged Euler equations and budget constraints. He solves the system analytically in order to make the mechanics of the solution more transparent so that he can derive time series implications given plausible benchmark parameter values describing the steady state growth path of the economy.

Finally, Christiano, Eichenbaum, and Evans (1997) present a comparison of the ability of two macroeconomic models to account for the facts concerning the response of various aggregate variables to a money supply shock. CEE begin by estimating a VAR to obtain impulse response functions of various aggregate variables to a shock in the fed funds rate. CEE then solve the two models for their respective theoretical responses of the same variables to a shock in the money supply and they then compare the quantitative responses of these models given certain calibrated parameter values to the empirical responses obtained from the just identified VAR.

¹ For a discussion and explanation of the method of undetermined coefficients, see Sargent, Thomas, 1987, *Macroeconomic Theory*, Academic Press, 2nd ed.

The articles mentioned above outline the solution and “test” strategy that this dissertation utilizes. The strategy is an attractive one since it facilitates comparison of theoretical dynamic responses of economic variables to responses obtained from a VAR. This is the case because you are taking linear approximations (in most cases Taylor series expansions of logged Euler equations) of equations that are normally not linear (even after taking logs). By doing this, one can obtain approximate analytic solutions that are linear functions of variables in logs, the usual format of equations in a VAR.

II. Dynamic optimizing models of consumer durable goods

I will begin by discussing a few works that utilize dynamic optimization models that incorporate consumer durables in a relatively frictionless setting. Perhaps the reasoning for the frictionless nature of these models is that they were not motivated by an attempt to explain empirical failures of the life-cycle permanent income hypothesis brought forth in previous works. Kau and Keenan (1980) develop a model of liquid consumer durable goods (p. 834). The purpose of this essay is to study the relationship between the real interest rate and the housing market.² The representative consumer chooses an n -vector of consumption goods and an n -vector of durable goods to maximize utility subject to an intertemporal budget constraint that takes into account that durables may be resold in any period in a frictionless market and that this is subsequently a possible source of income each period. The authors note that the only way that interest rates become consequential to consumer demand for durables is when a change in the current interest rate affects the expected value of future interest rates (p.835). The authors assume the simplest possible case of adaptive expectations where future interest rates are expected to remain at there

² The model is general enough, however, to be applicable to all consumer durables. The authors use the term “consumer durables” in their exposition of the model (see p. 834).

current levels. Kau and Keenan do introduce an additional assumption that the consumer goes into debt in early periods with the intention of paying off the debt in later periods. The consumer essentially borrows against future income in order to smooth his path of lifetime consumption. The authors present no exact specification of the utility function nor do they produce any empirical results. The effect of interest rates on the immediate demand for consumer durables is determined using a standard microeconomic theoretical approach incorporating the envelope theorem. The authors find that increases in interest rates depress the immediate demand for a liquid consumer durable. This paper presents a relatively simple, frictionless model that may be used as a starting point in analyzing and empirically testing intertemporal optimization models of consumer durables.

Mankiw (1985) also formulates a frictionless dynamic optimization model incorporating both consumer durables and non-durables. In this article Mankiw also tests how responsive expenditure on consumer durables is to changes in the real interest rate. Mankiw's goal is to extend the method used by others of examining the first order conditions of a consumer optimization problem rather than estimating reduced-form decision rules relating expenditure to income and interest rates. To achieve this goal, Mankiw specifies a model where a representative consumer maximizes the expected value of lifetime utility, which is dependent on consumption of the non-durable good and the stock of the durable good. Mankiw also assumes that the consumption of the durable good and the stock of the non-durable good are separable in utility³. Mankiw then discusses his simple budget constraint by specifying a nominal after tax interest rate, which is equal to the price at which the consumer can trade present for future expenditure. Next, Mankiw examines two first order conditions he derives by simple

perturbation arguments. The author considers the tradeoff between consuming the non-durable today and the non-durable tomorrow and then the tradeoff between consuming the services of the durable today versus consuming the non-durable tomorrow.⁴ Mankiw then assumes a standard iso-elastic utility function and then restates the first order conditions he derived using this exact form along with replacing the expected values of the variables with their actual values and additive error terms. The author then takes the natural logarithm of both sides of the equations and from these subsequent equations he derives implied theoretical elasticities of the percentage change in consumer durable and non-durable goods to changes in income, relative prices, and interest rates. Mankiw then estimates the model using U.S. time series data from 1950 to 1981, finding that the empirical elasticities have the same sign as the models implied theoretical elasticities and specifically that expenditure on consumer durables is very responsive to changes in the real interest rate. This paper is especially appealing because the author estimates equations he derived from the Euler equations from a simple dynamic optimization model incorporating consumer durables, which is somewhat in the spirit of this dissertation. Also, Mankiw (as well as Kau and Keenan (1980)) finds that interest rates affect the market for consumer durable goods which supports this dissertation's study of the effect of monetary policy on the market for consumer durables since there is an immense body of literature linking changes in the money supply to changes in interest rates.

Yet another article that makes use of a simple frictionless dynamic model of consumer durables is Wilson (1998). Wilson's goal is to determine whether or not

³ This is simply stating that the marginal utility of one good does not depend on the other.

⁴ Even though utility technically depends on the service flow from a durable good is common throughout the literature to assume that the service flow is proportionate to the stock of the durable. This is why Mankiw includes the stock of the durable good directly in the utility function.

precautionary motives are significant at the aggregate. The author develops this test by deriving an empirical specification for the relationship between the consumption of both durables and non-durables and labor income uncertainty. He derives this specification much in the same manner as Mankiw (1985). Wilson derives the Euler equations from a dynamic optimization model where the representative consumer chooses the stock of the durable good and consumption of the non-durable good to maximize a simple optimization problem. Wilson derives the results of his paper by specifying a utility function that is separable in durables and the consumption of non-durables. The purpose and results of Wilson's article are of no direct relation to this dissertation but this article is yet another example of the prevalence of such intertemporal optimization models of consumer durable goods throughout literature pertaining to a wide variety of studies and therefore deserves mention in this review.

The above-mentioned articles provide examples of simple, frictionless intertemporal optimization models that incorporate durables. Next let us move to a review of the literature involving dynamic models of consumer durables that are no longer frictionless. The word "frictions" imply that there is some aspect in these models that may inhibit the representative consumer from behaving as he would in the simple models of consumer choice outlined above.

Bernanke (1985) aims at testing the implications of the permanent income hypothesis⁵ by presenting a dynamic stochastic model of consumer choice that he derives from an intertemporal optimization model that incorporates consumer durable goods and non-durable goods. Bernanke's approach differs from the aforementioned models in that

⁵ The author tests for excess sensitivity of expenditure on both durables and non-durables to changes in income in the short run.

he assumes non-separability between consumer durables and non-durables. Bernanke's model also introduces a transaction cost of changing the consumer's stock of durables and makes this cost an argument in the representative consumer's utility function. The theory behind introducing transactions costs is that owing to the nature of consumer durable goods (size, imperfect information about quality, etc.), the consumer must forego leisure time when he wishes to adjust his stock of these goods. Bernanke concludes that the presence of transactions costs may affect the time series properties of both components of expenditure, perhaps causing excess sensitivity of consumption to income in the short run. Bernanke also finds that the assumption of separability in utility between consumer durables and non-durables does not fare badly empirically.

Startz (1989) incorporates both the concept of costs of adjustment of consumer durable stocks and non-separability of consumer durables and non-durables. Startz also is testing the life-cycle permanent income hypotheses and he also derives equations for durable purchases from the first order conditions of a representative agent utility maximization problem. Startz concludes, much like Bernanke, that adding adjustment costs affects the time series properties of durable goods purchases.⁶

Yet another study that incorporates transaction costs and actually performs a test for the presence of them is Eberly (1994). Eberly constructs a continuous time dynamic optimization model that incorporates only consumer durables and an optimal (S,s) rule that guides the behavior of consumer durable expenditure. She posits that there are upper and lower bounds to the stock of consumer durables and that consumers adjust their

⁶ Startz also concludes that non-separability affects the time series properties of durable purchases. To be exact, he finds that adding either non-separability or adjustment costs to the dynamic optimization model suggests that durable purchases follows an ARMAX process, which is in contrast to the theoretical predictions of the life-cycle permanent income hypothesis.

stocks of durables only when those bounds are reached due to the presence of transaction costs. Eberly introduces transactions costs in a different manner than Bernanke and Startz in that she does not enter the costs directly into the utility function, instead she motivates a separate constraint incorporating the concept of adjustment costs that the consumer is subject to when he optimizes. Eberly formulates a test for the effectiveness of her model in a somewhat similar way that this dissertation does. Eberly derives an empirical distribution of the ratio of wealth to automobile stocks from her representative agent model and then compares this theoretical distribution with the actual cross-sectional distributions over the years of 1983 and 1986. Eberly also simulates the response of expenditures on automobiles implied by her transactions costs model to actual yearly changes in the response of automobile expenditures over a five year period in the 1980s. Eberly finds that both the simulated distribution and expenditures match the observed data very well, causing her to support the inclusion of transaction costs in dynamic models of consumer durable goods.

Although Eberly (1994) seems to present concrete evidence of the inclusion of transaction costs when formulating dynamic optimization models of consumer durable goods, Browning (1989) presents evidence that discounts the relevance of such costs. Browning does not present a dynamic optimization model of consumer durables so the details of his paper will not be addressed in this review but it is still worth mentioning as a counterpoint to Eberly's findings since of the three papers that incorporate transactions costs above, only Eberly actually attempts some sort of test for the presence of adjustment costs. There are, however, other frictions that have been incorporated into

these dynamic durable goods models that may be more relevant to obtaining a clear understanding of aggregate behavior in the market for consumer durables.

Next we turn our attention to models that incorporate liquidity constraints. These models assert that not all economic agents can smooth consumption over time based on their expectations of their permanent income because they are unable to borrow the necessary amount to do so. These models typically impose restrictions on the representative consumer's maximization problem of the type that impose limits on the amount the consumer can borrow in any given period. These restrictions can have important implications on the expenditure patterns of the representative consumer, especially with regards to consumer durables because these are goods that are often times debt financed. These borrowing restrictions also have implications on the responsiveness of the demand for consumer durables (and non-durables) in the face of exogenous shocks to the economy because some consumers may not be able to adjust their spending plans in the same manner they would if they were not faced with such borrowing constraints.⁷

Chah, Ramey and Starr (1995) present a dynamic optimization model of consumer durable goods exactly like the models presented in the discussion of the frictionless models above except for the addition of the an additional constraint regarding the degree to which the representative consumer can finance expenditure of consumer durables. The consumer is constrained to have non-negative net financial assets. The purpose of this article is to develop a theory of optimal consumption behavior in the presence of this borrowing constraint and to test this theory using aggregate data to see if consumers behave as if they operate in a liquidity constrained framework. The authors derive an

⁷ "Borrowing Constraints" and "Liquidity Constraints" are often used interchangeably throughout the literature. The basis being that borrowing may depend on the liquidity of the consumer's portfolio.

equation for non-durable consumption expenditure from the Euler equation from their intertemporal optimization model. The results from their study support the hypothesis that consumers do indeed behave as if they are liquidity constrained.⁸

In a related article, Alessie, Devereux, and Weber (1997) also test for the presence of liquidity constraints. Their goal is to use pseudo-panel data to test for binding liquidity constraints on consumers in England in periods before and after a movement towards financial liberalization in 1982. The authors develop, once again, a model of dynamic optimization involving a representative agent choosing durable and non-durable goods in the presence of a typical intertemporal budget constraint along with a constraint on household borrowing. The constraint on borrowing is almost identical to the constraint in Chah, et al. (1995). These authors, however, do introduce an additional constraint. The authors impose a non-negativity restriction on the stock of consumer durables (in their case, automobiles). Alessie, et al. also assume non-separability in utility of consumer durables and non-durables where Chah, et al. (1995) assume separability. These authors also estimate an Euler equation derived from the dynamic model to achieve their results. The authors' results do indicate that, for young consumers prior to the period of financial liberalization (1982) in England, liquidity constraints were indeed binding. The authors also find that it cannot be assumed that utility is non-separable in consumer durables and non-durables.

Furthermore, two of the papers previously discussed give credence to the validity of liquidity constraints. Bernanke (1985) points out in his conclusion (p. 64) that

⁸ The authors are also able to distinguish between liquidity constraints and consumers following a Keynesian rule of thumb regarding consumption and current income (see p.284).

“...although ‘most’ spending may be done by PIH⁹ consumers, over the business cycle the ‘marginal’ consumer may be liquidity constrained”. Also, Eberly (1994) notes in her conclusion (p. 431) that half of the households in her sample exhibit behavior suggestive of liquidity constraints. The findings in the papers by Chah, et al. (1995), Alessie, et al. (1997) and the comments by Bernanke (1985) and Eberly (1994) give a great deal of support to the inclusion of liquidity/borrowing constraints in intertemporal optimizing models of consumer durable goods.

There are two other papers that study importance of household liquidity and its effect on behavior in the market for automobiles. Bernanke (1984) uses panel data on income and automobile expenditures in the U.S. to test the permanent income hypothesis. The author derives a stock adjustment model for automobiles and finds no evidence to refute the permanent income hypothesis, and therefore no evidence supporting liquidity constraints. However, in a later article, Lam (1991) incorporates a threshold adjustment process into Bernanke’s (1984) model and basically repeats Bernanke’s (1984) experiment using a subset of the same data Bernanke (1984) uses. Lam (1991) argues that his addition of a threshold adjustment process, in which consumers do not continually adjust their stock of automobiles, but do so only when the stock reaches an upper or lower threshold more closely matches the observed data. Lam (1991) finds no evidence that consumers are in anyway myopic; implying that macro models that incorporate rationality of economic agents may be appropriate. Lam (1991) does find, however, that the permanent income hypothesis fails due to the presence of liquidity constraints and resale market imperfections in the automobile market. This finding gives

⁹ PIH – “Permanent Income Hypothesis”

rationale to the inclusion of such constraints in dynamic optimization models incorporating automobiles and perhaps other consumer durable goods.

I next give attention to a couple of recent essays regarding intertemporal optimization models such as the ones discussed above. It should be noted that this dissertation basically is testing the ability of a model that implies Friedman's permanent income hypothesis to accurately predict dynamic economic behavior. There have been countless works that have tested the implications of the permanent income hypothesis and evidence both for and against it have been provided. In a recent symposium in the *Journal of Economic Perspectives*, Carroll (2001) sheds light on the importance of the degree of consumer's impatience. It is shown that if uncertainty and a certain level of impatience are taken into account, that consumers behave as if they are liquidity constrained. There is virtually no difference between the behavior of liquidity constrained consumers and those who are unconstrained but have a precautionary saving motive. Carroll claims that a target level of precautionary wealth exists where there is a balance between a consumer's levels of impatience and prudence. Carroll explains that tests for liquidity constraints should instead be thought of as tests for the average degree of impatience. In the same symposium, Angeletos, et.al (2001) present the hyperbolic consumption model. This model takes into account the possibility that a consumer's preference over the long run may not coincide with short run behavior. The general idea is that people are more impatient when they make short-run tradeoffs than when they make long run tradeoffs. The authors suggest changing the way economists traditionally have discounted future utility flows. The suggestions made from these two essays are not implemented in this dissertation, however they offer new channels for future research.

III. Theoretical and empirical evidence of the impact of money and interest rates on consumer durable goods

Two articles that discussed the effect of interest rates on the market for consumer durables were reviewed in section II.B. These were Kau and Keenan (1980) and Mankiw (1985). These were included in the section above because they also outlined dynamic optimization models of consumer durables. A review of the remaining literature follows.

In a seminal work Hamburger (1967) examines the effects of monetary variables on the demand for consumer durables. Hamburger takes interest rates to be his measure of monetary variables. The author derives a model to explain the quarterly movements in the two major components of consumer durable goods: automobiles and parts and all others. Hamburger then derives a reduced form stock adjustment equation for consumer durables that relates the adjustment of consumer's stocks of durables to income, interest rates, and prices. The author concludes, after empirically estimating the stock adjustment equation that automobiles and parts and other consumer durables are sensitive to changes in interest rates. However, these results are only significant when interest rates are incorporated into the model with a considerable lag (especially when the interest rate in question is the yield on Aaa bonds and commercial paper). This result may indicate that these interest rates serve as a proxy for the rates charged on consumer credit and that money has an effect on the demand of consumer durables through its effect on the cost and availability of consumer credit.

In another paper, Mishkin (1976) appeals to the illiquid nature of consumer durables to assess the impact of monetary policy on these goods. Mishkin develops a model that determines the effect of the relative illiquid nature of consumer durables on the

desirability of this asset. The author then develops a stock adjustment model which incorporates the results of his “liquidity” model and estimates the model using quarterly aggregate time series on consumer durable expenditure and its two component parts: automobile and parts and non-automobile consumer durable expenditure. Mishkin concludes that debt holdings have a negative effect on consumer durable expenditure while the financial asset holdings of consumers have a positive impact. He also finds that an increase in the user cost of durables has a negative effect on consumer durable expenditure. Therefore, Mishkin finds that owing to the illiquid nature of consumer durable goods, it is not just total wealth or income that matters but the composition of consumers’ portfolios. Mishkin goes on to explain that monetary policy has a major role to play in the demand for consumer durables for a number of reasons. First, monetary policy affects interest rates and therefore the user cost of capital. Second, monetary policy affects asset prices and therefore the household valuation of gross financial asset holdings, thereby affecting the demand for consumer durables. And finally, that monetary policy affects the cost and availability of credit. Therefore easy monetary policy in the past would have encouraged the build up of consumer debt holdings and therefore their liabilities, depressing the demand for consumer durables in the present.

In an article published two years later, Mishkin (1978) continued his study on the effect of monetary policy on the market for consumer durables. In this paper, Mishkin explores monetary policy transmission mechanisms to aggregate demand (and expenditure on consumer durables) using simulation experiments. In these simulation experiments the author uses the results from the stock adjustment model obtained in his 1976 paper in the *AER* along with a large-scale macroeconometric model. In this study,

the author simulates the dynamic response of real GNP and real consumer durable expenditure to changes in interest rates, household liabilities, and the value of stock market assets. Mishkin next simulates the response of consumer durable expenditure and real GNP to a change in the nominal stock and to an exogenous expenditure change (exports). The author concludes that real consumer durable expenditure declines as interest rates and household liabilities rise and increases as the value of stock market assets and the nominal money stock rise. Therefore, monetary policy has a definite dynamic effect on the demand for consumer durables.

It is worth noting one article that presents results contrary to Mishkin's so called "liquidity" hypothesis of consumer durables. Ruiter and Smant (1999) examine the relationship between the household balance sheet and consumer durable expenditure using time series data for The Netherlands. After estimating both a closed form consumption function that has been used repeatedly throughout the literature and an Euler equation derived from an intertemporal optimization model of consumer durables the authors find no evidence that "excessive" household debt ratios can be held responsible for slowing down consumer durable expenditure. They also find only a marginal influence of liquidity in the form of financial assets relative to debt on durable expenditure. Ruiter and Smant obtain these results primarily because they take into account the net effects of consumers' asset position on wealth.

Mankiw (1982) solves an intertemporal optimization model incorporating consumer durable goods only for the Euler equation relating the intertemporal tradeoff between durables today and durables next period. The author then derives an equation for the expenditure on durable goods and tests the hypothesis that expenditure on durable goods

is represented by an ARMA(1,1) process. Mankiw rejects the null that expenditure on durables is ARMA(1,1). Furthermore, the author, while estimating the equation he derived from the Euler equation, finds that lagged interest rates have predictive power for the expenditure on consumer durables (while lagged stock prices and lagged income does not).

Adda and Cooper (2000) build on Mankiw (1982) by considering the aggregation of the discrete dynamic choices of heterogeneous households. The authors find that they are able to explain Mankiw's (1982) results by estimating a dynamic discrete choice model of car replacement. This paper is particularly interesting because the authors attempt to match their model with a VAR representation of car sales, prices, and income. However, the VAR model presented in this paper is unidentified so the time series results derived are suspect at best.

Furthermore, Kretzmer (1989), puts forth an insightful view on the effect of monetary policy on consumer durable goods. Kretzmer states on page 293:

"A money shock may be regarded by agents as transitory income, having only a small impact on wealth. Then, most of the proceeds will be saved, or spent on assets yielding a stream of future benefits. Durability, as a measure of the length of the time period over which a good yields benefits, provides an indicator of the degree to which purchases of that good can be regarded as savings. This line of reasoning suggests that a money shock will lead to a larger real response the more durable the good in question."

Kretzmer's quote presents even further theoretical credence to the business of studying money's effect on consumer durables.

In another article outlining the effect of interest rates on the market for consumer durables, Wilcox (1990) tests whether nominal, not real interest rates matter in determining expenditure on non-durable and/or durable goods. Wilcox's motivation lies in the recognition that lenders, when choosing whether or not to supply consumer credit to potential borrowers, adhere to payment-to-income guidelines and that these guidelines rarely change. Wilcox then argues that since payments are determined by nominal interest rates, this must be a channel by which interest rates affect expenditure on consumer durables since consumer durables are largely debt financed. The author goes about proving his results by running a simple OLS regression of consumption expenditure (on both durables and on non-durables and services) on wealth, income, and nominal and real interest rates. Wilcox concludes from his results that the expected, real, after tax interest rate is not what matters to consumption but instead it is the nominal interest rate. The author goes on to show that this holds true even when the expected inflation rate is included in the regression¹⁰. This article still supports the fact that money affects the market for consumer durables since monetary policy affects nominal interest rates. However, this paper appeals more to a credit supply channel of monetary policy due to institutional features in the market for consumer credit than other traditional demand side transmissions of monetary policy on the consumer durables market.

¹⁰ He includes the expected inflation rate to control for the possibility that the nominal interest rate is just serving as a proxy for this variable.

Lastrapes and Loo (1998) use a VAR approach to identify the dynamic responses of industry level output to money supply shocks. This article shows (via impulse response functions) that the output of durable goods (furniture, electric machinery, non-electric machinery, transportation equipment, etc.) responds substantially to increases in the nominal money supply. This article, therefore, presents even more empirical evidence of the effect of the nominal money supply on the market for durable goods.

