Customer Search, Competition, and Monetary Non–Neutrality

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Abstract

In this paper, I study monetary non–neutrality in a frictional product market. The model incorporates the idea that goods are in general not monopolistically supplied; rather, consumers can purchase the same good from many outlets. I find that incorporating this feature into a menu cost model increases the degree of monetary non–neutrality. The reason is that competition between stores makes their prices complementary, so that firms face strong penalties for setting prices far away from their competitors. It makes pass–through of cost shocks heterogeneous and decreases the strength of the selection effect. I also use the model to study cyclical changes in monetary non–neutrality. I find that the data are consistent with a decline in the competitiveness of markets in recessions, which makes monetary policy less effective at stimulating output.

1 Introduction

An important feature of product markets is the ability to purchase the same good from different retailers. In this paper, I incorporate this idea into an otherwise standard monetary model. Following Kenneth Burdett and Guido Menzio (2017), I study a model with menu costs and a frictional product market. I find that including product market frictions increases the degree of monetary non–neutrality relative to a Mikhail Golosov and Robert E. Lucas (2007) benchmark. The intuition for this result is that (1) search frictions introduce strategic complementarities between the pricing decisions of firms and (2) reduce the size of the selection effect.

In a perfectly frictionless world, the law of one price holds and there is no price dispersion. To motivate the inclusion of product market frictions into my model, I begin by briefly documenting the degree and sources of price dispersion. Using the Kilts–Nielsen Retail Measurement Services scanner dataset, I show that there is significant dispersion in retail prices that cannot be explained with good or store characteristics. I find that this dispersion rises in recessions and is a pervasive feature across geographic markets of the United States.

I then present a model with sticky prices and frictional product markets. The model is one of a market for a homogeneous good. In the model, retailers post potentially heterogeneous nominal prices, face idiosyncratic productivity shocks, inflation, and sell output to customers. The frictions in the model follow Kenneth Burdett and Kenneth L Judd (1983): each consumer encounters either one or two firms in the market and can only purchase the good from a firm they have encountered. These product market frictions mean that firms care about the distribution of prices when they decide on their pricing policy.

I study the impact of a monetary shock on output in this model. The model nests Golosov and Lucas (2007), and I find that, in comparison to that benchmark, product market frictions significantly increase the degree of monetary non–neutrality. In response to an unexpected nominal shock, output responds more initially and remains higher for longer in the search economy than in the benchmark economy. The intuition for the result is that an increase in competitiveness means that firms want to keep their prices closer to their competitors' prices, increasing price rigidity. The mechanism also generates excess kurtosis in the distribution of price changes, reducing the selection effect and increasing price rigidity.

This paper is part of a literature studying the effects of demand and competition on monetary non–neutrality. Simon Mongey (2018) studies monetary non–neutrality in a duopoly, finding that modeling sectors as duopolists rather than monopolists increases price rigidity. Peter J. Klenow and Jonathan L. Willis (2016) studies whether kinked demand curves could generate increased monetary non–neutrality. They find that the mechanism can increase price rigidity that it is inconsistent with micro–data. In this paper, I find that modeling sectors as search markets rather than monopolists increases monetary non–neutrality and is not inconsistent with micro–data on price changes and productivity.

2 Price dispersion

2.1 Data

The data I use to document price dispersion are the Kilts–Nielsen Retail Scanner Dataset[1]. These data are UPC–level point–of–sale weekly price and sales data from 35,000 mass–market retail and grocery stores across the United States. A typical observation in the data is the quantity and sales–weighted average price of a particular product sold at a particular store in a given week. A benefit of these data is that it allows us to observe variation in the price of the same good at different stores.

2.2 Decomposing price dispersion

I follow Greg Kaplan and Guido Menzio (2015) and decompose the price of good j at store s in week t into three components:

$$\log p_{jst} = \mu_{jt} + y_{st} + z_{jst}.$$

The price of a good is then the sum of a good–specific average price μ_{jt}, a store–specific average price y_{st}, and a store–good component z_{jst}. This decomposition captures differences in the prices of different goods (e.g., a 12oz bottle of coca-cola is less expensive than a 54oz bottle of laundry detergent) and differences in the amenities different stores offer (e.g., a grocery store in a wealthy neighborhood might set a higher price for Coca–Cola than a discount store). The store–good component z_{jst} captures dispersion in the price of the same good at stores that set, on average, the same prices for the same goods.

In a model of monopolistic competition, dispersion in $\log p_{jst}$ is not evidence of deviations from the law of one price. If we consider products to be differentiated along the margin of both UPC and store, then it is natural for different store–good pairs to sell at different prices. However, dispersion in in the store good component z_{jst} does represent a deviation from the law of one price in this model. This measure abstracts from the fact that some stores offer different amenities than others, and that consumers are willing to pay different prices for different goods. I estimate these components separately on the top 1000

[1] Researcher(s) own analyses calculated (or derived) based in part on data from The Nielsen Company (US), LLC and marketing databases provided through the Nielsen Datasets at the Kilts Center for Marketing Data Center at The University of Chicago Booth School of Business. The conclusions drawn from the Nielsen data are those of the researcher(s) and do not reflect the views of Nielsen. Nielsen is not responsible for, had no role in, and was not involved in analyzing and preparing the results reported herein.

products by sales within 99 Core–Based Statistical Areas (CBSAs) using following procedure (separately by CBSA):

1. Compute the good component μ_{jt} as

$$\mu_{jt} = \frac{1}{S}\sum_{s=1}^{S} \log p_{jst}$$

   where S is the number of stores in that CBSA.