Finally, Ludvigson (1998) sets out to examine if tight monetary policy leads to a decline in the supply of bank loans and if this, in turn, leads to a decline in consumption. This article, much like Wilcox (1990) focuses more on the credit channel of monetary policy. Ludvigson estimates a VAR using automobile and other aggregate data as well as “credit” data (data on the ratio of bank loans to the sum of commercial credit and bank loans) to obtain impulse response functions to answer the first part of his question. The author then estimates reduced form automobile expenditure equations to address the second part of his question. Ludvigson concludes that tight money does indeed lead to a decline in the supply of bank loans, which, in turn, does lead to a decline in automobile expenditure.

IV. VAR identification

In this sub-section I will give a very brief review of an influential article that outlines the VAR identification strategy I use in this dissertation. A more thorough analytical discussion of the details of the identification strategy is presented in subsequent chapters of this dissertation.

In a pioneering article, Blanchard and Quah (1989) outline how a VAR could be identified by imposing long-run restrictions on the dynamic responses of variables in the

system to exogenous shocks. As an example of how this strategy can be applied to the concept of long-run monetary neutrality, the reader is referred to Lastrapes (1998) in which he not only describes how the impulse responses of variables in the system to a shock in the nominal money supply can be identified by imposing nothing more than long-run monetary neutrality but also describes how the scale of the money supply shock implied by long-run monetary policy can be derived.

The above literature review demonstrates a few main points. There are a number of articles that support the method of solving dynamic optimization models by taking linear approximations of the Euler equations to obtain approximate analytic solutions and for empirically testing their predictive power for plausible calibrated parameter values. Second, there are a large number of intertemporal optimization models of durable goods with many different characteristics. Some are “frictionless” while many others incorporate a wide variety of additional constraints on consumer behavior. According to the literature, the most relevant of these additional restrictions may be liquidity constraints. Third, the wide body of empirical and theoretical work on the effect of money on consumer durables, and the fact that this literature almost exclusively deals with *expenditure* on consumer durables, supports this dissertation’s focus of the impact of monetary policy on the equilibrium *price* of consumer durables. And finally, there is concrete literature supporting the use of the restriction this dissertation employs to identify the VARs presented.

CHAPTER 3: THE DYNAMIC EFFECT OF MONEY SUPPLY SHOCKS ON THE MARKET FOR CONSUMER DURABLE GOODS: EMPIRICAL RESULTS

I. Introduction

Studying the market for consumer durable goods is essential to gaining a clear understanding of macroeconomic fluctuations. From 1959 to 1999, real personal expenditure on durable goods in the United States (billions of 1992 dollars seasonally adjusted at annual rates) increased from \$97.467 million to \$822.7 million. Furthermore, the percentage increase in personal expenditures on durable goods is over 3.5 times the increase in non-durable goods over this period. And although average real personal consumption expenditure on durables is only 31.6% the size of average real personal consumption expenditure on non-durables, the standard deviation of the percentage change in real expenditure on durables is over double that of non-durables. Research that examines the precision of the response of the market for consumer durable goods to exogenous shocks can therefore be very fruitful in shedding light on variations in total consumption and can help us gain insight into the transmission of policy shocks to aggregate demand.

This chapter analyzes empirically the impact of nominal money supply shocks on the market for consumer durable goods in a time series context, focusing both on the relative price of consumer durables and real personal consumption expenditure on durables. Both consumer durables in general and the market for new automobiles are analyzed. The estimated dynamic responses are obtained by estimating a just-identified

vector autoregression (VAR). This VAR is identified by imposing a set of very plausible assumptions that is widely used throughout the literature on time-series macroeconomics.

Why the choice to study the effect of nominal money supply shocks? First, the nature of durable goods implies that the demand for durables is very likely to be sensitive to changes in the rate of interest and much research has focused on the effect of money and interest rates on the market for these goods.¹ Durable goods differ from non-durables in that they have a positive depreciation rate (d) that is less than one. Durables offer a flow of services *over time* from which economic agents derive utility. Therefore, the interest rate plays a key role in the demand for durables because these future service flows must be discounted to the present when agents are planning their expenditure outlays. Figure 3.1 graphs both the real price of consumer durables and the interest rate. The real price of consumer durables is measured by deflating the PPI for consumer durable goods by the PPI for all commodities and the interest rate measure is the yield on the 3-month T-bill. Just by looking at figure 3.1 one can recognize a general negative correlation between the two variables.

Furthermore, there is a wide body of literature that examines the influence of nominal money supply shocks on interest rates and it is generally accepted that positive money supply shocks do indeed cause interest rates to decline in the short run (the liquidity effect)². Therefore, since the nature of durable goods causes their demand to be interest sensitive, and since the real interest rate is influenced by nominal money supply shocks in the short run, it is interesting to study the impact of nominal money supply shocks on the market of consumer durable goods.

¹ See Hamburger (1967), Mishkin (1976), Mishkin (1978), Kau and Keenan (1980), Mankiw (1982), Mankiw (1985), Kretzmer (1989), Wilcox (1990), Lastrapes and Loo (1998), and Ludvigson (1998).

² Christiano, Eichenbaum, and Evans (1999)

Yet another reason for studying the impact of nominal money supply shocks as opposed to other exogenous shocks is that imposing a very limited set of restrictions can identify nominal money supply shocks. In this paper, for example, I rely on long-run monetary neutrality, a phenomenon that has almost reached the status of a stylized fact in macroeconomics, to identify money supply shocks³. Identifying VARs using long-run monetary neutrality has become common throughout time series economics and of course has definite precedent throughout the literature on macroeconomic VAR models.

It is worth noting that this chapter, as well as the dissertation as a whole, is primarily concerned with the dynamic response of the relative *price* of consumer durables to nominal money supply shocks. I focus on the price of consumer durables because even though there have been other works that study the effect of money and/or interest rates on the market for consumer durables, these works tend to focus primarily on durable expenditure. This dissertation realizes that a durable good is an asset and studies to what degree decreases in the rate of interest brought about by an increase in the nominal supply of money are capitalized in the price of this asset. Many other papers that study consumer durables neglect this “asset pricing” issue and simply study to what extent expenditure on consumer durables is sensitive to changes in the rate of interest. Future research may focus more on durable expenditure.

The following section discusses the empirical model that is employed throughout the remainder of this chapter as well as the identifying restrictions. Section III presents the estimated impulse responses from a six variable VAR incorporating aggregate consumer durable goods. Section IV narrows its focus and analyzes the market for new

³ See Blanchard and Quah (1989)

automobiles. Section V estimates an eight variable system to check for robustness.

Finally, Section VI gives concluding remarks.

II. Estimating the Dynamic Responses to Money Supply Shocks

a. Empirical Model and Identifying Restrictions

Let z_t be an $n \times 1$ vector of endogenous random variables at time t . This vector contains variables pertaining to the market for consumer durable goods as well as other macroeconomic variables that are included to aid in the identification of nominal money supply shocks. Assume that the following linear, dynamic structural model generates z_t :

$$A_0 z_t = A_1 z_{t-1} + \mathfrak{V} + A_p z_{t-p} + u_t. \quad (1)$$

where u_t is an $n \times 1$ vector of shocks that are assumed to be uncorrelated both serially and contemporaneously. Furthermore, these shocks are normalized to have unit variance. This model consists of equations that represent optimal decision rules and equilibrium conditions and u_t is a vector of behavioral exogenous shocks. The moving average representation of the structure is:

$$z_t = (D_0 + D_1 L + D_2 L^2 + \mathfrak{V}) u_t$$

$$z_t = D(L) u_t \quad (2)$$

The coefficient matrices in $D(L)$ are dynamic multipliers that show the equilibrium response of the endogenous variables in z_t to impulses in the exogenous shocks, u_t where

$$D_0 = A_0^{-1} \text{ and } D_i = A_0^{-1} A_i.$$

The goal is to estimate the elements in $D(L)$ that correspond to shocks in the nominal stock of money. To understand how this is done, first analyze the moving average of the reduced form of the empirical model:

$$z_t = (I + C_1 L + C_2 L^2 + \dots) e_t \quad (3)$$

$$z_t = C(L) e_t$$

$C(L)$ shows the dynamic responses to shocks in e_t , where $e_t = D_0 u_t$, and $C_i = D_i D_0^{-1}$.

Of central importance to our identification strategy is the fact that, given our normalization of the elements in u_t ,

$$E e_t e_t' = \Sigma = D_0 D_0' . \quad (4)$$

The parameters in $C(L)$ and Σ are directly estimable from the vector autoregression representation of z_t . The identification problem arises because (4) is not a unique mapping from structure to reduced form. The identification strategy usually employed in VAR studies consists of imposing a sufficient number of restrictions on D_0 to identify the structural coefficients from $C(L)$ and Σ . The strategy I employ is weaker than the normal strategy in that the restrictions I impose identify the dynamic multipliers associated with money supply shocks only. The full system in (2) remains underidentified, as noted below. This strategy is nonetheless acceptable in this study because I am only interested in the responses of the variables to shocks in the supply of nominal money.⁴

The method I use to identify the structural coefficients in $D(L)$ was first pioneered by Blanchard and Quah (1989) and Shapiro and Watson (1988). The method consists of imposing restrictions implied by long run monetary neutrality. Let

$$\tilde{z}_t' = (p_t \quad d_t \quad r_t \quad y_t \quad m_t \quad M_t)$$

⁴ See Christiano, Eichenbaum, and Evans (1999) for a discussion of partial identification in VAR models.

where p_{dt} is the log of the real price of consumer durables, d_t is the log of a flow measure of the quantity of consumer durable expenditure, r_t is the interest rate on debt securities, y_t is the log of aggregate output, m_t is the log of real money balances, and M_t is the log of nominal money balances. To employ the proposed identification strategy, first assume each of the variables in z_t contain a single unit root.⁵ Therefore, in the structural model in (2), set $z_t = \Delta \tilde{z}_t$. This implies that

$$\lim_{k \rightarrow \infty} \frac{d \tilde{z}_{t+k}}{du_t} = D_o + D_1 + D_2 + \mathfrak{Q} \quad (5)$$

$$= D(1)$$

is the matrix of infinite horizon multipliers with respect to the levels of the variables in z_t . Taking into account the specific ordering I have imposed on z_t , it is apparent that long run monetary neutrality implies that every element in the last column of $D(1)$ is zero except for the final row. I will now show how these restrictions on $D(1)$ are sufficient to identify the responses to nominal money supply shocks (the last columns of D_i) although the entire system remains underidentified.

First, partition the $n \times n$ long-run multiplier matrix $D(1)$ as:

$$D(1) = \begin{pmatrix} D_{11} & D_{12} \\ D_{21} & D_{22} \end{pmatrix} \quad (6)$$

where D_{11} has dimensions $(n-1) \times (n-1)$, D_{21} is $1 \times (n-1)$, D_{12} is $(n-1) \times 1$ and D_{22} is a scalar. Given the order of the variables in the VAR, monetary neutrality implies that only D_{12} is equal to zero. Therefore, since D_{11} is not lower triangular, $D(1)$ is block recursive, but not lower triangular.

⁵ Tests for the presence of unit roots are presented in section IIIa.

The correspondence between the structural model and the reduced form implies that the infinite horizon multipliers are related to the covariance matrix obtained from the estimated VAR:

$$D(1)D(1)' = C(1)\Sigma C(1)' \quad (7)$$

Let R denote the Cholesky factor of the right-hand-side matrix in equation (7):

$$RR' = C(1)\Sigma C(1)' \quad (8)$$

so that R is lower triangular. By partitioning R to conform with $D(1)$, and combining (7) and (8) and using the restriction that $D_{12} = 0$, one obtains:

$$\begin{pmatrix} D_{11}D_{11}' & D_{11}D_{21}' \\ D_{21}D_{11}' & D_{21}D_{21}' + D_{22}D_{22}' \end{pmatrix} = \begin{pmatrix} R_{11}R_{11}' & R_{11}R_{21}' \\ R_{21}R_{11}' & R_{21}R_{21}' + R_{22}R_{22}' \end{pmatrix} \quad (9)$$

where R_{11} is lower triangular. Note that the values of R are known values given estimation of the VAR.

The aim is to express D_{22} as a function of the partitioned matrices in R . From (9), note that:

$$D_{11}D_{21}' = R_{11}R_{21}' \quad (10)$$

Therefore,

$$R_{21}R_{21}' = R_{21}R_{11}'(R_{11}^{-1})R_{21}' \quad (11)$$

$$R_{21}R_{21}' = D_{21}D_{11}'(R_{11}^{-1})R_{11}^{-1}D_{11}D_{21}' \quad (12)$$

where the second equality uses (10). But note that equation (9) implies that:

$$D_{11}D_{11}' = R_{11}R_{11}' \quad (13)$$

Pre-multiply by D_{11}^{-1} , post multiply by $(D_{11}')^{-1}$, then invert to obtain:

$$D_{11}'(R_{11}^{-1})^{-1}D_{11} = I \quad (14)$$

Then use (13) in (12) to get:

$$R_{21}R_{21}' = D_{21}D_{21}' \quad (15)$$

Finally, this result and the (n, n)

$$D \quad R \quad R' \quad$$

$C(1)\Sigma C(1)'$, which is estimable from the VAR. This

holds true assuming only that $D_{12} = 0$ (monetary neutrality), not that $D(1)$ is lower triangular. Therefore, D_{22} is identified given only long-run monetary neutrality. To see how the elements in $D(L)$ are obtained from knowledge of the elements in $D(1)$, recall that $C_i = D_i D_0^{-1}$. This implies that $D(L) = C(L)D_0$, or $D(1) = C(1)D_0$. Therefore, since $C(1)$ is obtained from the VAR estimation, and imposing long-run monetary neutrality identifies $D(1)$, we can identify D_0 . Now, since $C(L)$ is directly estimated from the VAR, and we now know D_0 , we can identify the parameters of $D(L)$.

III: Estimating a VAR with Aggregate Consumer Durables

III.a. Data Description and Characteristics

In this section I apply the estimation strategy outlined above using long-run monetary neutrality to monthly U.S. data ranging from 1959:01 to 2001:03. I use the following macro variables: M1, 3-month Treasury bill rate, industrial production index, and the producer price index for all commodities. I deflate the monetary aggregates by the latter to construct real variables. I also use the producer price index for consumer durable goods and personal consumption expenditure on durables (annual rates in millions of dollars). I also estimate the system using the chain-weighted price index for consumer

durables (obtained from personal consumption expenditures) to check for robustness in the consumer durable price response since this is what I am most interested in⁶. The chain-weighted price index is attractive because due to the method used for computing the index, the choice of base year does not impact the measured growth rate of the price. This is sometimes a problem for fix-weighted indexes in time series analysis. I deflate personal consumption expenditure on durables by the PPI for consumer durables to construct a real quantity measure and deflate the two price measures for consumer durables by the PPI for all commodities to create relative prices. When the chain-weighted price index for consumer durables is used, I deflate personal consumption expenditures on durables by this to obtain a real quantity measure. The data are obtained from the Bureau of Labor Statistics (PPI for consumer durables and the PPI for all commodities), the Bureau of Economic Analysis (personal consumption expenditure on consumer durables and the chain-weighted price index for consumer durables), and the Federal Reserve Board (industrial production, M1, and the T-Bill rate). Each data series is seasonally unadjusted except for personal consumption expenditure on durables, and all except for the t-bill rate are transformed to natural logs. Figure 3.2 graphs the PPI for consumer durables and real personal consumption expenditure on durables to give the reader an overall feel for the data. Although there is an upward trend in real expenditures on consumer durables, the relative price of consumer durable goods exhibits a great deal of unpredictability. Studying how much of this unpredictability is explained by nominal money supply shocks seems to be a worthwhile task.

⁶ For details on how Personal Consumption Expenditures and the Chain-Weighted Price Index are computed see the Data Appendix as well as Landefeld and Parker (1997) and U.S. Department of Commerce (1990).

Table 1 reports the results of unit root tests performed on the data. Augmented Dickey- Fuller tests (using 6 lags) were performed on the data both in levels and in first differences. We cannot reject the null of a unit root for each data series included in the model at the 5% significance level. Furthermore, the null hypothesis of a unit root is rejected once the data are first differenced, indicating that each data series contains but a single unit root. This provides a rationalization for first differencing the data, which is a necessary step when imposing long-run monetary neutrality⁷.

III.b. Estimating the VAR

The VAR includes a constant, seasonal dummy variables and 12 common lags across variables and equations⁸. The sample range for the VAR estimation is February 1960 to March 2001. There are 495 total observations in the model and 411 degrees of freedom. The Ljung-Box Q-Statistics provide evidence that the residuals are not autocorrelated⁹. This tells us that 12 lags are sufficient to whiten the residuals.

Figure 3.3 reports the estimated dynamic responses of each variable in the system to a nominal money supply shock when the price of consumer durables is proxied by using the PPI for consumer durables. One-standard error bands that were computed from Monte Carlo simulations with about 1000 replications are included.¹⁰ The money supply shock leads to a monotonically increasing stock of nominal money that ultimately settles

⁷ I performed cointegration tests on the data for each system I estimate. I ran a number of tests (two variations of the Johansen test as well as the Engle-Granger test) and found no conclusive evidence of cointegration. The results were not robust across which test I used. I therefore assume there is no cointegration present.

⁸ In also estimated each of the VARs in this chapter with the real price of oil included as a deterministic component to take into account the oil price shocks of the early 1970's. The results were not changed when I included this variable.

⁹ The highest estimated value for this Q-statistic is 30.069. The degrees of freedom used for this chi-square test is 43. This is well below the critical value for rejecting the null hypothesis of no autocorrelation in the residuals (5% significance level).

¹⁰ In 13 out of the 1000 replications, the simulated largest root of the VAR exceeded one. This will cause the standard error bands to explode as the forecast horizon increases – so these replications were dropped.

at a new steady state that is .8% higher than before the shock. In the short run, real money increases by about the same magnitude as nominal money, indicating stickiness in the price level. However, ultimately the price level rises, causing the long run real money response to fall to zero (by construction). Industrial production responds with a considerable lag, which is a common finding. It does not rise above its initial steady state level until seven months after the nominal money shock. It reaches a peak increase of .5% 15 months after the shock and then begins its decline back to its original steady state. There is evidence of a liquidity effect in the market for government securities. On impact, the non-annualized yield of the 3-month T-bill decreases by 2.5 basis points and two months after the money supply shock the yield is 3.3 basis points lower than before the shock. There is a quick adjustment back to the original steady state for the yield on the T-bill. The yield is back to its original level approximately 15 months after the shock. These findings are typical of other studies that analyze the effect of nominal money supply shocks.

Now focus on the response of the consumer durable variables. The relative price of consumer durables (using the PPI for consumer durables) rises on impact by .18% and reaches a peak after 3 months at a .2% higher level than before the shock. The response then begins to fall to zero (again, by construction) and after only 10 months the response is no longer significantly different from zero. Real personal consumption expenditure on durables increases on impact by .4%, this response seems large, but it falls within the standard error bands. Real durable expenditure does eventually increase by a significant amount and after 10 months is .8% higher than before the money supply shock before returning to its original steady state level.

Figure 3.4 reports variance decompositions for the 6 variable system using the PPI for consumer durables. The upper-left most graph in figure 3.4 tells us that approximately 10% of the variance on the real price of consumer durables is due to the variance in the nominal money supply. This percentage declines as the time horizon increases. Also, figure 3.4 shows that after 15 months, roughly 12% of the variance in real personal consumption expenditure on consumer durables is due to the variance in the nominal money supply. These results shed more light on the effect changes in the nominal money supply has on the market for consumer durables.

Figure 3.5 reports the estimated responses when the chain-weighted price index is used for the price of consumer durables. The response of the macro variables is roughly the same as when the PPI for consumer durables is used as the relevant consumer durable price measure. The relative price of consumer durables in this model increases by .18% on impact before reaching a peak increase of just over .2% six months after the shock. After 13 months the relative price of consumer durables returns to its original steady state level. Note that the magnitude of the increase in the relative price of consumer durables is almost identical regardless of which price measure is used (PPI for consumer durables or the chain-weighted price index for consumer durables). However, there is more persistence in the price response when the chain-weighted price index is used instead of the PPI for consumer durables. The price response when the chain-weighted price index is used returns to zero 3 months after the price response when the PPI for consumer durables is used. The only other major difference in the two VARs shows up in the response of real personal consumption expenditure on consumer durable goods. In the latter model, real personal consumption expenditure responds with a considerable lag.

Only after one year is the response significantly different from zero. The response reaches a peak of .04% fourteen months after the shock and six months later returns to zero.

Figure 3.6 reports variance decompositions for this system. The percentage of variance in the real price of consumer durables due to the variance in the nominal money supply is roughly the same no matter which consumer durable price measure is used. However, the percentage of variance in real expenditure on these goods attributable to the variance in the nominal stock of money is smaller when the system is estimated using the chain-weighted price index.

The results of figures 3.3 & 3.5 demonstrate that the estimated increase in the real price of consumer durables to a nominal money supply shock is indeed robust. The estimated responses in these figures are evidence that an increase in the nominal stock of money reduces interest rates and increases the relative price of consumer durables as well as the real quantity of consumer durables purchased and sold, at least gradually. Even though the initial expenditure response is not very robust, these results seem to tell a story of an increase in the demand for consumer durables brought about by an increase in the supply of nominal money.

IV: A VAR Focusing on the Market for New Automobiles

IV.a. Data Description and Characteristics

In this section I employ the same identification strategy as in the previous section to identify responses to a nominal money supply shock. This section focuses only on new automobiles rather than all consumer durable goods. This is done to see what happens when a specific type of consumer durable is analyzed rather than all consumer durable

goods. New automobiles represent the largest portion of consumer durable goods and this market has been researched extensively in the past. It will be interesting to see if the results presented in the previous section hold true when this disaggregated measure of consumer durables is analyzed. I use the same macro variables as in section III but in this model I include the relative price of new automobiles as well as real personal consumption expenditure on new autos rather than for all consumer durables.

I use monthly personal consumption expenditures in chained dollars for new autos (billions of dollars, seasonally adjusted at annual rates) as my real quantity measure. To flush out the price of new autos I take the ratio of monthly personal consumption expenditures in current dollars to monthly personal consumption expenditure in chained dollars¹¹. I deflate this implicit price measure by the PPI for all commodities to obtain the relative price of new autos. My motivation for computing the price of new autos in this fashion is that the earliest available date I found for the CPI of new autos was 1971:6. By computing the price of new autos by taking the ratio of nominal to real expenditures on new autos I obtain over 12 more years of monthly observations. The data are obtained from DRI/Citibase and the data range from 1959:1 to 1999:9. Once again, each data series is transformed to natural logs except the T-bill yield.

Figure 3.7 plots the real price of new cars and the nominal interest rate. Notice the general negative correlation between the two series. This is similar to figure 3.1, which focuses on all consumer durables. Figure 3.8 reports the real price of new autos and real personal consumption expenditure on new autos. Notice the volatility present in this

¹¹ For an explanation of how personal consumption expenditure is measured by the BEA see U.S. Department of Commerce (1990)

market. This provides support for studying what effect changes in the nominal money supply, possibly induced by economic policy, has on this market.

Table 2 reports the results of unit root tests. As in the previous section, augmented Dickey- Fuller tests incorporating 6 lags were performed on the data both in levels and in first differences. Once again, we cannot reject at reasonable levels the null of a unit root for each data series included in the model. No data series present in this model is stationary. Furthermore, the null hypothesis of a unit root is rejected for the first differenced data (at the 5% significance level), indicating the presence of just a single unit root in each series.

IV.b. Estimating the VAR

Just as before, the estimated VAR includes 12 lags across equations, a constant, and seasonal dummy variables. There are 476 total observations and 392 degrees of freedom and Q-Statistic diagnostics demonstrate that there is no autocorrelation present in the residuals of the VAR.¹² Figure 3.9 reports the estimated responses of each variable in the VAR to a nominal money supply shock. Once again, standard error bands were created using Monte-Carlo simulations using roughly 1000 replications.¹³ The responses reported in figure 7 for the macro variables are very similar to those reported in figures 3 and 4, showing considerable robustness in the estimated responses of the macro variables to a nominal money supply shock. The relative price of new automobiles increases on impact by just over one quarter of one percent. The price response reaches a peak increase of roughly .36% six months after the nominal money supply shock and then begins a

¹² The highest Ljung-Box Q-Statistic is 32.63 (43 degrees of freedom), indicating that 12 lags are once again sufficient to whiten the residuals (95% significance level).

¹³ In 11 of the replications, the largest simulated root of the VAR exceeded 1. Once again, these replications were simply dropped.

monotonic decline to zero. There is considerable persistence in the response of the relative price of new autos. The price response does not reach zero until about a year and a half after the nominal money supply increase.

Upon impact, real expenditure on new automobiles actually declines by over 1%, but this negative response is short lived (it is negative for only one month). This is a puzzling response and it may be indicative of misidentification. Eventually, real expenditure on new autos increases and 13 months after the nominal money supply shock is a full percentage point higher than before the shock. There is a great deal of persistence in this expenditure response, as it stays significantly different from zero for roughly 32 months. Figure 3.9 shows that increases in the nominal money supply cause both the relative price of new automobiles as well as real expenditure on new autos to increase. Furthermore, a comparison of figure 3.9 to figures 3.3 and 3.5 show that increases in the nominal money supply tend to have a greater effect on new automobiles than all consumer durable goods combined. Both the response of the relative price of new autos and real expenditure on new autos is higher than the corresponding responses for all consumer durables and these responses are positive for considerably longer time horizons. This tells us that increases in the nominal money supply tend to increase the demand for new autos, and this demand increase is greater and more persistent than the same demand increase for aggregate consumer durable goods.

Figure 3.10 reports variance decompositions for the new auto system. Note that of 25% of the variance in the relative price of new autos is due to the variance in the nominal money supply. This is a greater percentage than was found for the real price of aggregate consumer durables. This also tells us that shocks to the nominal money supply

have a greater impact on this more narrow market than for all consumer durables combined.

V: An Eight Variable VAR with Aggregate Consumer Durables and New Autos

V.a. Motivation and Estimation

The previous two sections presented evidence that nominal money supply shocks have real effects on the market for both aggregate consumer durable goods and new automobiles. This evidence was obtained by estimating two separate just identified vector autoregressions. This section is motivated by a test for robustness of these estimated results. In this section, an eight variable VAR is estimated incorporating prices and quantities of both aggregate consumer durables and new automobiles. The reason behind estimating this larger VAR is that there may be some interaction between the two markets and this needs to be taken into effect when attempting to isolate how shocks to the nominal money supply affect each market independently. The eight variable VAR is estimated with all of the same data series that were included in the previous two sections. Since in section III, two different price measures for consumer durables were used, the eight variable system is estimated twice, once with the PPI for consumer durables and once with the chain-weighted price index for consumer durables. There are 476 total observations and 368 degrees of freedom present in the VAR and Ljung-Box Q-Statistics show no signs of autocorrelation in the residuals of the VAR. Just as in the previous estimated systems, each variable is transformed to logs except for the yield on the 3-month T-Bill and each series is first differenced.¹⁴

¹⁴ Unit root tests are not reported in this section because each data series has been tested for non-stationarity in previous sections.

This larger VAR also includes 12 lags across equations, a constant, and seasonal dummy variables. The identification strategy is the same as before. Figure 3.11 reports the estimated responses of each variable in the system to a nominal money supply shock when the PPI for consumer durables is used to construct the relative price of aggregate consumer durables. Figure 3.12 shows variance decompositions. Inspecting the four right-hand-side graphs of figure 3.11 reveals the consistency of the estimated responses of the macroeconomic variables to a nominal money supply shock. These results are almost identical to those reported in sections III and IV. Increases to the nominal money supply raise industrial production, cause a decline in the non-annualize yield on government securities, and temporarily increases real money balances.

Now compare the estimated responses of the relative price of aggregate consumer durable goods when the PPI for consumer durables is employed to compute the relative price of these goods. The estimated response of this price in figure 3.11 is almost identical to the estimated price response reported in figure 3.3. In figure 3.11, the relative price of consumer durable goods increases on impact by just less than .2% and roughly 11 months after the nominal money shock the response is no longer statistically significant from zero. Recall that this is almost exactly the response reported in section III.b.

Next, focus on the response of the real price of new automobiles. Figure 3.11 reports that the real price of new autos increases on impact by about .2% and six months after the shock is just over .3% higher than before the nominal money supply increase. This is very similar to the response of the real price of new autos to a nominal money supply shock reported in figure 3.9 (the six variable system incorporating new autos). However,

the response of the real price of new autos as reported in figure 3.11 returns to zero within 12 months of the nominal money supply shock. This return occurs approximately six months sooner than in the six variable case.

The response of real personal consumption expenditure on consumer durable goods reported in figure 3.11 is also similar (although not identical) to that reported in figure 3.3. This estimated response in the eight variable system is not significantly different from zero until 5 months after the nominal money supply shock and reaches a peak of roughly .7% seventeen months after impact. There is also a great deal of persistence, as the response does not return to zero until 38 months after the nominal money increase.

The estimated response of real expenditure on new autos presented in figure 3.11 is negative on impact, just as in figure 3.9. This negative response is slightly larger in the eight variable system than in the corresponding six variable system but is still relatively short lived (roughly 2 months). This estimated response in the larger VAR reaches a peak of roughly 1% one year after impact but this response is no longer significant from zero just nineteen months after the increase in nominal money. So although the magnitude of the response of real expenditure on new autos as reported in figure 3.11 closely matches that of the response in the six variable system, the persistence of the response in the smaller VAR is not evident.

Figure 3.13 reports the estimated responses of each of the variables in the eight variable system to a nominal money supply shock when the chain-weighted price index is used to compute the real price of consumer durables. Figure 3.14 reports variance decompositions. It is easily seen that the estimated responses of industrial production, the yield on the 3-month T-Bill, real expenditure on new autos and real expenditure on

consumer durables do not match those for the six variable systems reported in figures 3.5 and 3.9. In figure 3.13, the response of industrial production to a nominal money supply shock is never statistically greater than zero. Also, the 3-month T-Bill yield does decline, but not by as great a magnitude as reported in the previous estimations. Furthermore, both real expenditures on aggregate consumer durables and on new autos are significantly negative on impact, and neither is ever statistically greater than zero. These results are somewhat disheartening. However, simple inspection shows the estimated responses of the real price of consumer durables and the real price of new automobiles reported in figure 3.13 do match those reported in figures 3.5 and 3.9 respectively. This match is present both in magnitude and in persistence.

The results of figures 3.3, 3.5, 3.9, 3.11 and 3.13 demonstrate a definite robustness in the estimated response of the real price of both aggregate consumer durables and new automobiles to a nominal money supply shock. The response of real expenditure on consumer durables and new autos is not found to be very robust. This is somewhat puzzling and may suggest a problem with identification. The relative price response, however, is what this chapter, and dissertation, is particularly interested in. These results imply that it can be said with a great deal of confidence that decreases in interest rates brought about by an increase in the nominal supply of money are indeed capitalized in the real price of consumer durable goods. This result holds true whether one focuses on an aggregate measure of consumer durable goods, or a disaggregated measure (new automobiles).

VI: Conclusion

This chapter presents empirical evidence of the real dynamic effects of nominal money supply shocks on the market for consumer durable goods. Evidence of these effects is presented in both the market for aggregate consumer durables as well as the market for new automobiles. It is shown that nominal money supply shocks cause short run increases in both the relative price and real expenditure of consumer durables. These results are found to hold when both the market for aggregate consumer durable goods is examined as well as the market for new automobiles. Furthermore, the increase in the relative price of consumer durables resulting from a shock to the nominal money supply is found to be robust across different measures of the real price of consumer durables as well as across different estimated models.

This chapter estimates a number of vector autoregressions to check for robustness in the response of the real price of consumer durables. Imposing nothing more than long-run monetary neutrality identifies these vector autoregressions. Long-run monetary neutrality has almost reached the status of a stylized fact in macroeconomics and the identification scheme employed based on this assumption has wide precedent throughout the literature in macroeconomic time series analysis.

The results of this chapter add to the already wide body of evidence of the short-run real effects of changes in the nominal supply of money and are of independent interest. However, this chapter makes no attempt to uncover the economic forces underlying these real effects on the market for consumer durables. It is important for economists to attempt to illuminate these economic forces if this volatile market is to ever be fully understood. In the next chapter, an attempt is made to reconcile economic theory to the

estimated results presented above. In particular, the next chapter studies to what extent the estimated increase in the real price of consumer durable goods can be explained by dynamic optimizing behavior.

Figure 3.1: The Real Price of Consumer Durables and the Interest Rate

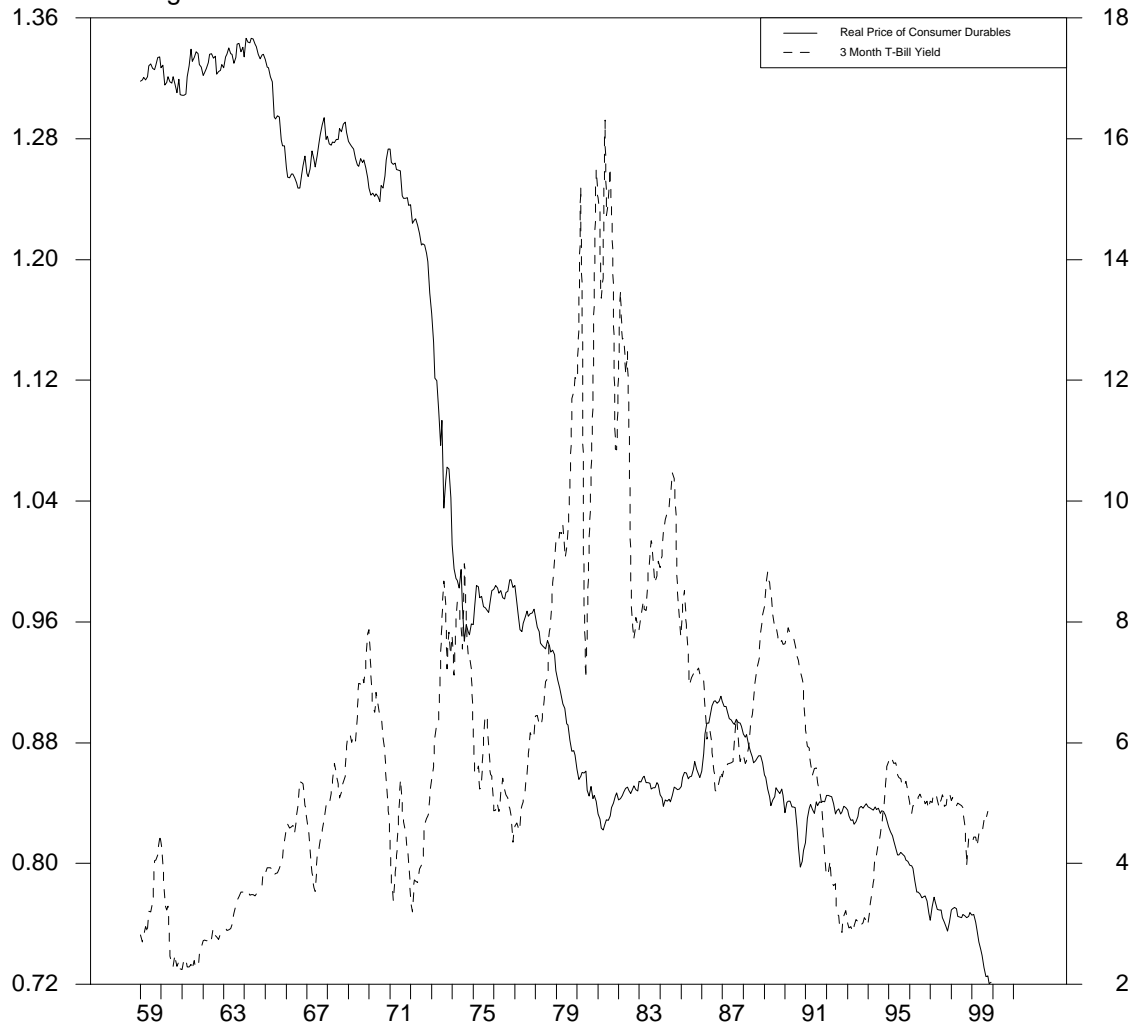
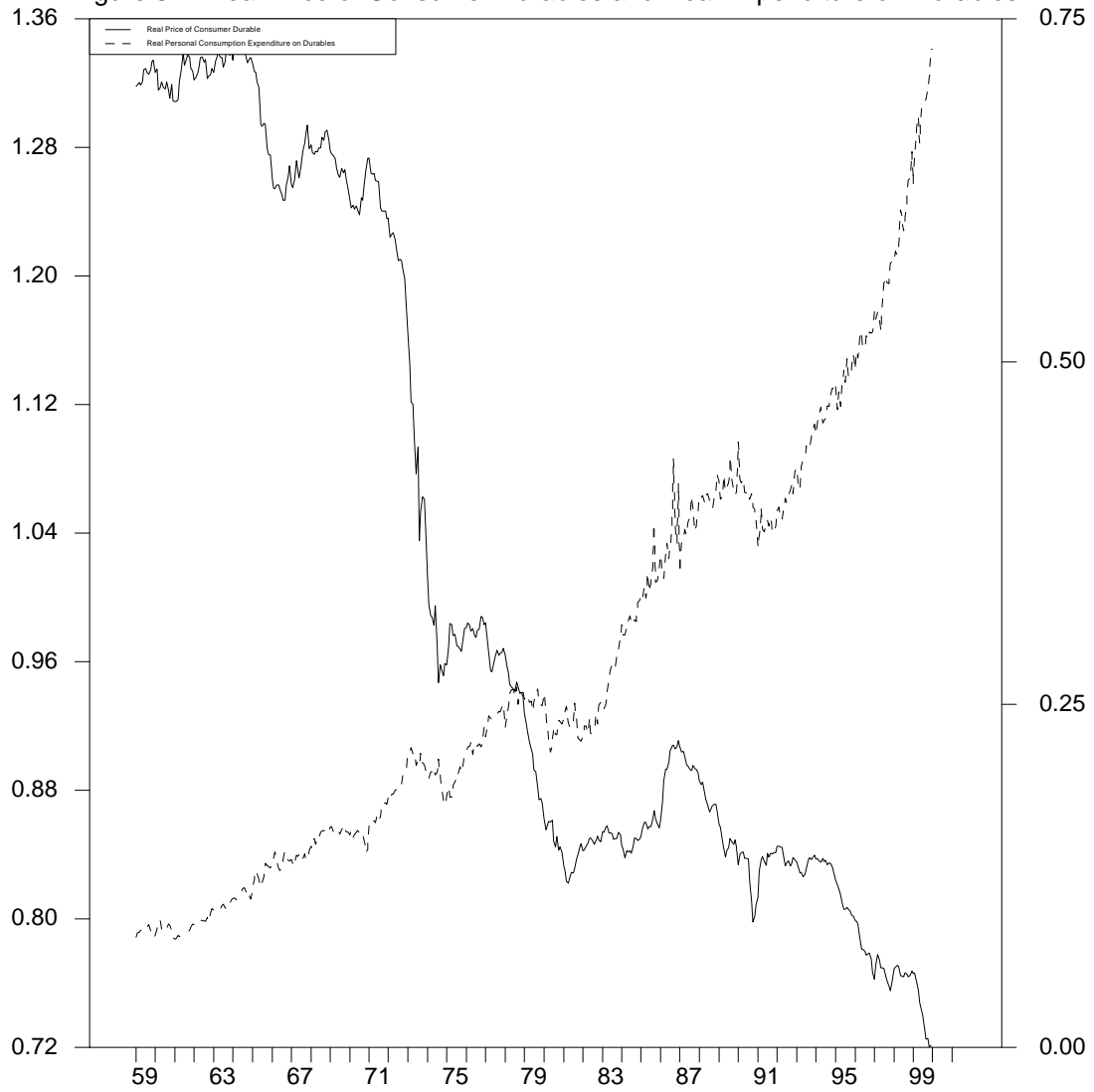


Figure 3.2: Real Price of Consumer Durables and Real Expenditure on Durables



| TABLE 1 | | |
|--------------------------------------|-----------|--------------------|
| Unit Root Tests (t-statistics) | | ADF Tests (6-lags) |
| Variable (in logs except for T-Bill) | In Levels | First Differences |
| PPI for Consumer Durables | -1.697 | -8.735 |
| Chain Weighted Price Index | -0.507 | -6.254 |
| Expenditure on Consumer Durables | -1.058 | -8.644 |
| Yield on 3 month T-Bill | -2.007 | -10.33 |
| Industrial Production Index | -1.176 | -8.396 |
| Real Money | -0.692 | -7.539 |
| M1 | -0.507 | -8.922 |
| ADF Tests (6-lags and time trend) | | |
| | In Levels | First Differences |
| PPI for Consumer Durables | -1.105 | -8.844 |
| Chain Weighted Price Index | -1.737 | -6.247 |
| Expenditure on Consumer Durables | -2.344 | -8.652 |
| Yield on 3 month T-Bill | -1.878 | -10.357 |
| Industrial Production Index | -2.56 | -8.413 |
| Real Money | -1.366 | -7.533 |
| M1 | -1.051 | -8.922 |

Figure 3.3: Responses to Money Supply Shocks (PPI) - LR Restrictions

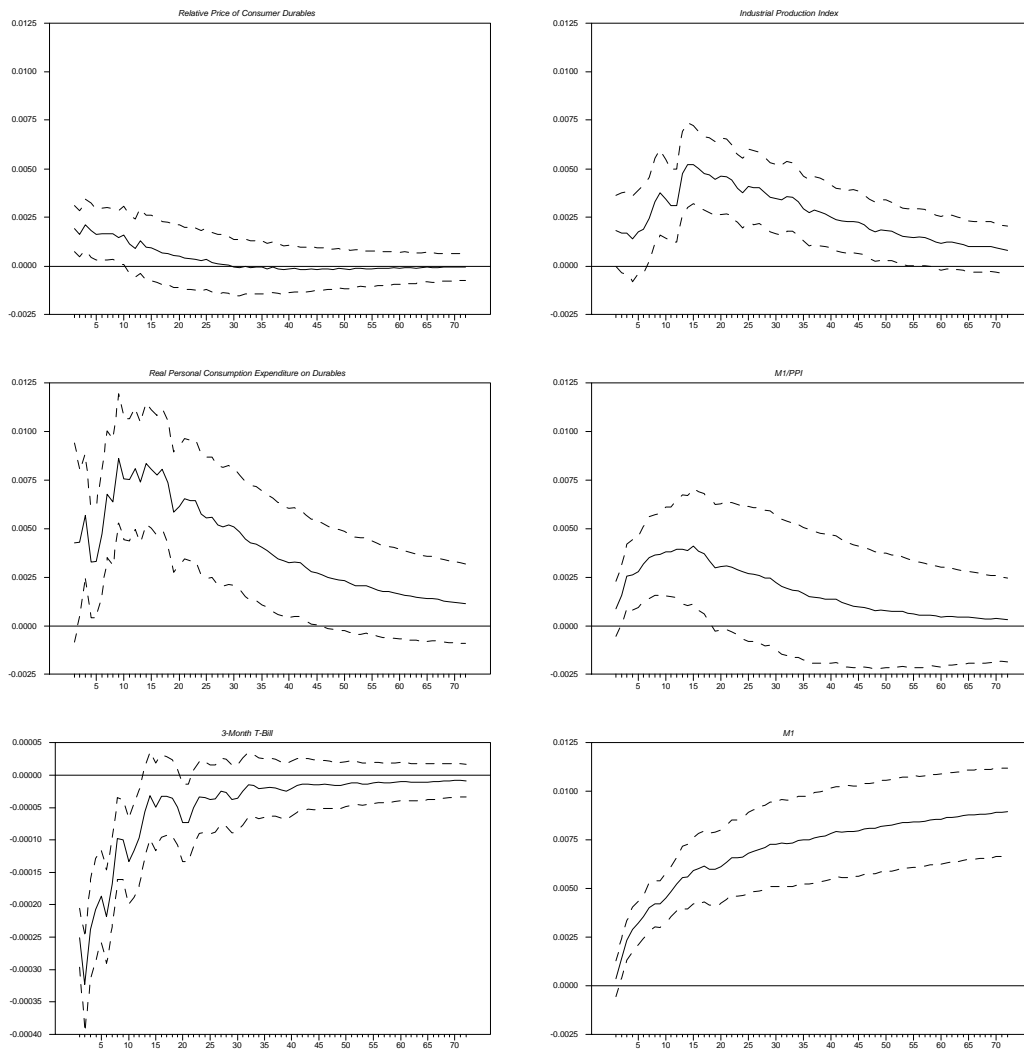


Figure 3.4: Contribution of Money Supply Shocks to Variance

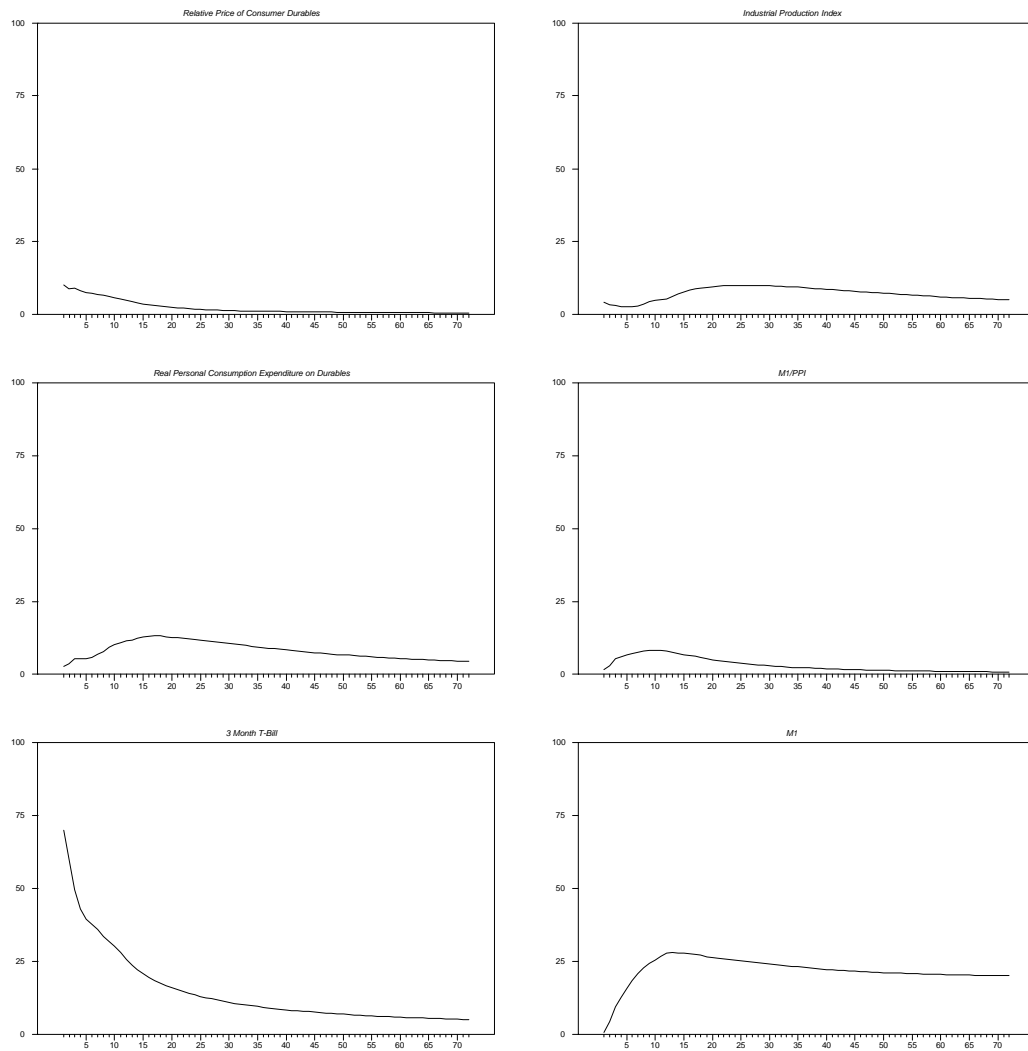


Figure 3.5: Responses to Money Supply Shocks (CWPI) - LR Restrictions

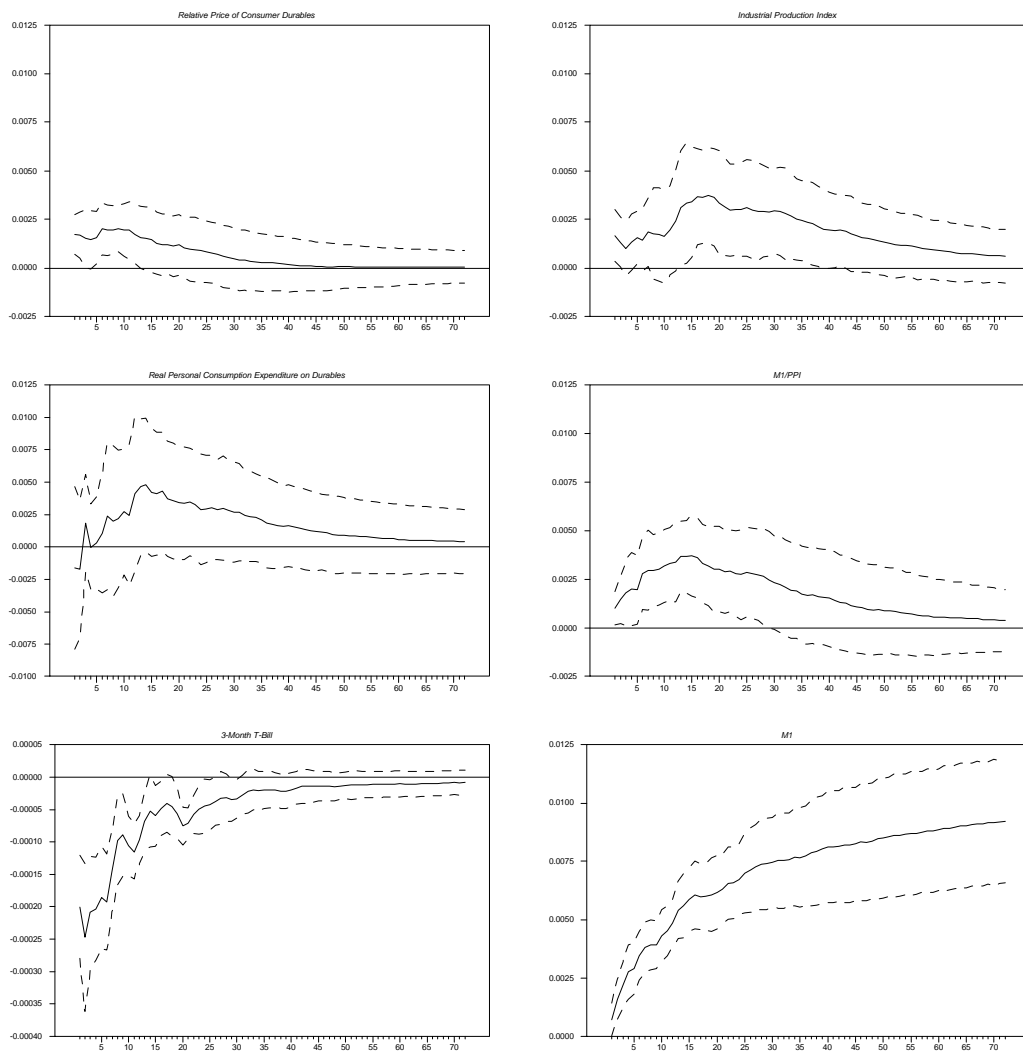


Figure 3.6: Contribution of Money Supply Shocks to Variance - CWPI

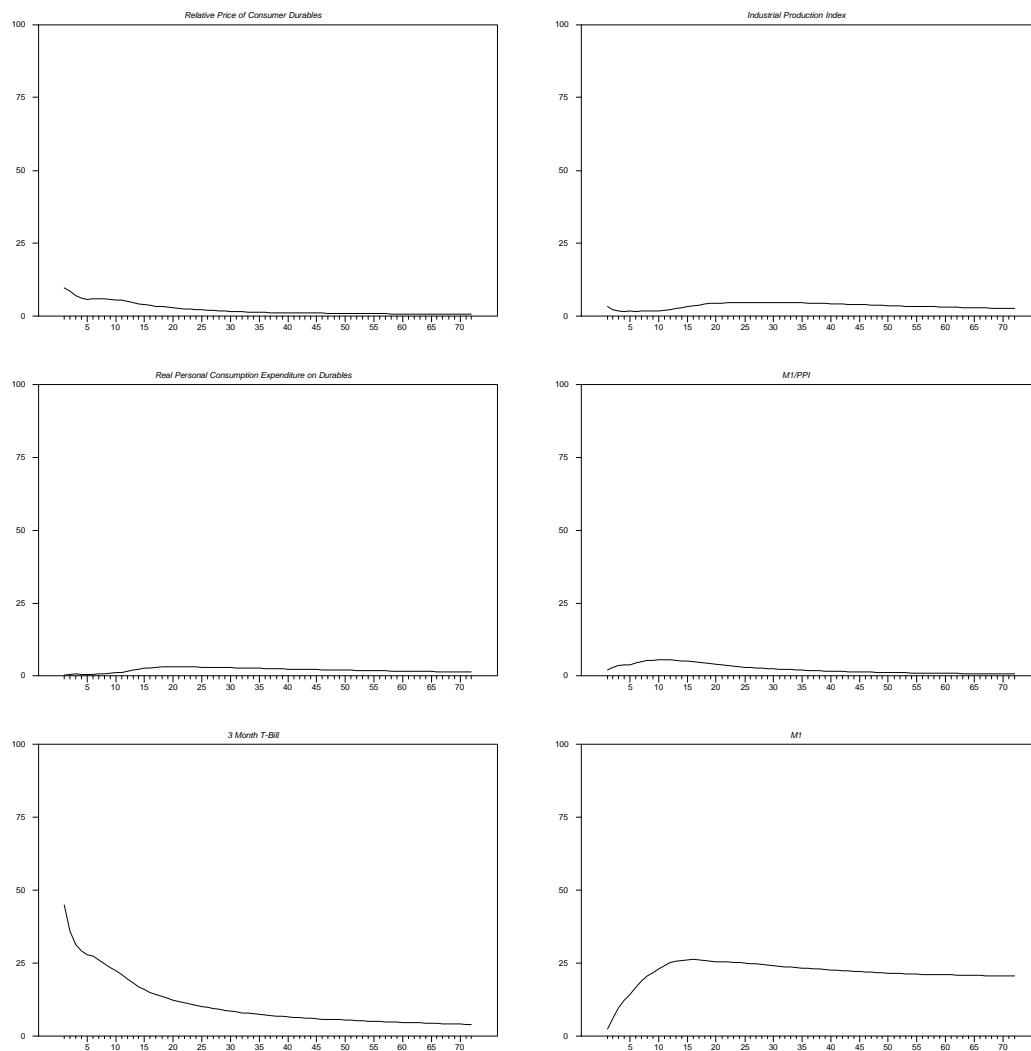


Figure 3.7: The Real Price of New Autos and the Interest Rate

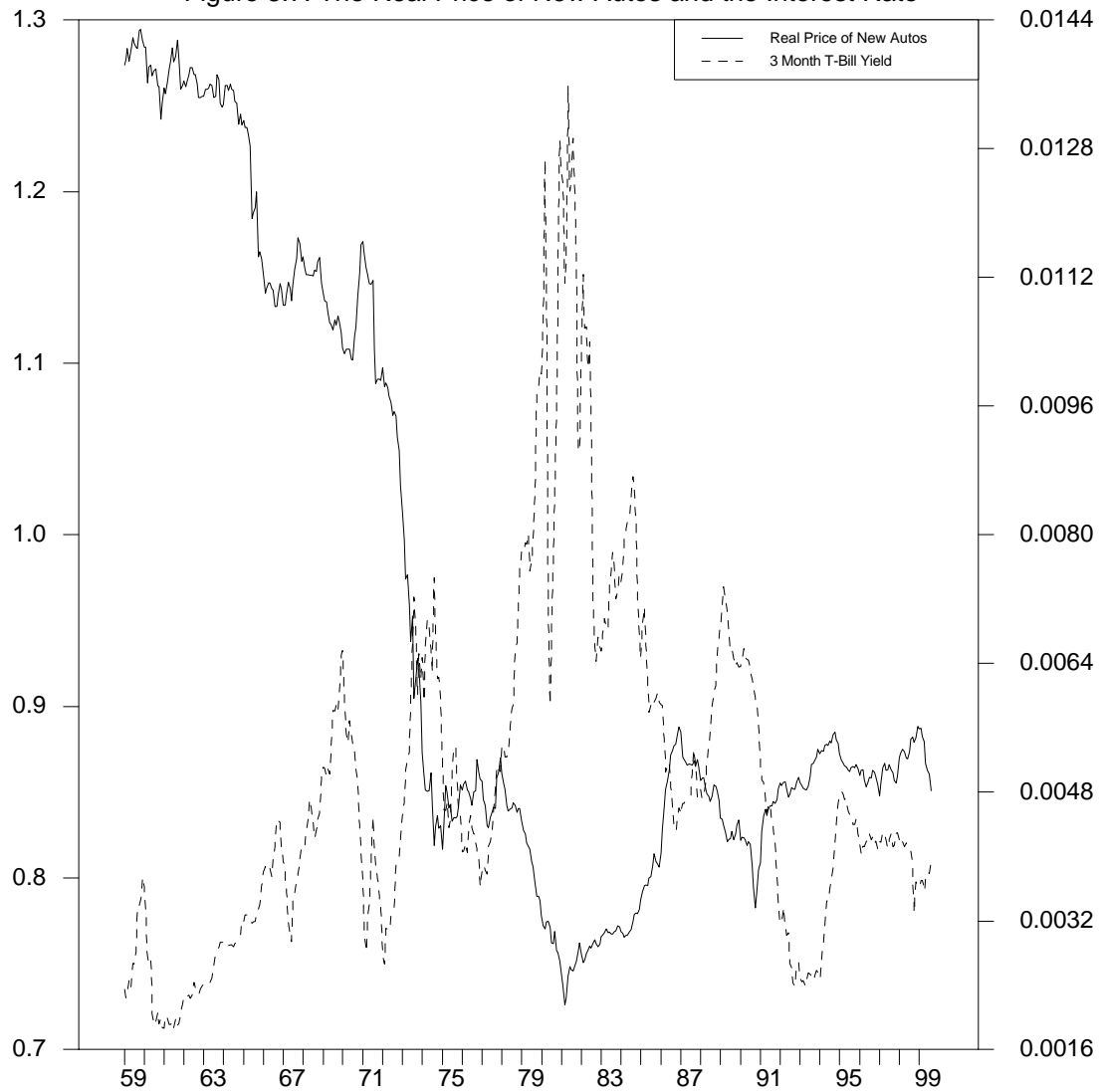
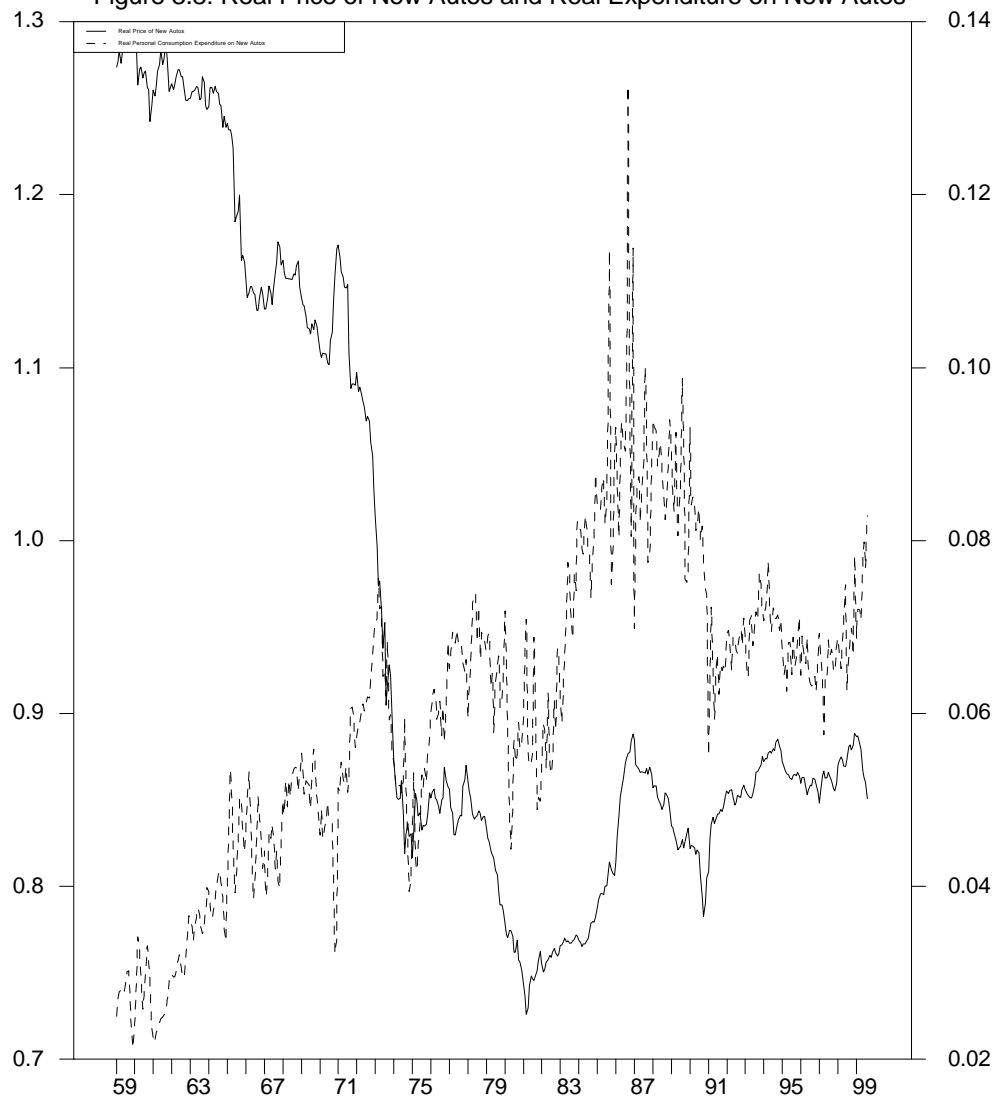


Figure 3.8: Real Price of New Autos and Real Expenditure on New Autos



| TABLE 2 | | |
|--------------------------------------|--|-------------------|
| Unit Root Tests (t-statistics) | Augmented Dickey Fuller Tests (6-lags) | |
| Variable (in logs except for T-Bill) | In Levels | First Differences |
| Relative Price of New Autos | -1.733 | -6.651 |
| Real Expenditure on New Autos | -2.101 | -10.532 |
| Yield on 3 month T-Bill | -1.977 | -10.311 |
| Industrial Production Index | -1.124 | -8.332 |
| Real Money | -0.697 | -7.54 |
| M1 | -0.709 | -8.746 |
| ADF Tests (6-lags and time trend) | | |
| | In Levels | First Differences |
| Relative Price of New Autos | -1.111 | -6.796 |
| Real Expenditure on New Autos | -2.339 | -10.563 |
| Yield on 3 month T-Bill | -1.824 | -10.347 |
| Industrial Production Index | -2.54 | -8.344 |
| Real Money | -1.368 | -7.533 |
| M1 | -0.678 | -8.759 |

Figure 3.9: Responses to Money Supply Shocks - LR Restrictions

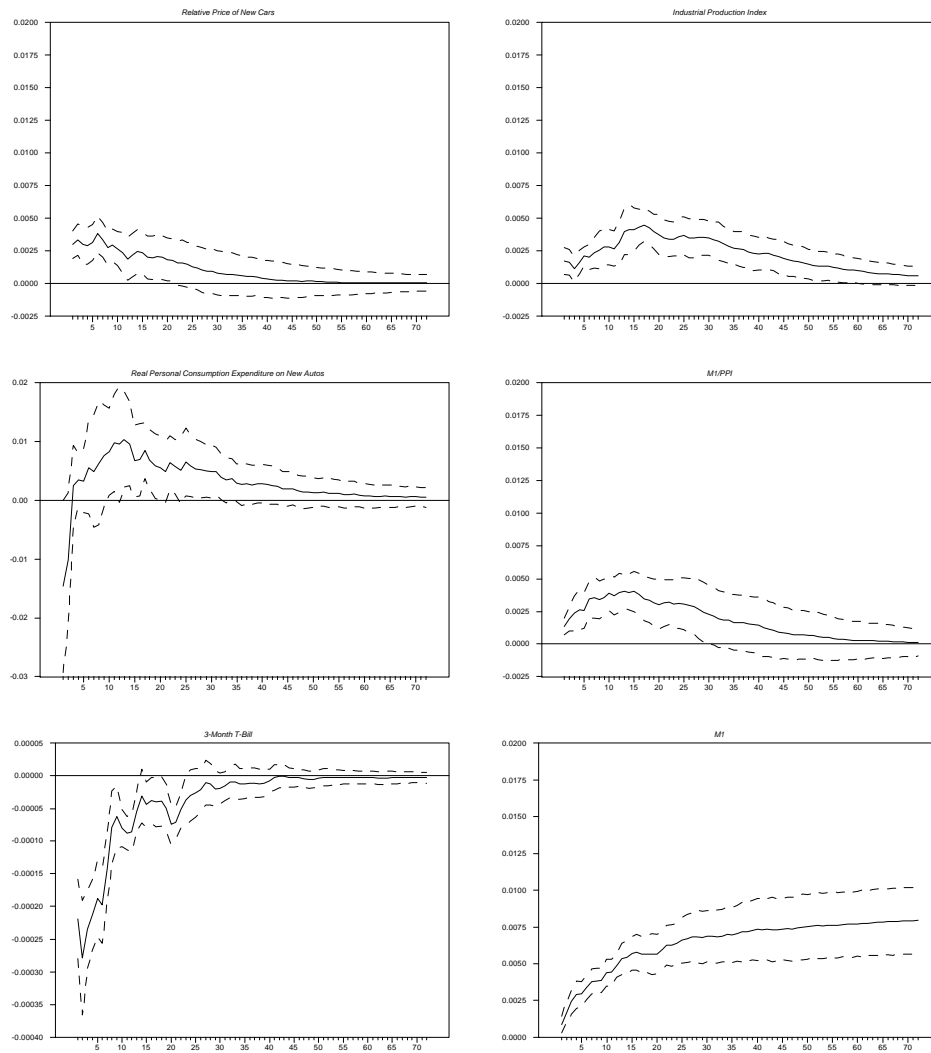


Figure 3.10: Contribution of Money Supply Shocks to Variance

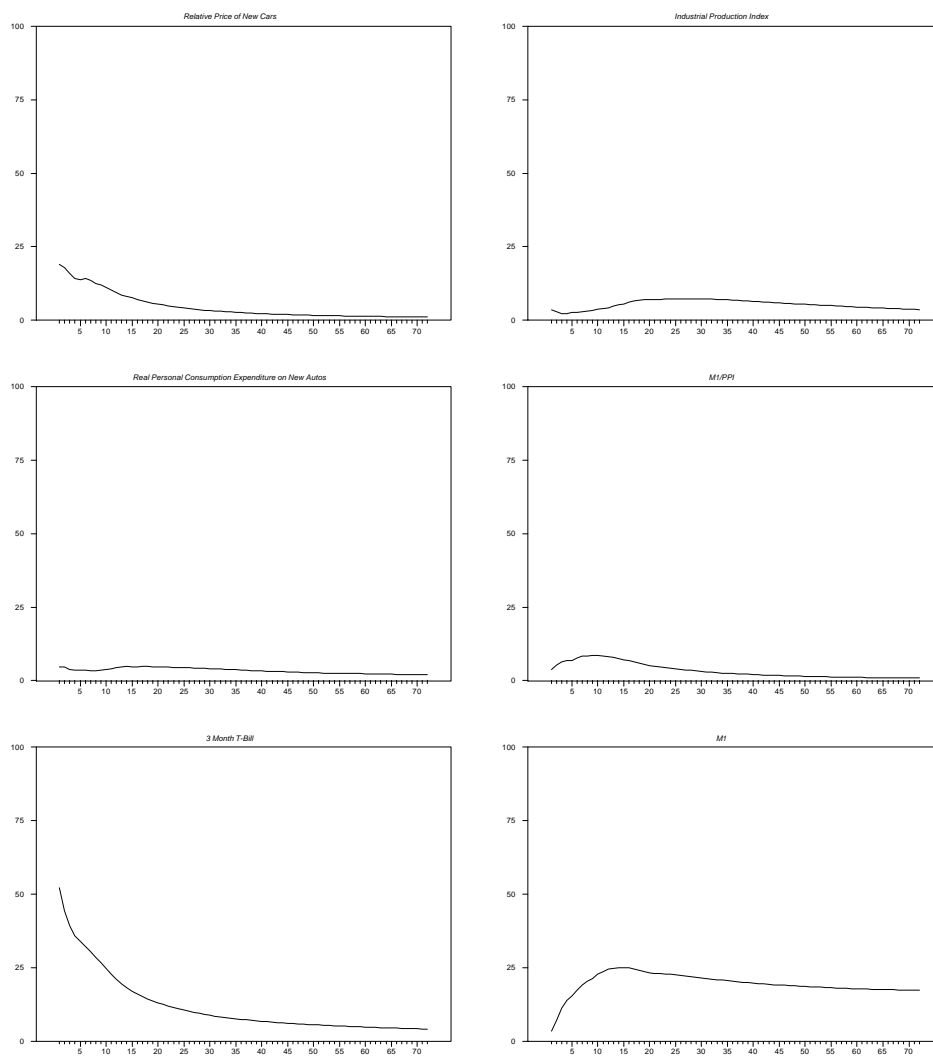


Figure 3.11: Responses to Money Supply Shocks (PPI-CD) - LR Restrictions

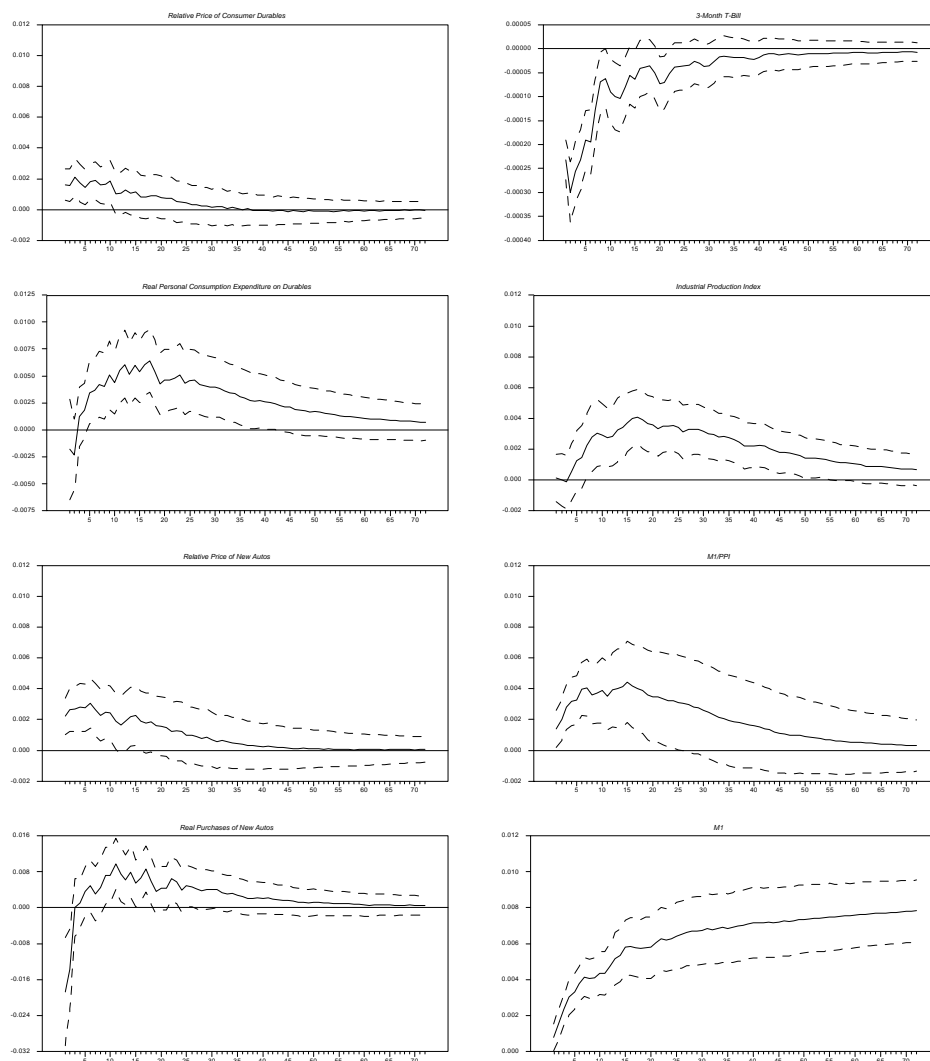


Figure 3.12: Contribution of Money Supply Shocks to Variance

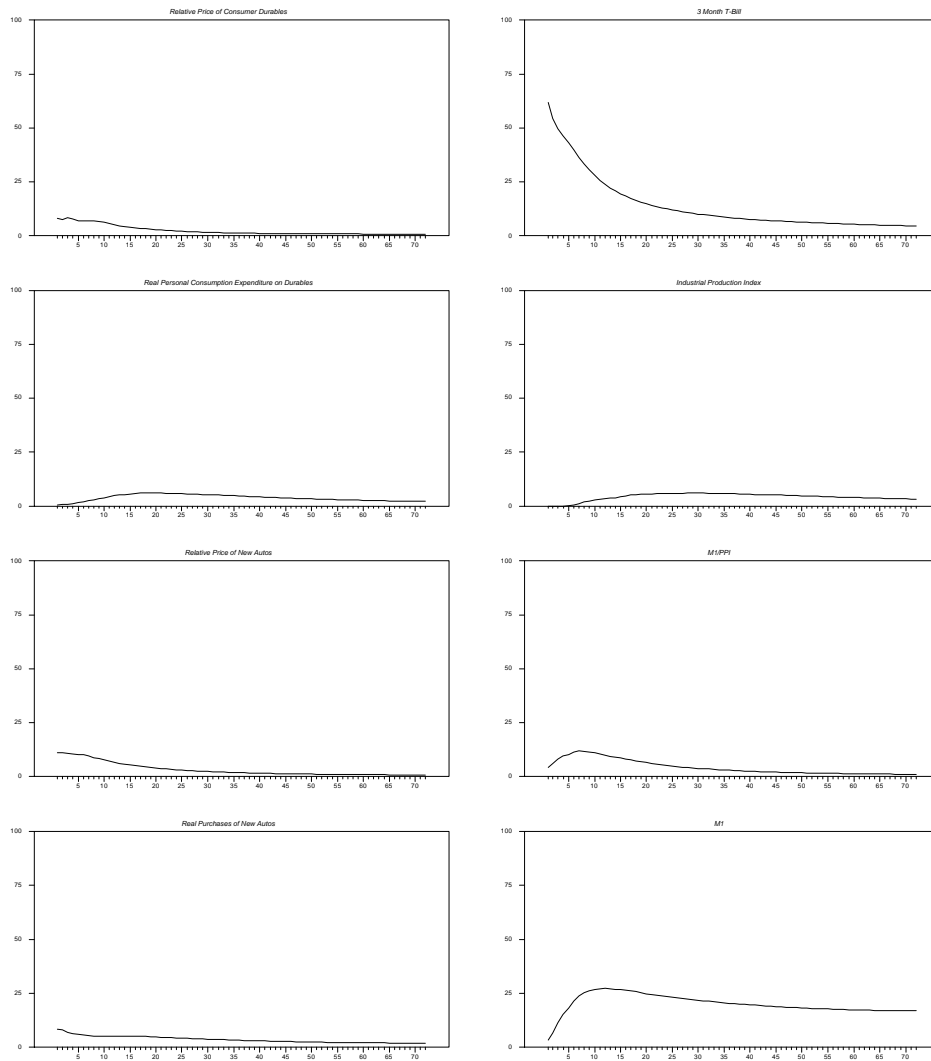


Figure 3.13: Responses to Money Supply Shocks (CWPI) - LR Restrictions

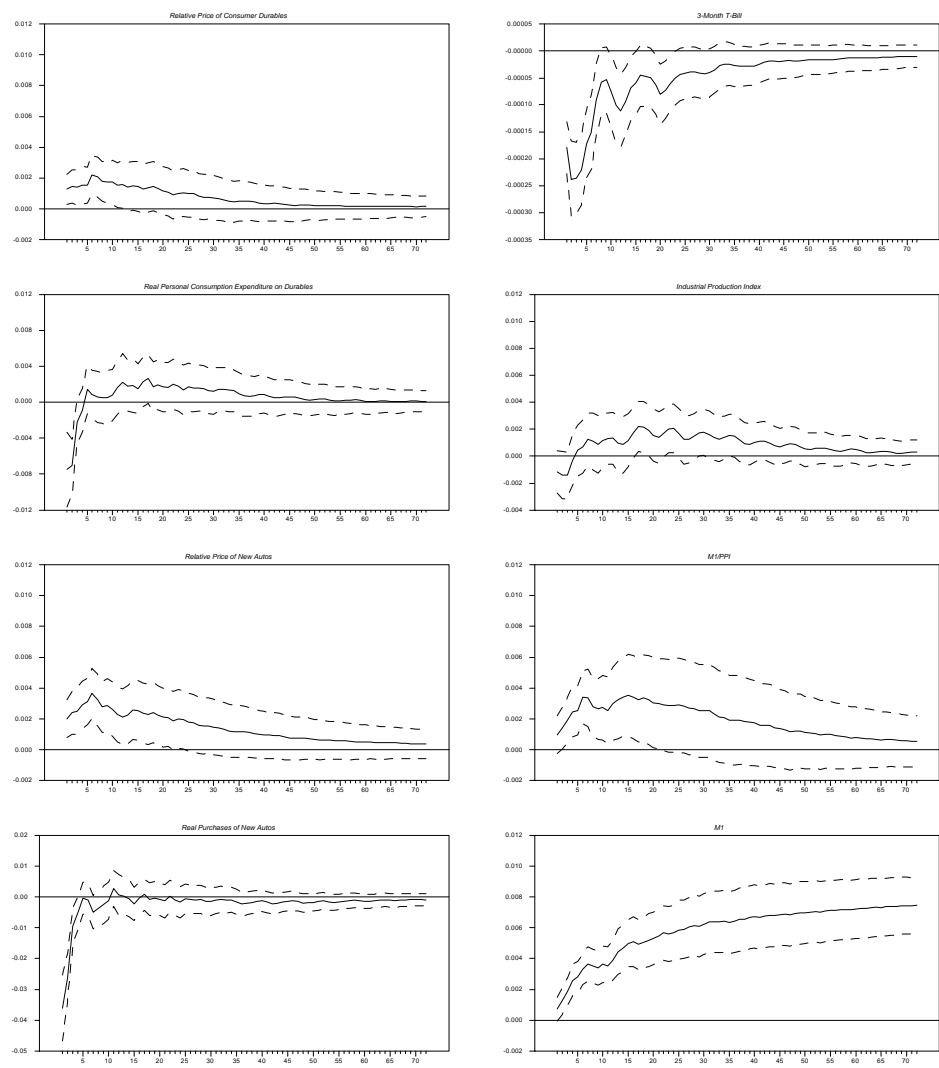
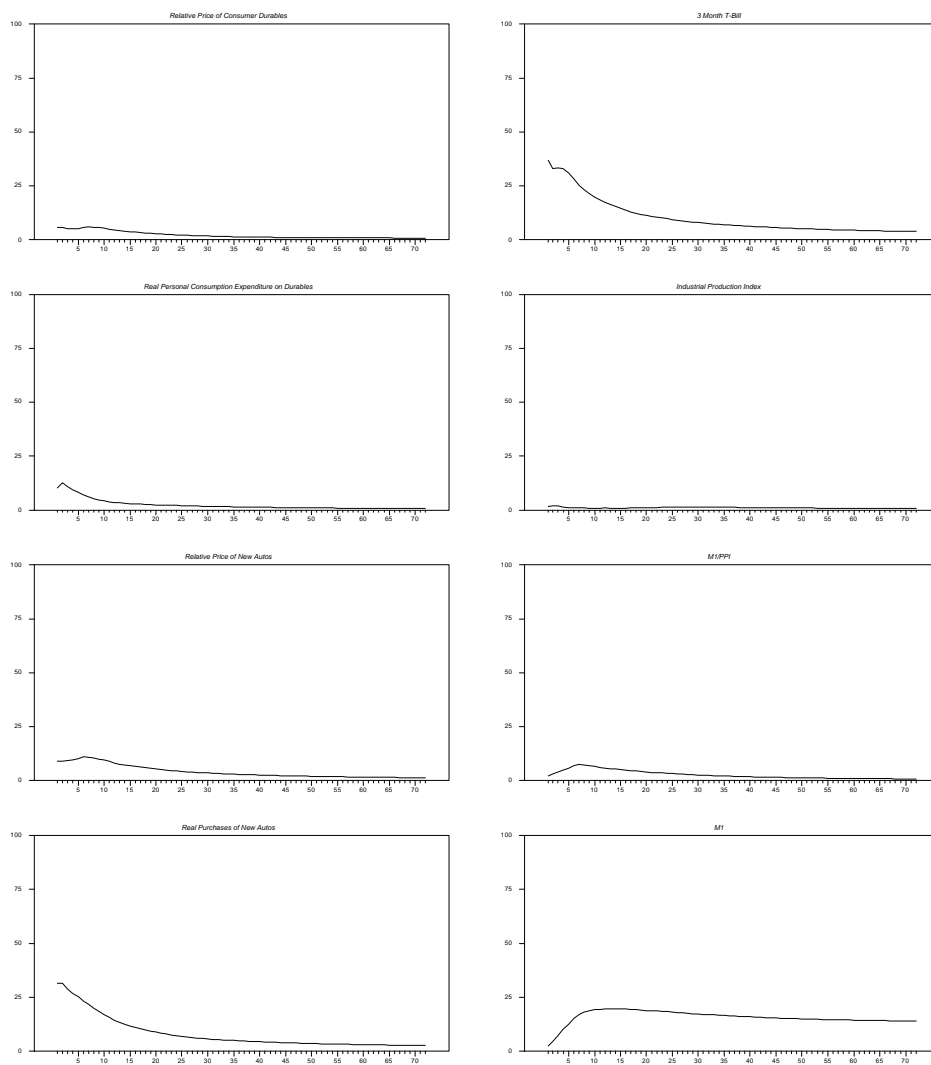


Figure 3.14: Contribution of Money Supply Shocks to Variance - CWPI



CHAPTER 4: DYNAMIC OPTIMIZATION AND SIMULATIONS

I: Introduction

The previous chapter presented empirical evidence regarding the dynamic response of relative prices and real expenditure in the market for consumer durable goods to a nominal money supply shock. These responses were obtained by estimating just identified vector autoregressions incorporating the assumption that nominal money is neutral over infinite time horizons. Although the results presented in the previous chapter are interesting in their own right, in this chapter we examine the economic forces at work behind these estimated empirical responses.

The purpose of this chapter is to reconcile economic theory to actual estimated dynamic responses. In particular, this chapter attempts to find out if the estimated dynamic equilibrium price response presented in chapter 3 can be explained by dynamic optimizing behavior. This chapter studies the extent to which representative agent, dynamic equilibrium models can accurately predict the response of the equilibrium price of consumer durable goods to a shock in the nominal money supply.

In this chapter I specify a basic dynamic optimization model incorporating consumer durables and solve for the first order conditions. I then follow Campbell (1994) and linearly approximate an Euler equation implied by the models first order conditions as well as a simple supply schedule to obtain an approximate equilibrium price equation. I then simulate how this equilibrium price responds to a nominal money supply shock.

This method has previously been reserved for studying real business cycle theories and has yet to be applied to consumer durable goods. Solving these intertemporal models in this manner allows me to examine the channels through which exogenous shocks affect the real price of consumer durables. It is found in this chapter that a nominal supply shock affects the demand for consumer durables through its influence on the user cost of consumer durables, which is dependent upon the expected time path of nominal interest rates and inflation.

Much research has been devoted to developing dynamic optimization models of consumer durables. Obsteld and Rogoff (1996), Kau and Keenan (1980), and Mankiw (1985) present frictionless representative agent models. Chah, Ramey, and Starr (1995) and Alessie, Devereux, and Weber (1997) consider liquidity constraints. Furthermore, Bernanke (1985), Eberly (1994), and Startz (1989) introduce transactions costs. These studies, among others, utilize models of consumer durable goods to analyze a variety of economic questions. However, there has been no attempt as of yet to empirically test the dynamic implications of models such as these in the manner in which this essay does.

This chapter compares the predictive power of a simple frictionless model to one incorporating liquidity/borrowing constraints. Both aggregate consumer durables are considered as well as new automobiles. As discussed in the literature review in chapter 2, liquidity constraints may be the most relevant of all frictions that may be added to intertemporal optimization models incorporating consumer durables. It is shown that although the frictionless model does a relatively effective job of accurately depicting dynamic behavior, the liquidity constraint model can improve upon the simple model for certain measures of consumer durable goods.

The next section presents a frictionless dynamic model of consumer durable goods. This model is formulated and solved for the approximate equilibrium price response to a nominal money supply shock. Simulation results are presented for certain calibrated parameter values. Section III performs the steps for a dynamic model incorporating a liquidity/borrowing constraint. The predictive power of this model is compared to that of the frictionless model. Finally, section IV gives concluding remarks.

II: A Frictionless Dynamic Model of Consumer Durables

II.a. Theoretical Model

In this section I consider a simple representative agent, dynamic equilibrium model that incorporates consumer durables. The model has the representative agent considering the intertemporal tradeoff between consumption goods and durable goods in order to maximize expected lifetime utility. This model is very similar to many other durable goods models found in the literature (Chah, Ramey and Star (1995), Wilson (1998), Kau and Keenan (1980), and Obstfeld and Rogoff (1996), pp. 96-98). The model is one of perfect foresight, which ignores risk.

The model is set up as follows. Let the representative agent maximize the intertemporal objective function:

$$V_0 = \sum_{t=0}^{\infty} (1/1 + \mathbf{r})^t U(D_t, C_t) \quad (1)$$

where C_t is the quantity of nondurable consumption, D_t is the stock of consumer durables and \mathbf{r} is the pure rate of time preference.¹ Also, although agents derive utility from the

¹ The discount function associated with this objective function ignores the possibility pointed out by Angeletos, et. al (2001) that often times consumers are more impatient when they face short-run tradeoffs

flow of services that durable goods offer over time, I follow convention and assume that this flow is proportional to the stock of durables. I also assume that the decision frequency is the same as the data frequency.

The consumer is faced with an intertemporal budget constraint:

$$Y_t(1-t) + \left[\frac{1+(1-t)R_t}{1+\Pi_t} \right] A_t = A_{t+1} + C_t + P_{dt} \mathbf{m} D_t + P_{dt} (D_t - D_{t-1} + \mathbf{d} D_{t-1}) \quad (2)$$

This budget constraint is in real terms with nondurables as the numeraire. The left hand side of the budget constraint represents sources of funds. The first term is real after tax income (t is the income tax rate), followed by the stock of financial assets (A_t) plus interest earnings. The right hand side defines the uses of funds: financial assets carried over into next period (A_{t+1}), current consumption (C_t), expenses incurred through maintenance, repairs, and insurance of ownership of durable goods \mathbf{m} (assumed to be proportional to the current stock) and finally, gross expenditure on consumer durables, where \mathbf{d} is the rate of depreciation.²

The representative consumer solves the model by choosing C_t , D_t , and A_{t+1} to maximize (1) subject to (2). The Euler equations implied by the model are:

$$(1/1+r)^t U_c(D_t, C_t) = I_t \quad (3)$$

$$\frac{I_{t+1}}{I_t} = \frac{1+\Pi_{t+1}}{1+(1-t)R_{t+1}} \quad (4)$$

$$(1/1+r)^t U_D(D_t, C_t) = I_t P_{dt} (1+\mathbf{m}) - I_{t+1} P_{dt+1} (1-\mathbf{d}) \quad (5)$$

rather than long-run tradeoffs. The authors suggest a hyperbolic discount function rather than the standard geometric function utilized here.

² Carroll (2001) asserts that intertemporal utility maximization models should incorporate uncertainty and a certain level of consumer impatience. Without these aspects one may draw false implications from intertemporal models such as this one.

where λ_t is the multiplier associated with the budget constraint at time t . By substituting (3) and (4) into (5) to eliminate the multipliers we achieve the tangency condition that explains the optimal intratemporal tradeoff between consumption goods and durable goods:

$$\frac{U_D(D_t, C_t)}{U_C(D_t, C_t)} = P_{dt}(1 + m) - P_{dt+1} \left[\frac{1 + \Pi_{t+1}}{1 + (1 - \delta)R_{t+1}} \right] (1 - d) \quad (6)$$

Equation (6) tells us that along the optimal path, the marginal rate of substitution between durables and nondurables equals the user cost of durables. The user costs of durables is the amount of nondurable consumption foregone by purchasing one unit of a durable good, using it, and then selling it at the end of the period. The first term on the right hand side of (6) represents the cost of purchasing a durable good in period t . The second term on the right hand side is the discounted resale value of the undepreciated durable good in period $t+1$. It will be shown that shocks to the nominal money supply alter the user cost, thereby causing the demand for consumer durables to react. This condition, combined with the intertemporal resource constraint, determines the optimal paths of consumption on durables and nondurables.

To complete the market for consumer durables, we must include supply behavior. I therefore assume the following simple relationship:

$$D_{t+1} - D_t = aP_{dt} - dD_t \quad (7)$$

where:

$$a > 0$$

This simply states that the quantity supplied of consumer durables is positively related to the price of consumer durables. Equation (7) describes the evolution of the stock of

consumer durables. The first term on the right-hand side of (7) represents the flow supply of new durables. This supply equation is obviously extremely simple and ignores many potentially important channels, such as interest rate effects on the supply of consumer durables.

II.b. Log-Linearization and Implied Responses

This section attempts to answer the question of whether or not this basic dynamic equilibrium model predicts an equilibrium price response of consumer durables that is consistent with the estimated response functions reported in the previous chapter. To answer this question I solve the model for the approximate equilibrium price response and simulate how this theoretical equilibrium price responds to nominal money supply shocks. I assume that the rate of interest and inflation are exogenous to the market for consumer durables. This assumption rules out feedback effects from the market for consumer durables to financial markets but it makes the solution tractable and it has precedent in the literature³. I also assume that shocks to the nominal money supply do not indirectly affect consumer durable expenditure through its effect on nondurable consumption. This assumption implies that the only channel through which money supply shocks affect equilibrium in the market for consumer durables is through their effect on the rate of interest and inflation. I can therefore, given certain calibrated parameter values, simulate the theoretical response of the price of consumer durables to the estimated dynamic responses of inflation and the interest rate to nominal money supply shocks.

³ See, for example, Wilcox (1990) and Mankiw (1985)

To implement this solution strategy I follow Campbell (1994). The strategy involves log-linearly approximating the Euler equations and the supply equation, and then solving the log-linear system for the equilibrium price. This allows the theoretical equilibrium real price of consumer durables to be a log-linear function of exogenous shocks, as in the VAR. Taking on this approach involves specifying a specific form for the point-in-time utility function. For simplicity, I assume the Cobb-Douglas form:

$$U(D_t, C_t) = g \log(C_t) + (1 - g) \log(D_t). \quad (8)$$

Substitute this form of the utility function into (6), the intratemporal trade-off, and make approximations for the ratios of gross interest rates to obtain:

$$\left(\frac{1-g}{g} \right) \frac{C_t}{D_t} = p_{dt}(1 + m) - p_{dt+1}(1 + \Pi_{t+1} - (1 - t)R_{t+1} - d) \quad (9)$$

Solving for p_{dt} and taking logs yields:

$$\log(p_{dt}) = \log \left\{ \left(\frac{1-g}{g} \right) \frac{C_t}{D_t} + p_{dt+1} [1 - d - (1 - t)R_{t+1} + \Pi_{t+1}] \right\} - \log(1 + m) \quad (10)$$

In general, note that the first order Taylor Series approximation of $f(y, x) = \log(ay + bx)$ around (y_0, x_0) is:

$$f(y, x) \approx \log(ay_0 + bx_0) + \left(\frac{ay_0}{ay_0 + bx_0} \right) [\log(Y) - \log(Y_0)] + \left(\frac{bx_0}{ay_0 + bx_0} \right) [\log(X) - \log(X_0)]$$

When this approximation is applied to (10), and the constant terms are collected in K_1 (recall that $\log(C_t)$ is constant by assumption) one gets:

$$\log(p_{dt}) = K_1 - w_1 \log(D_t) + w_2 \log(p_{dt+1}) + x_t \quad (11)$$

for:

$$\mathbf{w}_1 = \left[\frac{\left(\frac{1-\mathbf{g}}{\mathbf{g}} \right) \frac{C_0}{D_0}}{\left(\frac{1-\mathbf{g}}{\mathbf{g}} \right) \frac{C_0}{D_0} + \left(1-\mathbf{d} - \tilde{r}_0 \right) p_0} \right] \quad (12)$$

$$\mathbf{w}_2 = (1 - \mathbf{w}_1) \quad (13)$$

Where $x_t = -\mathbf{w}_2 \left(\tilde{R}_{t+1} - \Pi_{t+1} \right)$. Variables in the form of X_0 are to be evaluated at steady-

state values. Furthermore, taking logs of (7) yields:

$$\log(D_{t+1}) = \log[(1-\mathbf{d})D_t + \mathbf{a}P_{dt}] \quad (14)$$

Applying the Taylor Series approximation to this equation gives us:

$$\log(D_{t+1}) = K_2 + \mathbf{j}_1 \log(D_t) + \mathbf{j}_2 \log(p_{dt}) \quad (15)$$

for:

$$\mathbf{j}_1 = \left[\frac{(1-\mathbf{d})D_0}{(1-\mathbf{d})D_0 + \mathbf{a}p_0} \right] \quad (16)$$

$$\mathbf{j}_2 = (1 - \mathbf{j}_1) \quad (17)$$

It is straightforward to show that the parameters defined above all lie between zero and one. Solving (15) for $\log(D_t)$ and substituting into (11) produces the following second order difference equation in price:

$$\log(p_{dt}) = \mathbf{a}_0 \log(p_{dt+1}) + \mathbf{a}_1 \log(p_{dt-1}) + \left[\frac{1}{1 + \mathbf{w}_2 \mathbf{j}_1} \right] (x_t - \mathbf{j}_1 x_{t-1}) \quad (18)$$

where $\mathbf{a}_0 = \left(\frac{\mathbf{w}_2}{1 + \mathbf{w}_2 \mathbf{j}_1} \right)$ and $\mathbf{a}_1 = \left(\frac{\mathbf{j}_1 - \mathbf{w}_2 \mathbf{j}_2}{1 + \mathbf{w}_2 \mathbf{j}_1} \right)$. This is a stock equilibrium condition: the current stock equals the demand to hold the stock. The stable saddlepath solution of this second order difference equation is

$$\log(p_{dt}) = (1 - \mathbf{I}_1 L)^{-1} \mathbf{y} \sum_{i=0}^{\infty} \mathbf{I}_2^{-i} v_{t+i} \quad (19)$$

where $\mathbf{y} = (1 - \mathbf{a}_0 \mathbf{I}_1)^{-1} (1 + \mathbf{w}_2 \mathbf{j}_1)^{-1} > 0$, $v_{t+i} = x_t - \mathbf{j}_1 x_{t-1}$ and \mathbf{I}_1 and \mathbf{I}_2 are the roots of the appropriate characteristic equation, $\mathbf{a}_0 \mathbf{I}^2 - \mathbf{I} + \mathbf{a}_1 = 0$. These roots depend only on \mathbf{w}_1 and \mathbf{j}_1 . Under the conditions of the log-linearization, \mathbf{I}_1 is less than one in absolute value and \mathbf{I}_2 is greater than one. The solution in (19) is written by solving this unstable root forward to impose stability.⁴ One can expand v_{t+i} to see more of the intuition behind how shocks to the nominal money supply could affect the demand for consumer durables and therefore the equilibrium price:

$$v_{t+i} = -\mathbf{w}_2 \left(\tilde{R}_{t+i} - \Pi_{t+i} \right) + \mathbf{j}_1 \mathbf{w}_1 \left(\tilde{R}_{t+i-1} - \Pi_{t+i-1} \right) \quad (20)$$

or, conversely:

$$v_{t+i} = \mathbf{j}_1 \mathbf{w}_2 \left(\tilde{R}_{t+i-1} - \Pi_{t+i-1} \right) - \mathbf{w}_2 \left(\tilde{R}_{t+i} - \Pi_{t+i} \right) \quad (21)$$

This shows that the equilibrium real price of consumer durables depends on the difference between the real interest rate in the current period and the real interest rate in the next period. This is the portion of the user cost that is working to change the demand for consumer durables when there is a shock to the nominal supply of money. If the real

⁴ See Sargent (1987).

interest rate is declining due to the influence of a nominal money supply increase, then v_{t+i} is positive and the real equilibrium price of consumer durables will increase.⁵

Next, analyze the theoretical model's predicted equilibrium price response to a serially uncorrelated shock, u_t :

$$\frac{d \log(p_{dt+k})}{du_t} = \gamma_1^k \sum_{i=0}^{\infty} \gamma_2^{-i} \frac{dv_{t+i+k}}{du_t}. \quad (22)$$

If u_t is thought of as a shock to the nominal money supply, then (22) shows the theoretical impulse response of the price of consumer durables that is analogous to the estimated impulse response function reported in the previous section. Since the only channels through which shocks to the money supply affect the market for consumer durables in this model is through the interest rate and inflation, this theoretical price response can be simulated by filtering the responses of the interest rate and inflation obtained from the VARs in chapter 3 through the right hand side of (22). In effect, the simulation allows us to formally evaluate the model's prediction regarding the relationships among the responses of the price, interest rates, and inflation.

II.c. Simulation Results

Figure 1 reports the simulated responses of the theoretical consumer durable price to shocks in the nominal money supply for various calibrated parameter values and compares them to the estimated consumer durable price response as reported in figure 3 of chapter 3 (the PPI for durables is used to compute the relative price). Figure 2 reports the simulations for the case where the chain-weighted price index is used for the price of

⁵ The decline in the interest rate must be great enough to offset the fact that the previous period's interest rate is assigned a weight of $\gamma_1 \mathbf{w}_2$ rather than just \mathbf{w}_2 , where γ_1 is positive and lies between zero and one.

consumer durables and provides comparison to the estimated price response in figure 4 of chapter 3 . The simulated responses are presented for various values of w_1 and j_1 . The parameter w_1 varies between .01 and .2 and j_1 takes on values of .5, .6, .7, .8, and .9. Each graph corresponds to different values of w_1 while plots of the simulation within each graph correspond to different values of j_1 . Smaller values of j_1 are associated with the higher dotted lines.

In each graph in figures 4.1 and 4.2, the shaded response is the response of the price of consumer durables estimated from the VAR and is the same graph reported in the upper left-most panel of figure 3.3 and 3.5 respectively. For each possible set of parameter values, the simulated price response is positive but temporary. A positive shock to the nominal supply of money leads to a decrease in the yield on financial assets and an increase in inflation that, according to the theory, will lead to a decrease in the user cost of consumer durables thereby increasing the demand for them. Since the elasticity of supply of consumer durables is not infinite, this increase in demand will lead to an increase in the equilibrium price. However, given that the effect of money supply shocks on inflation and the interest rate is only temporary, as time passes the user cost returns to its original pre-shock level and the demand for consumer durables returns to its original state causing the long run price response to be zero. This “story” of the impact of money on the market for consumer durables is reflected both in the empirical responses reported in chapter 3 as well as the simulated responses reported here.

The results shown in figure 4.1 provide informal support for the predictive power of the simple frictionless consumer durables model concerning the dynamic price response in the face of nominal money shocks for short time horizons for some parameter values.

In particular, when w_1 is equal to .05 and .07 and when j_1 is equal to .5 or .6 the theory does a reasonable job of quantitatively matching the estimated price response obtained from the VAR, at least over the first 10 months. For smaller values of w_1 , the predicted responses tend to exceed the actual response at almost all horizons. For larger values, the theory under-predicts at short horizons. The simulated responses, for high values of j_1 , tend to lie below the estimated responses.

Figure 4.2 also provides support for the frictionless optimization model. Notice that when w_1 is .05 the simulated responses closely match the estimated responses, particularly when j_1 takes on values of .5, .6, and .7. As in figure 4.1, when w_1 takes on values of .15 and .2 the simulated responses fall considerably below the estimated responses and w_1 is equal to .01 and .03 the simulated responses overshoot the estimated responses. Also, when the chain-weighted price index is used as the relevant consumer durable price the simulated responses stay closer to the estimated responses over longer time horizons than when the PPI for consumer durables is used.

Figure 4.3 reports the simulation results for the relative price of new autos. The shaded area in each graph in figure 4.3 is the estimated impulse response function in the upper left-most graph in figure 4.7 in chapter 3. Once again w_1 ranges from .01 to .2 and j_1 takes on values of .5, .6, .7, .8, and .9. The results presented in figure 4.3 are also supportive of the simple optimization model. Notice that when w_1 is equal to .03, the simulated price response closely matches the estimated price response of new autos. As in the case of all consumer durables, when w_1 is relatively large (.15 and .2) the model under-predicts the estimated price response and when w_1 is equal to .01, the simulations

lie above the estimated response for most time horizons. It is interesting to note that when the price of new autos is analyzed rather than the price of aggregate consumer durable goods, the simulated price responses closely match the estimated price responses over longer time horizons.

Logically, the next issue to address is the feasibility of the parameter values that yield a close match between the simulated and estimated responses of the price of consumer durables and new autos to money shocks. The easiest parameter to analyze is j_1 . As seen in (15), j_1 measures the persistence in the stock of durables due to depreciation rates and construction activity. Monthly depreciation rates for consumer durables and automobiles have been estimated to be anywhere from .03% to 2.1%⁶ and we can expect the flow supply of durables to be small relative to the outstanding stock of durables. Therefore, values for j_1 in the range of .7 would seem to be feasible, however, .8 or .9 may be more accurate.

To estimate the plausible magnitude of w_1 , first recall the exact functional form of this parameter:

$$w_1 = \left[\frac{\left(\frac{1-g}{g} \right) \frac{C_0}{D_0}}{\left(\frac{1-g}{g} \right) \frac{C_0}{D_0} + \left(1-d-\tilde{r}_0 \right) p_0} \right]$$

Use the intratemporal euler equation (11) along with the Cobb-Douglas utility function to note that the left hand side of (11) is equal to $\left(\frac{1-g}{g} \right) \frac{C}{D}$, which shows up in w_1 . The right hand side of (11) consists of observable variables. Therefore, w_1 is now solely a

⁶ See Chah, Ramey, and Starr (1995), and Baxter (1996)

function of observable variables. Plugging in steady state values for variables that appear on the right hand side of (11) leads to a value of this portion of \mathbf{w}_1 of .037⁷. Plugging in corresponding steady state values yields a value for $\left(1 - \mathbf{d} - \tilde{r}_0\right)p_0$ of .979. These two parameter values lead to a value of \mathbf{w}_1 of approximately .036. So parameter values for \mathbf{w}_1 that give a reasonable fit for the simulation are plausible.

III: A Dynamic Model of Consumer Durables with Liquidity Constraints

III.a. Theoretical Model and Log-Linearization

The previous section shows that a simple, frictionless dynamic optimization model incorporating consumer durable goods does a reasonably good job of predicting the dynamic response of the real equilibrium price of consumer durable goods to a nominal money supply shock. Although, this model performs somewhat well in this direction, it definitely is not perfect. In particular, when the price of aggregate consumer durable goods is analyzed, the model predicts more persistence in the price response than is shown in the estimated responses obtained from the VARs in chapter 3. Perhaps a more complex model would do an even better job of simulating the dynamic price response of consumer durables to a nominal money supply shock.

If consumers are in some way unable to fully finance their desired purchases of consumer durables, then the increase in effective demand for these goods brought about by an increase in the nominal supply of money may not be as great or as long lived than

⁷ The monthly depreciation rate is set equal to .016, the marginal income tax rate is set equal to .30, and the monthly percentage of consumer durable price used on maintenance, repairs, and insurance is set to .015. A value of .036 is reached when the means (1959 to 2001) of inflation, interest rates, and prices are used. Means are used because the Taylor series approximation is performed around the steady state values of the variables.

if consumers are free to borrow as they please. There have been many works that discuss liquidity constraints in dynamic optimization models and perform tests for their presence.⁸ As stated in the literature review in chapter 2, liquidity constraints may be the most relevant of all additional constraints added to simple frictionless dynamic optimization models such as the one presented in the previous section.

This section extends upon the work in the previous section by applying the solution strategy employed above to an intertemporal optimization model of consumer durables that incorporates liquidity constraints⁹. Begin by assuming that the representative consumer maximizes the following intertemporal optimization problem:

$$V_0 = \sum_{t=0}^{\infty} (1/1 + \mathbf{r})^t U(D_t, C_t) \quad (23)$$

Note that this is of the same form as above. The consumer is faced with the following constraints:

$$Y_t(1-\mathbf{t}) + \left[\frac{1 + (1-\mathbf{t})R_t}{1 + \Pi_t} \right] A_t = A_{t+1} + C_t + P_{dt} \mathbf{m} D_t + P_{dt} (D_t - D_{t-1} + \mathbf{d} D_{t-1}) \quad (24)$$

$$A_t + \mathbf{b} P_{dt} D_t \geq 0 \quad (25)$$

The first constraint is the same intertemporal budget constraint used above and all the variables are as defined above. Equation (25) is the liquidity/borrowing constraint. This is what separates this model from the frictionless model. \mathbf{b} is the portion of durable expenditure that is allowed to be financed and is therefore restricted to lie between zero and one. Equation (25) states that the consumer is constrained to have non-negative total assets at all time periods. The consumer is always constrained to have a “liquid”

⁸ See Chah, Ramey and Starr (1995), Alesie, Devereux, and Weber (1997), Lam (1991), Eberly (2000), and Carroll (2001).

⁹ The following model is almost identical to the model presented in Chah, Ramey, and Starr (1995).

portfolio. Note that if \mathbf{b} is allowed to be equal to 1, then purchases of consumer durable goods are fully financeable and the constraint is relaxed.

To solve the model, first substitute the traditional budget equation into the objective function. The conditions for maximization are:

$$U_c(t+1) \left(\frac{1+\tilde{r}_{t+1}}{1+\mathbf{r}} \right) = U_c(t) - \mathbf{m}_t \quad (26)$$

$$U_k(t) = U_t(t) p_{dt} - \left(\frac{1}{1+\mathbf{r}} \right) U_c(t+1) p_{dt+1} (1-\mathbf{d}) - \mathbf{m}_t \mathbf{b} p_{dt} \quad (27)$$

$$\mathbf{m}_t \geq 0 \quad (28)$$

$$(A_t + \mathbf{b} p_{dt} K_t) \mathbf{m}_t = 0 \quad (29)$$

Where \tilde{r}_t is the after tax real interest rate. Following convention $U_c(t+1)$ represents the derivative of the utility function with respect to C evaluated at time t+1. \mathbf{m}_t is the shadow price of date t of the nonnegativity constraint controlling the household's assets. Combining (26) and (27) yields the following Euler equation:

$$U_k(t) = U_c(t) \left[p_{dt} - p_{dt+1} \left(\frac{1-\mathbf{d}}{1+\tilde{r}_{t+1}} \right) \right] - \mathbf{m}_t \left[\mathbf{b} p_{dt} - p_{dt+1} \left(\frac{1-\mathbf{d}}{1+\tilde{r}_{t+1}} \right) \right] \quad (30)$$

Notice that (30) is identical to (11) (the Euler equation in the frictionless model) if the liquidity constraint is not binding (i.e., if $\mathbf{m}_t=0$). I will solve this model by imposing a positive value for \mathbf{m}_t . I am interested in testing how accurately a liquidity constraint model predicts a response of the real price of new autos to a nominal money supply shock

compared to a simple frictionless model. Therefore I assume that the liquidity constraint is binding in this model.

To solve the model, substitute for m_t from (26). After working through the algebra, the resulting intratemporal Euler equation is:

$$\frac{U_D(t)}{U_C(t)} = P_{dt} \left[(1 - \mathbf{b}) + \frac{U_C(t+1)}{U_C(t)} \left(\frac{1 + \tilde{r}_{t+1}}{1 + \mathbf{r}} \right) \mathbf{b} \right] - \frac{U_C(t+1)}{U_C(t)} \left(\frac{1 - \mathbf{d}}{1 + \mathbf{r}} \right) P_{dt+1} \quad (31)$$

Let us now analyze this Euler equation in detail. The left hand side of (31) is the marginal rate of substitution between durables and non-durables. The first term in the brackets on the right-hand side of (31) is the direct cost of purchasing one unit of a durable. The second term is the discounted opportunity cost of the amount of non-durable consumption that is lost next period due to the consumer's repayment of principle and interest on the portion of the durable that was financed. The last term in equation (31) is the discounted benefit the consumer derives next period from the resale of the non-depreciated durable. The right hand side of (31) is still to be thought of as the user cost of a durable good, but it differs from the expression of the user cost derived from the frictionless model due to the presence of the liquidity constraint.

I formulate the same supply equation as before:

$$D_{t+1} - D_t = \mathbf{a}P_{dt} - \mathbf{d}D_t \quad (32)$$

$$\mathbf{a} > 0$$

It should be noted once again that this supply equation leaves out possible interesting channels, such as interest rates having an effect on the supply of consumer durables. I will also remind the reader that interest rates and inflation are assumed to be exogenous

to the market for durables. Furthermore, I assume that shocks to the money supply do not indirectly affect the market for durables through its effect on non-durable consumption.

I again utilize the Cobb-Douglas utility function to solve the model. After substituting the functional form of the utility function into (31), solving for the price of consumer durables, and taking logs, a first order Taylor series approximation yields the following price equation:

$$\log(p_{dt}) = K_1 - \Theta_1 \log(D_t) + \Theta_2 \log(p_{dt+1}) + x_t \quad (33)$$

where:

$$x_t = -\Theta_3 \left(\tilde{R}_{t+1} - \Pi_{t+1} \right)$$

$$\Theta_1 = \left[\frac{\left(\frac{1-g}{g} \right) \frac{C_0}{D_0}}{\left(\frac{1-g}{g} \right) \frac{C_0}{D_0} + (1-d-r) \dot{C}_0^{-1} p_{d0}} \right] \quad (34)$$

$$\Theta_2 = (1 - \Theta_1)$$

$$\Theta_3 = \left[\frac{b \left(1 + \tilde{r}_0 - r \right) \dot{C}_0^{-1}}{(1-b) + b \left(1 + \tilde{r}_0 - r \right) \dot{C}_0^{-1}} \right] \quad (35)$$

Once again, X_0 is X evaluated at its long run steady state. \dot{C}_0^{-1} is the inverse of the steady state growth path of non-durable consumption. The presence of Θ_3 is what separates the solution of the liquidity constraint model with that of the frictionless model.

Note that if nondurable consumption is assumed to be constant then \dot{C}_0^{-1} is equal to one. Furthermore, if the long run steady state value of the real after tax interest rate is assumed to be the pure rate of time preference then $\left(r_0 - \tilde{r}\right)$ is equal to zero. These assumptions cause Θ_3 to collapse to \mathbf{b} . This is appealing because it allows for easier calibration of the model since \mathbf{b} is simply the percentage of durable purchases that are allowed to be debt financed. These same assumptions cause Θ_1 to be identical to \mathbf{w}_1 in the frictionless model. The only difference between the linearized demand equation in this liquidity constraint model (33) and that of the simple, frictionless model (11) appears in x_t . In the frictionless model, the coefficient on the real interest rate in x_t is restricted to be \mathbf{w}_2 , which is $(1 - \mathbf{w}_1)$. In the liquidity constraint model, the coefficient on the real interest rate in x_t is \mathbf{b} . The two models differ to the extent that \mathbf{w}_2 differs from \mathbf{b} . Therefore, the models predictions will diverge depending on the calibration of \mathbf{w}_1 as well as the percentage of a durable purchase that can be financed. If in the frictionless model \mathbf{w}_1 is set equal to $(1 - \mathbf{b})$ the frictionless model will predict the same dynamic price response as the liquidity constraint model.

The linear approximation of the supply equation is the same as before:

$$\log(D_{t+1}) = K_2 + \mathbf{j}_1 \log(D_t) + \mathbf{j}_2 \log(p_{dt}) \quad (36)$$

After solving (36) for $\log(D_t)$ and substituting into (33) one obtains the following second order difference equation in price:

$$\log(p_{dt}) = A + \mathbf{a}_0 \log(p_{dt+1}) + \mathbf{a}_1 \log(p_{dt-1}) + \left[\frac{1}{1 + \mathbf{w}_2 \mathbf{j}_1} \right] (x_t - \mathbf{j}_1 x_{t-1}) \quad (37)$$

where $\mathbf{a}_0 = \left(\frac{\Theta_2}{1 + \Theta_2 \mathbf{j}_1} \right)$ and $\mathbf{a}_1 = \left(\frac{\mathbf{j}_1 - \Theta_2 \mathbf{j}_1}{1 + \Theta_2 \mathbf{j}_1} \right)$. The stable saddlepath solution of this

difference equation is:

$$\log(p_{dt}) = (1 - \mathbf{I}_1 L)^{-1} \mathbf{y} \sum_{i=0}^{\infty} \mathbf{I}_2^{-i} v_{t+i} \quad (38)$$

where:

$$\mathbf{y} = (1 - \mathbf{a}_0 \mathbf{I}_1)^{-1} (1 + \Theta_2 \mathbf{j}_1)^{-1} \quad (39)$$

and, once again:

$$v_{t+i} = x_t - \mathbf{j}_1 x_{t-1} \quad (40)$$

Where \mathbf{I}_1 and \mathbf{I}_2 are the characteristic roots of the same characteristic equation as before and \mathbf{I}_1 is less than one in absolute value while \mathbf{I}_2 is greater than one. The unstable root is solved “forward” to impose stability. The theoretical model’s predicted equilibrium price response to a serially uncorrelated shock is in the exact same form as above:

$$\frac{d \log(p_{dt+k})}{d u_t} = \mathbf{y} \mathbf{I}_1^k \sum_{i=0}^{\infty} \mathbf{I}_2^{-i} \frac{d v_{t+i+k}}{d u_t} \quad (41)$$

I next calibrate the parameters of both the frictionless model and the liquidity constraint model to plausible values consistent with long run steady state values of the variables of which they are functions. I then filter the responses of interest rates and inflation to an exogenous shock to the money supply obtained from the VAR outlined in the first section of this chapter into the right side of the steady state equilibrium price

response derived from the two models. This allows me to compare how accurately the models predict the dynamic response of the real price of consumer durables to an exogenous money shock. The predictive power of the liquidity constraint model is then compared to the predictive power of the frictionless model to see which model would better serve to analyze policy effects on the market for consumer durables.

III.b. Simulation Results

Figure 4.4 reports the simulation results for the liquidity constraint model for the price of aggregate consumer durable goods when the producer price index is used to construct the relative price of consumer durable goods and when $\mathbf{b} = .9$. Figure 4.5 reports the same results when the chain-weighted price index is used to compute the real price of consumer durables. Θ_1 is allowed to vary from .01 to .2 as it is the same parameter as \mathbf{w}_1 in the frictionless model. Also, as before, \mathbf{j}_1 takes on values of .5, .6, .7, .8, and .9. Once again, lower values of \mathbf{j}_1 correspond to the higher dashed lines in each graph. As before, the shaded area represents the corresponding estimated responses obtained from the VAR estimations presented in chapter 3. Notice that when purchases of consumer durables are allowed to be 90% debt financed the simulations present for the liquidity constraint model closely match those for the frictionless model. This is to be expected since as \mathbf{b} approaches one the liquidity constraint is relaxed.

Figures 4.6 and 4.7 report the simulation results for the relative price of aggregate consumer durables using the PPI for durables and the chain-weighted price index for durables, respectively, when $\mathbf{b} = .6$. These simulations are therefore constructed when consumers are faced with a considerably “tighter” borrowing constraint than when \mathbf{b} is equal to .9. When aggregate consumer durable purchases are only 60% financeable, the

simulated responses more closely match the estimated responses for smaller values of Θ_1 than when consumer durable purchases are 90% financeable. The values of Θ_1 that yield the closest match between the simulated responses and the estimated responses are .07 and .05 when the constraint is only loosely binding ($b=.9$). Conversely, the values of Θ_1 that produce the tightest fit are .05 and .03 when consumers can only finance 60% of their purchases of durable goods. Recall in the previous section that w_1 was found to be approximately equal to .036 when an attempt was made to arrive at an exact value for this parameter. Since Θ_1 in the liquidity constraint model is identical to w_1 in the frictionless model, the results of the simulations in figures 4.4 through 4.7 may indicate that the market for aggregate consumer durables may be one in which liquidity/borrowing constraints are indeed binding.

Now let us analyze figures 4.8 and 4.9. These figures present the simulation results for the response of the relative price of new automobiles to a nominal money supply shock. Figure 4.8 reports the simulations when purchases of new automobiles are allowed to be 90% debt financed. As in the frictionless simulations, values of .03 and .05 for Θ_1 give the tightest fit of the simulated responses to the estimated responses when $b=.9$, with .03 yielding the closer fit. Figure 4.9 shows that the simulated responses lie closest to the estimated responses when Θ_1 is equal to .01 and .03 when new automobile purchases can only be 60% financed, with .01 providing the closer fit if the two. The results of figures 4.8 and 4.9 tell us that, if .036 is to be taken seriously as our actual estimated value for Θ_1 , it seems to be the case that the market for new automobiles is best characterized as one where consumers are not faced with tight borrowing constraints.

IV: Conclusion

This chapter attempts to explain if the empirical dynamic price responses obtained in chapter 3 can be explained by dynamic optimizing behavior. This is done by simulating the dynamic response of the approximate equilibrium real price of consumer durables implied by both a frictionless dynamic optimization model and one that incorporates liquidity constraints. These implied responses are then compared to the estimated empirical responses obtained from the VARs in chapter 3 to test and compare the predictive power of the two dynamic models presented. The models are solved by a method suggested by Campbell (1994), which consists of log-linearizing the equations of the model to obtain approximate analytic solutions. This method has previously not been applied to the market for consumer durable goods.

The results indicate that the frictionless optimization model does a reasonable job of accurately predicting the dynamic response of the relative price of aggregate consumer durables and new automobiles for plausible calibrated parameter values. However, the match between the simulated responses and the estimated responses is hardly perfect. In particular, the frictionless model seems to predict too much persistence in the price response, especially when the market for aggregate consumer durables is analyzed.

The dynamic optimization model incorporating liquidity constraints is introduced in an attempt to improve upon the results of the frictionless model. It is shown that this model presents the closest fit for calibrated values of the parameters in the model that may be more realistic than the calibrated parameter values that provide the closest fit for the frictionless model. This is especially true for the relative price response of aggregate consumer durable goods. The results indicate that the market for aggregate consumer

durables may be best described as one in which consumers are faced with binding borrowing constraints, while the market for new automobiles is relatively void of binding constraints in the credit market.

Figure 4.1: Simulation for Price of Consumer Durables (PPI)

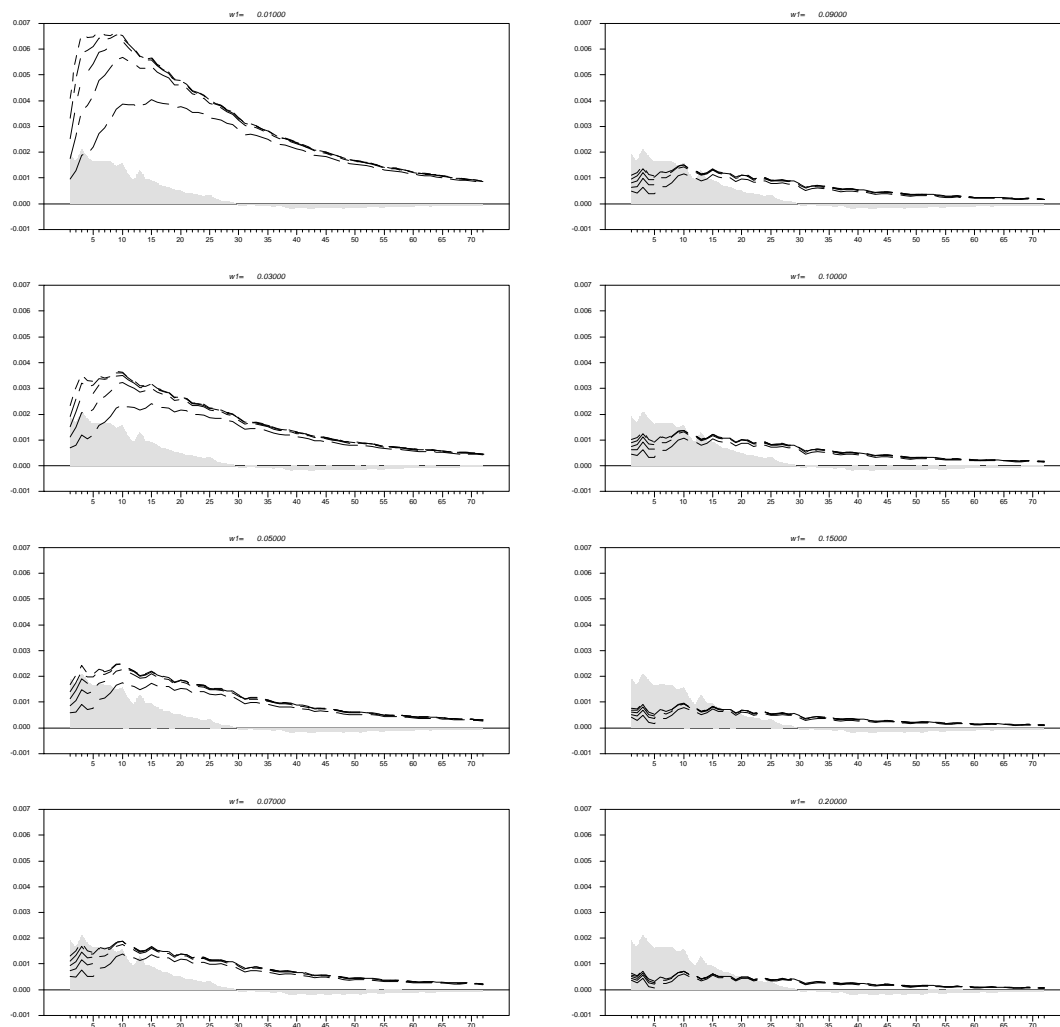


Figure 4.2: Simulation for Price of Consumer Durables (CWPI)

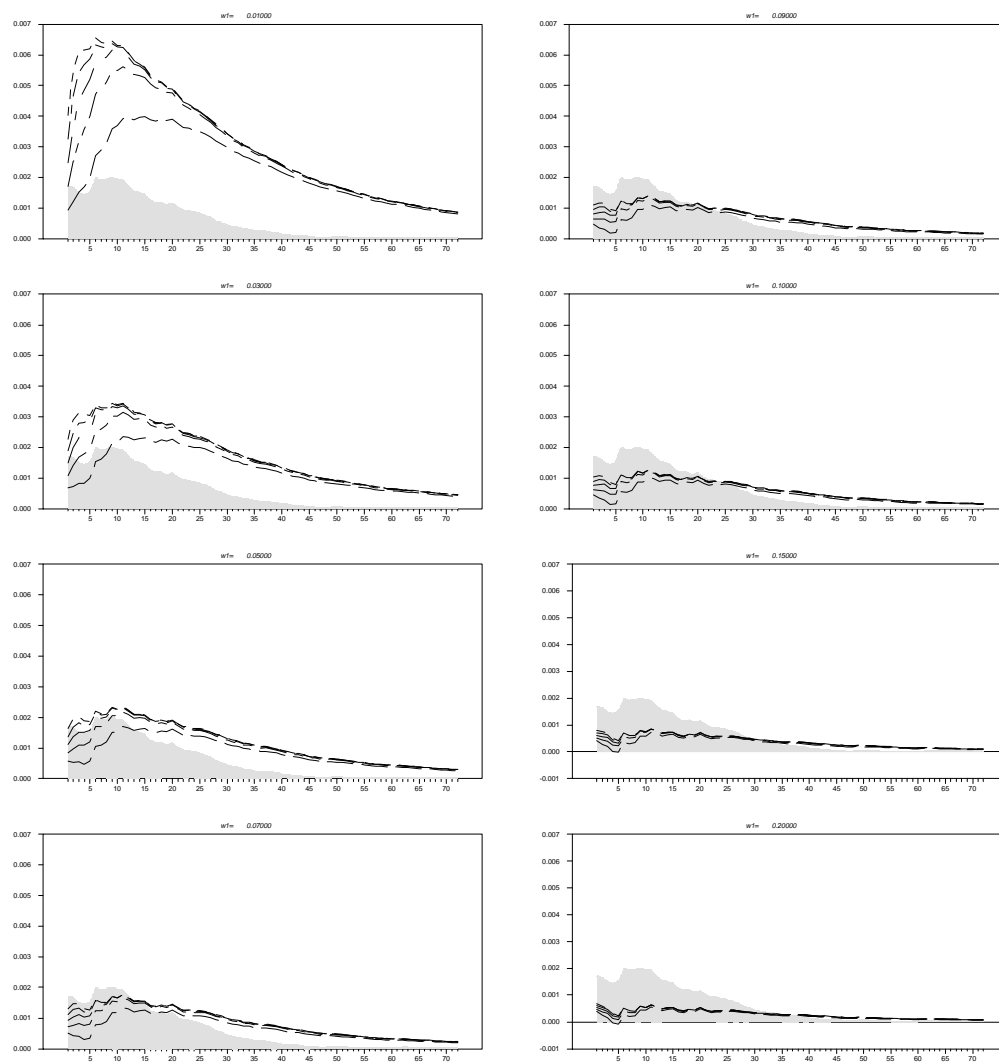


Figure 4.3: Simulation for Price of New Cars

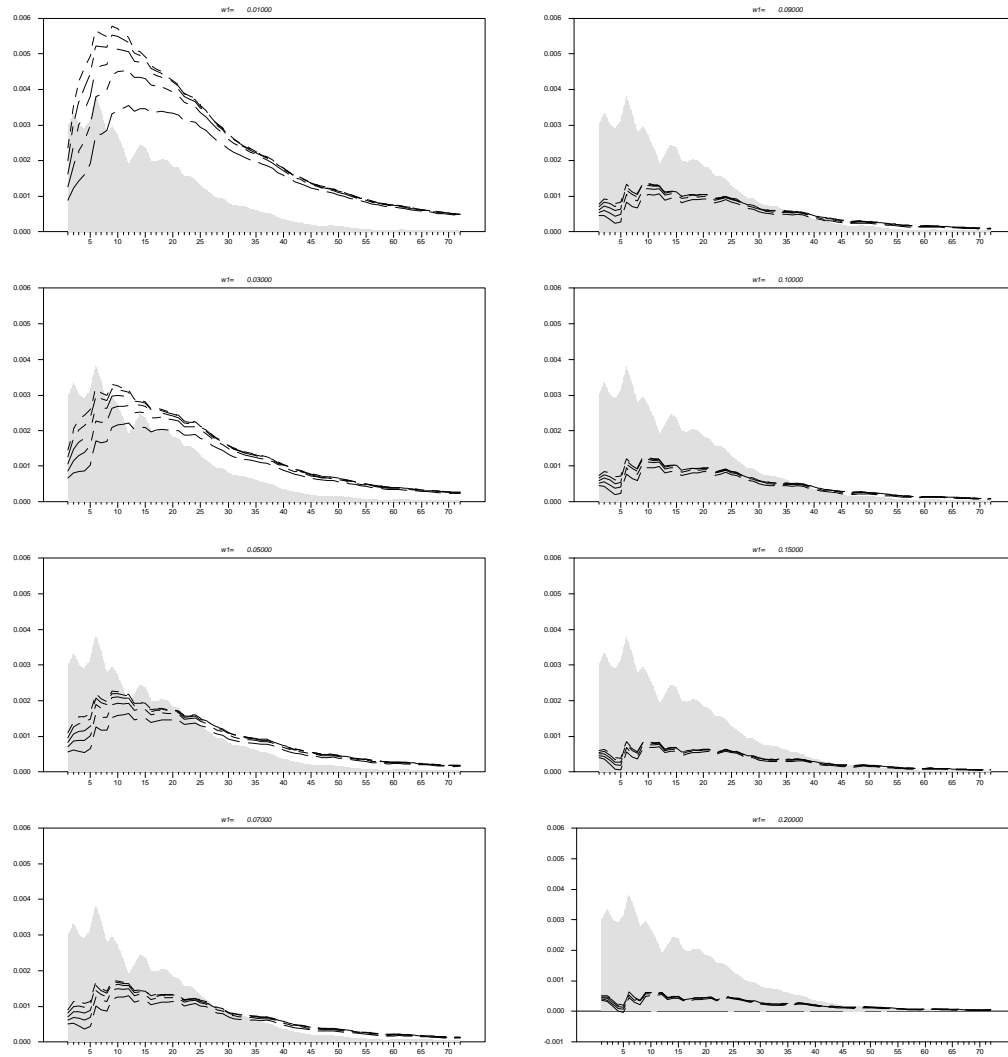


Figure 4.4: Simulation for Price of Consumer Durables (PPI)-L.C. Model-B=.9

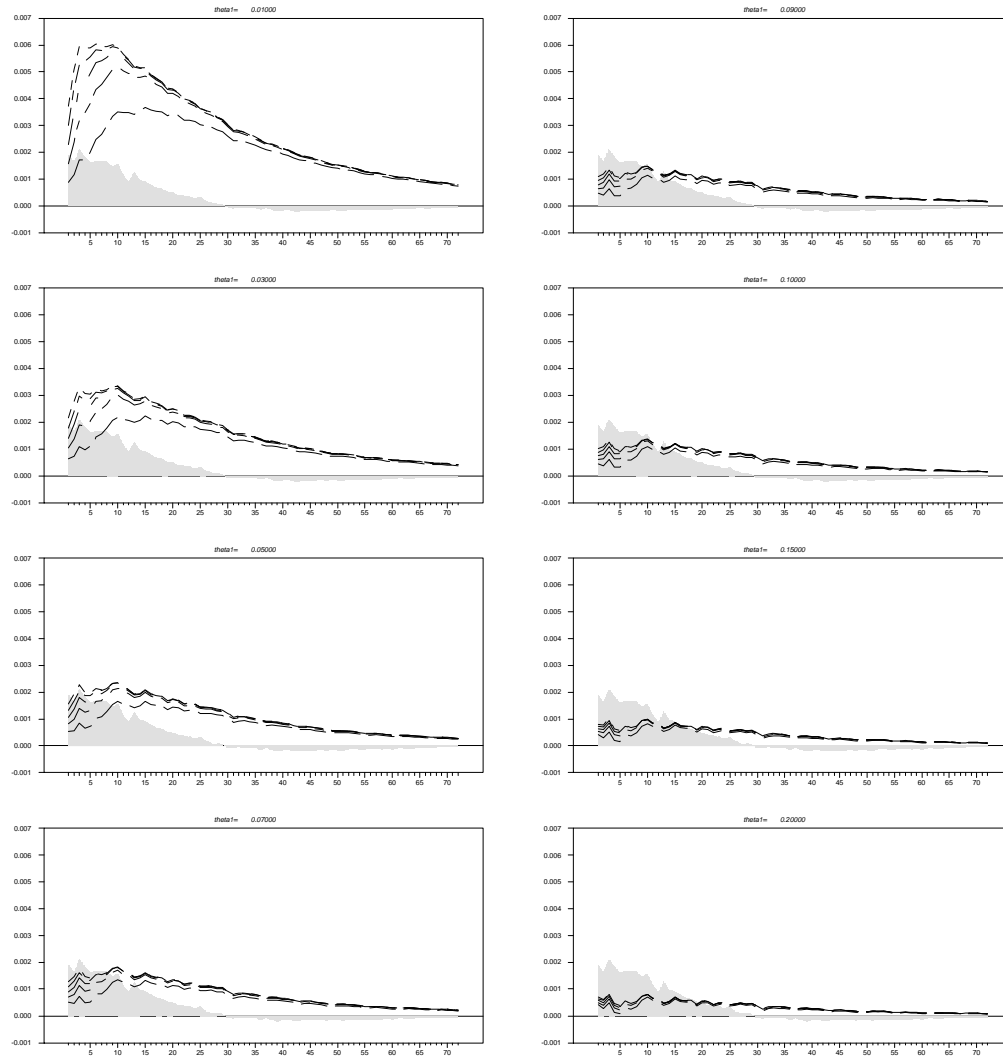


Figure 4.5: Simulation for Price of Consumer Durables (CWPI)-L.C. Model-B=.9

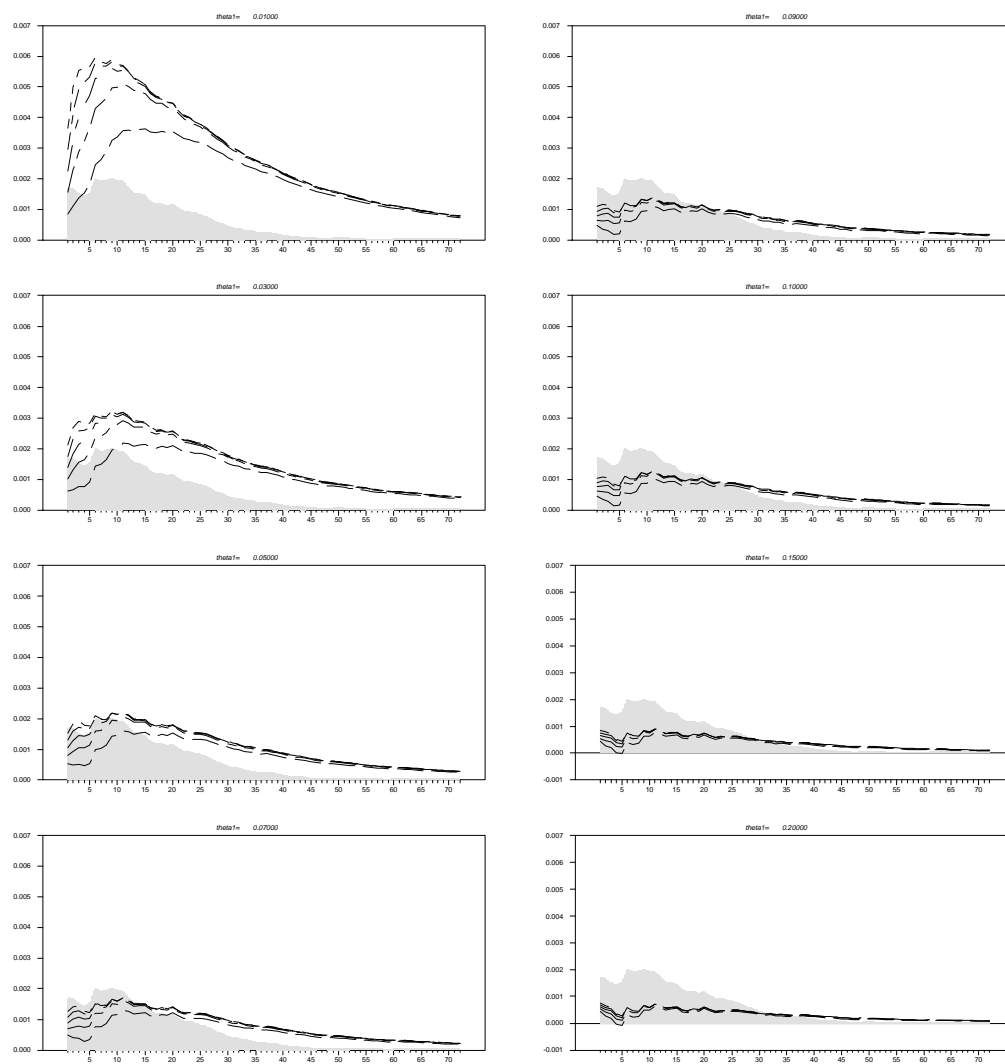


Figure 4.6: Simulation for Price of Consumer Durables (PPI)-L.C. Model-B=.6

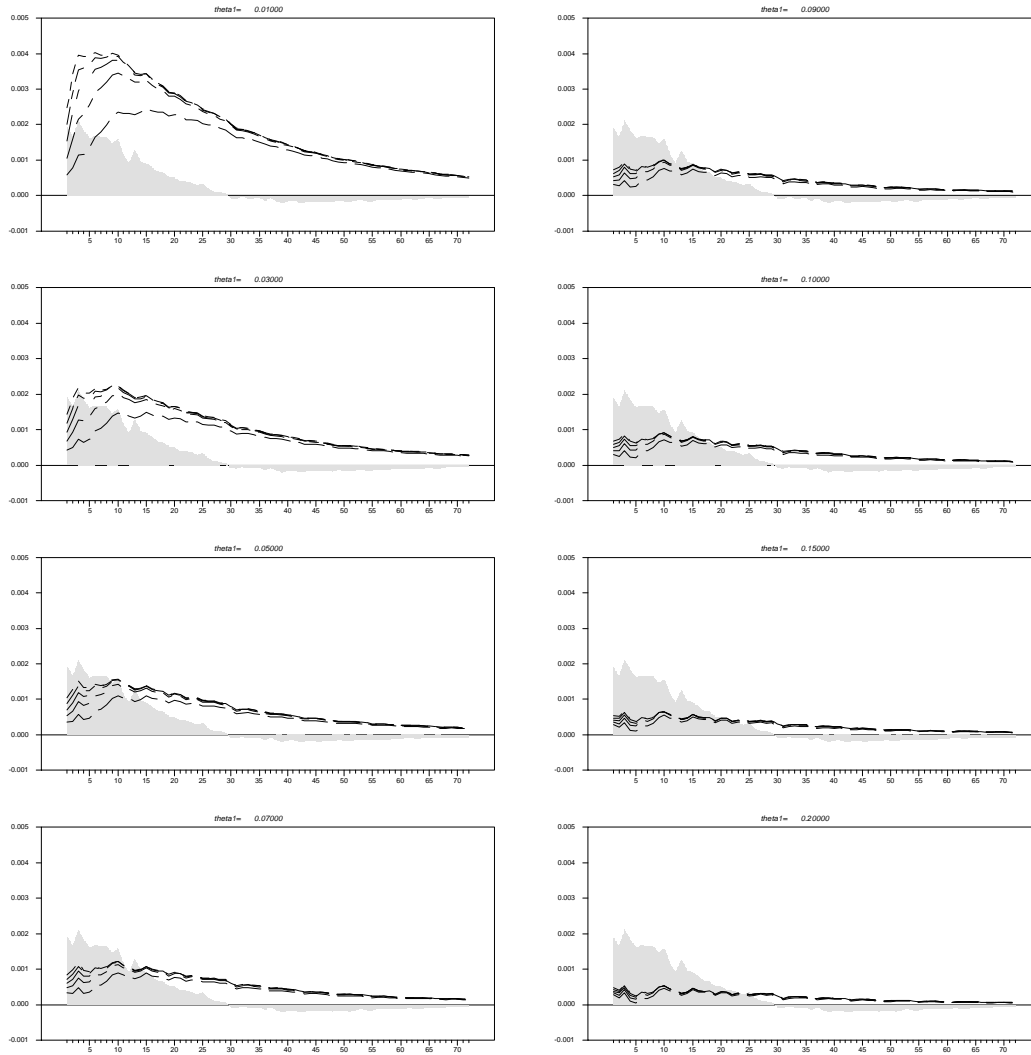


Figure 4.7: Simulation for Price of Consumer Durables (CWPI)-L.C. Model-B=.6

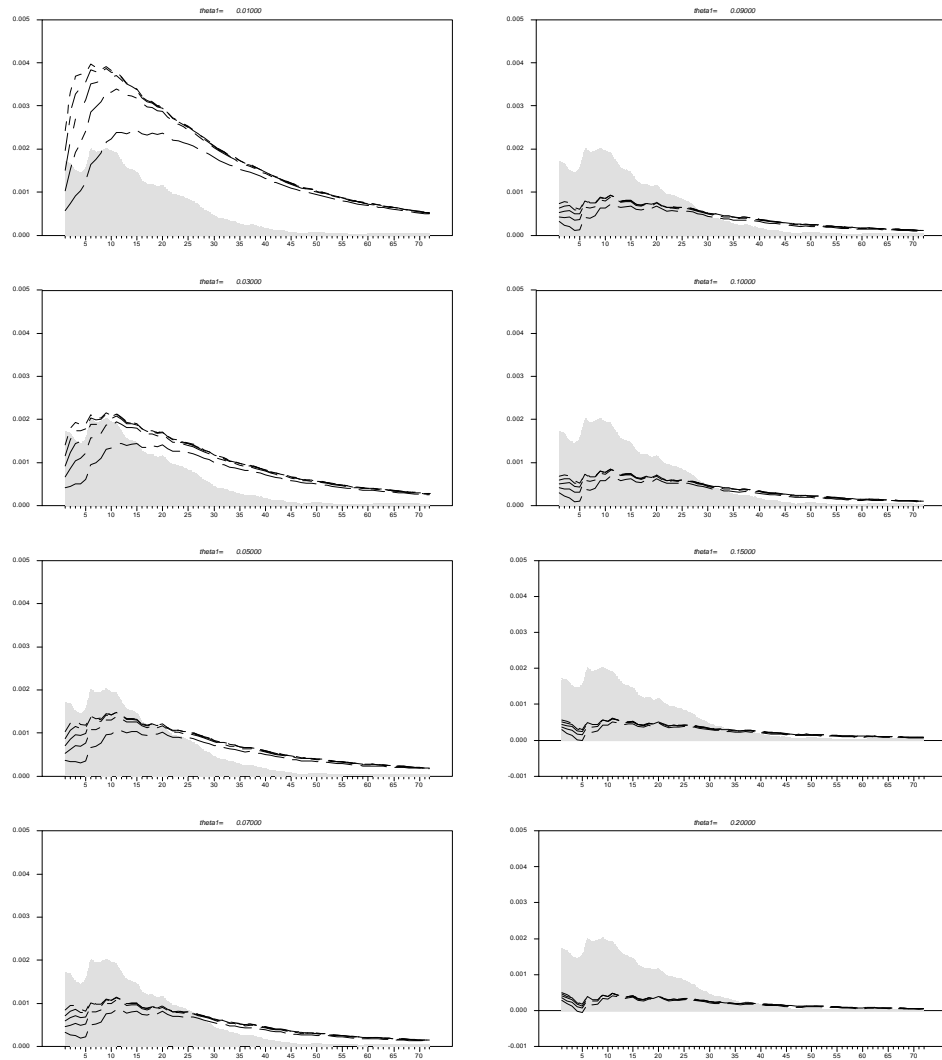


Figure 4.8: Simulation for Price of New Cars-L.C. Model-B=.9

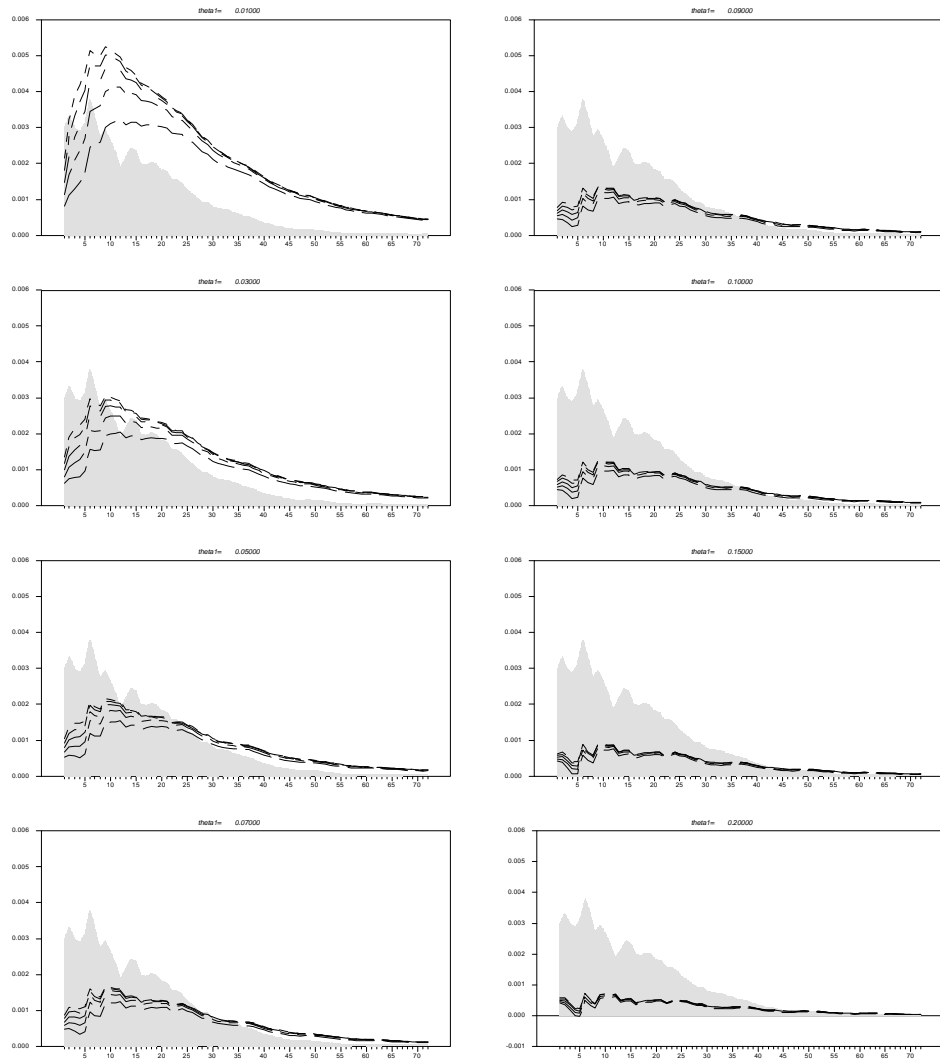
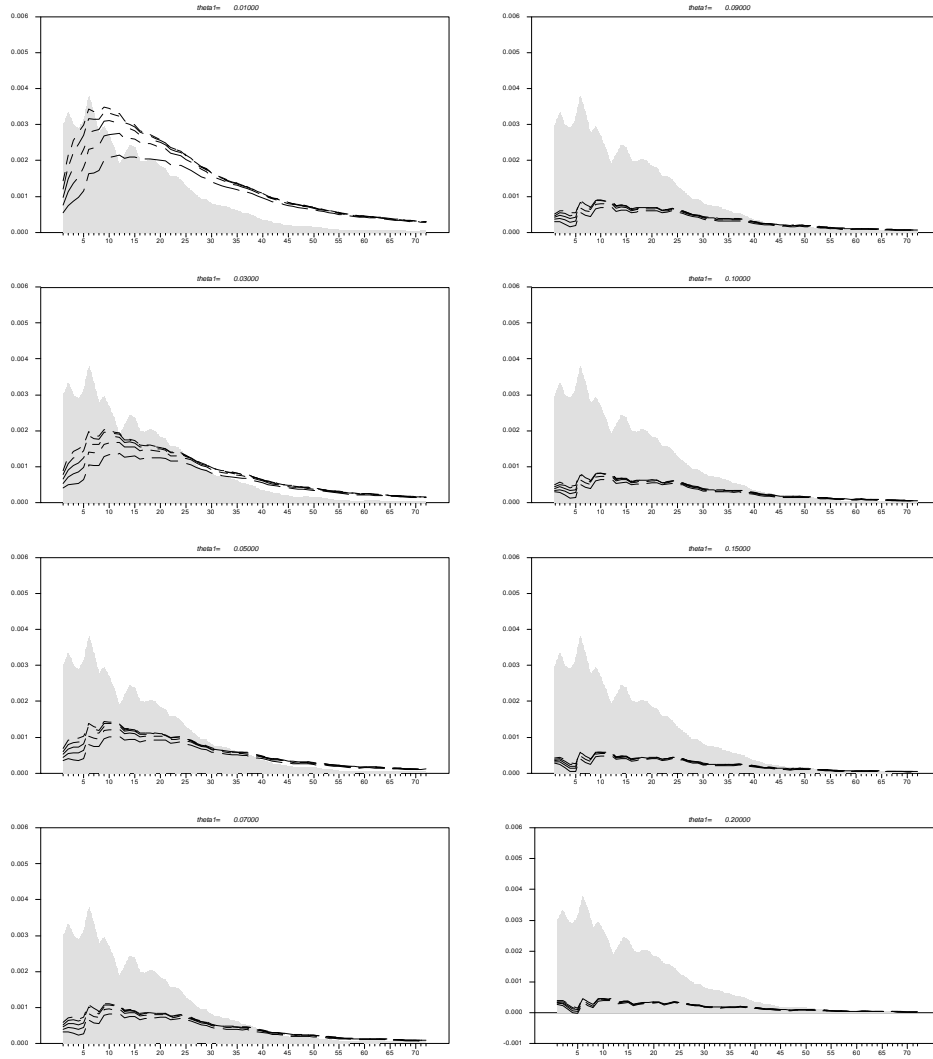


Figure 4.9: Simulation for Price of New Cars-L.C. Model-B=.6



Chapter 5: Conclusion

This dissertation presents two main findings. First empirical results are presented that show real dynamic effects of nominal money supply shocks on the market for consumer durable goods. Second, it is shown that dynamic optimizing representative agent models incorporating consumer durables do a nice job of simulating the dynamic response of the real equilibrium price of consumer durables to a nominal money supply shock. The first finding is important because it adds to the body of evidence pertaining to the short run real effects of changes in the nominal supply of money. The second finding is important because it provides support for the use of dynamic, rational expectation, optimization models of consumer durable goods for policy analysis.

Chapter 3 presents the empirical evidence of the real dynamic effects of nominal money supply shocks on the market for consumer durable goods. Results are presented for both the aggregate consumer durable goods market as well as the market for new automobiles. It is shown that nominal money supply shocks cause short run increases in both the relative price and real expenditure of aggregate consumer durables and new autos. Furthermore, this estimated increase in the relative price of consumer durables resulting from a shock to the nominal money supply is found to be robust across different measures of the real price of consumer durables as well as across different estimated models.

Chapter 3 employs a variety of vector autoregressions to estimate the response of the market for consumer durable goods to nominal money supply shocks. Imposing nothing more than long-run monetary neutrality identifies these vector autoregressions. Long-run monetary neutrality has almost reached the status of a stylized fact in macroeconomics and the identification scheme employed based on this assumption has wide precedent throughout the literature in macroeconomic time series analysis.

Chapter 4 asks if the empirical dynamic price responses obtained in chapter 3 can be explained by dynamic optimizing behavior. This question is answered by simulating the dynamic response of the approximate equilibrium real price of consumer durables implied by both a frictionless dynamic optimization model and one that incorporates liquidity constraints. These implied theoretical responses are then compared to the actual estimated empirical responses obtained from the various empirical models presented in chapter 3. The purpose is to measure and compare the predictive power of a frictionless dynamic optimization model and one that incorporates liquidity/borrowing constraints. The models are solved by Campbell's (1994) method. Campbell (1994) suggests log-linearizing the equations of the models to obtain approximate analytic solutions. This method has previously only been applied to real business cycle theories and has yet to be applied to models of consumer durable goods.

The results of chapter 4 indicate that the frictionless optimization model does a reasonable job of accurately predicting the dynamic response of the relative price of aggregate consumer durables and new automobiles. However, the simulations do not perfectly match the estimated impulse response functions obtained in chapter 3. In

particular, the frictionless model predicts excessive persistence in this price response, especially in the market for aggregate consumer durable goods.

The dynamic optimization model incorporating liquidity constraints presents the closest fit between the simulated dynamic relative price response of consumer durables to a nominal money supply shock and the actual estimated response for calibrated parameter values that may be more realistic than the calibrated parameter values that provide the closest fit for the frictionless model. This is especially true for the equilibrium price response of aggregate consumer durables. The results of chapter 4 indicate that the market for aggregate consumer durables may be best described as one in which consumers are faced with binding borrowing constraints, while the market for new automobiles is relatively void of binding constraints in the credit market.

It is important to note that this dissertation incorporates a number of assumptions that may be relaxed for future research. The supply schedule for consumer durables presented in this dissertation is a very simple one that ignores many possibly interesting channels (such as interest rate effects on the supply of consumer durables). Also, interest rates and inflation are assumed to be exogenous to the market for consumer durable goods. This assumption ignores possible feedback effects from the market for consumer durable goods to stabilization policy. Furthermore, a more complex utility function could be utilized. Also, the assumption that money supply shocks do not indirectly affect the market for consumer durables through their effect on non-durables could also be relaxed.

The door is definitely open for additional work following in the footsteps of this dissertation. Future research along the line of this dissertation could incorporate various additional features of the market for consumer durables such as transactions costs and

upper and lower bounds governing stock adjustment. Also, the recent work regarding the introduction of hyperbolic discount functions into dynamic optimization models may provide fruitful extensions.

DATA APPENDIX

In this appendix I will explain how the BEA computes its chain weighted price indices as well as give some additional detail regarding other data series I employ in this dissertation. First of all, the BEA defines a durable good as a tangible good that can be stored or inventoried and has an average life of at least three years. Personal consumption expenditure on these goods is purchases by U.S. residents and consists mainly of purchases of new goods by individuals from private business. In addition, personal consumption expenditure includes purchases by non-profit organizations, net purchases of used goods by individuals and non-profit organizations, and purchases abroad by U.S. residents.

To compute the chain weighted price index, the BEA uses the following formula:

$$p_t = \sqrt{\frac{\sum p_t q_{t-1}}{\sum p_{t-1} q_{t-1}} \times \frac{\sum p_t q_t}{\sum p_{t-1} q_t}} \quad (\text{A.1})$$

Where p_t is the price of the good in question in year t . The BEA uses this method because in many cases where a fixed-weight index is used, the measured growth rate in a variable can depend on which base year is used. This method corrects for this potential shortfall by not using a fixed base period to compute the price index.

Finally, I use personal consumption on new autos in chained 1992 dollars. The BEA computes this series by multiplying the 1992 current dollar value by a corresponding quantity index number divided by 100. For example, if personal consumption expenditure on durable goods is equal to \$100 in 1992, and if in 1993 real expenditure on

these goods increased by 10%, then the chained (1992) dollar value of this variable would be $\$110(\$100 \times 1.10)$ in 1993.

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