2. Then compute normalized good prices as

$$x_{jst} = \log p_{jst} - \mu_{jt}$$

3. The store component is then

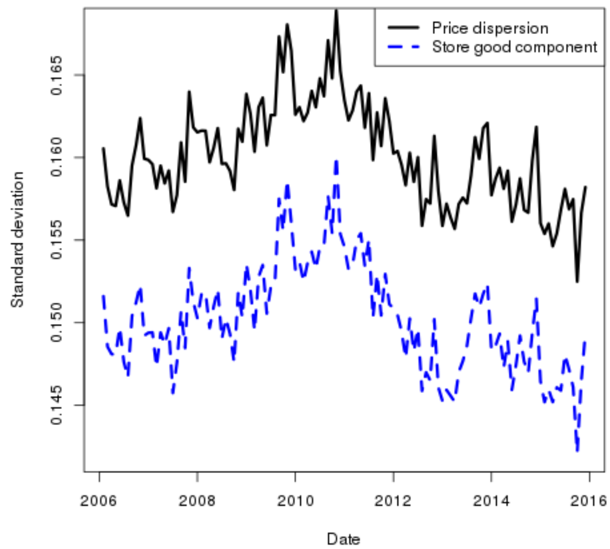
$$y_{st} = \frac{1}{J}\sum_{j=1}^{J} x_{jst}$$

4. The store–good component is

$$z_{jst} = x_{jst} - y_{st}$$

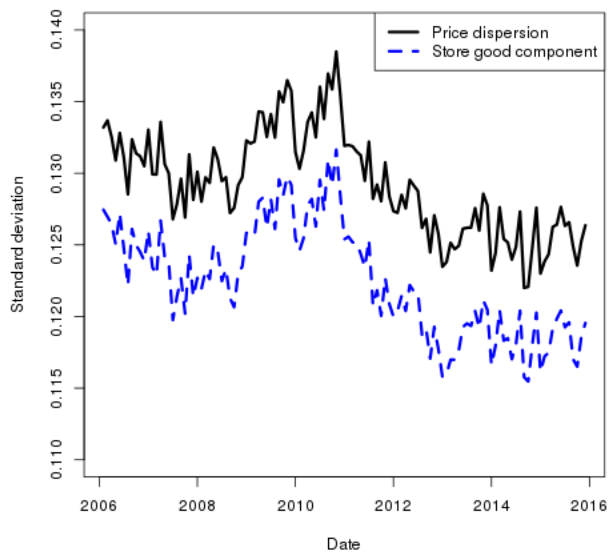
I then compute the standard deviation for each CBSA in each week and compute the national average of those dispersions. Figure 1 depicts the behavior of average normalized price dispersion and store–good price dispersion over time. Dispersion rises through the recession until 2010, at which point it begins to fall, eventually declining to its 2006 levels. A large portion of price dispersion is due to dispersion in the store–good component: the time series mean of normalized price dispersion is 15.6 %, and the time series mean of store–good price dispersion is 14.6 %.

Figure 1: Price dispersion over time



One might worry about outliers driving these results; perhaps a few small stores with low sales drive these measures of dispersion. To address these concerns, I compute the same decomposition, weighting each component by its total sales. I find results that are broadly similar. Figure 2 depicts the results of this exercise. Price dispersion is somewhat lower on average, but the store–good component still accounts for a large portion of dispersion in prices. In both measures, price dispersion rises through 2011 and falls thereafter.

Figure 2: Price dispersion over time, weighted by sales



In summary, I find that there is a significant degree of price dispersion in retail markets and that a large portion of this dispersion is due to differences in the price of the same good at different stores.

3 A Quantitative Model of Sticky Prices and Competition

3.1 Households

The model is one of a single market for a homogeneous good y. There is a background level of inflation π each period, so that the real value of the price of a good with fixed nominal price depreciates by π each period. This could be microfounded by a constant growth rate of money π and households with linear disutility of labor and a cash–in–advance constraint.

Each period, a continuum of measure one of households seeks to purchase the homogeneous good. Each household purchases the good from a single firm. An individual household, facing a real price p, has demand schedule

$$y = d(p) \equiv p^{-\theta}.$$

This is the demand schedule that firms in a particular sector would face in a model with a continuum of sectors with a representative household and a CES aggregator over sectoral output. The downward sloping demand function implies that when sectoral prices fall relative to the wage, sectoral output rises.

Each period, each household visits the market and searches for a firm to purchase the good from. Firms post prices and commit to producing any amount of the good for the posted price. Upon visiting the market, each household encounters either one or two firms in the market. The number of firms each household encounters is a random variable whose value *iid* across households and over time; a fraction α of households encounters only one firm each period, and the remaining fraction encounter two firms. We denote households households that only encounter one firm as "captive." Upon meeting with either one or two firms, the household purchases a quantity $d(p)$ of the good from the firm with the lower real price p.

3.2 Firms

A continuum of firms of measure 1 indexed by j each produces the homogeneous good y using a linear technology in labor l

$$y_t^j = z_t^j l_t^j.$$

The input l_t can be hired on a frictionless market at fixed real cost W, so that the marginal cost of producing one unit of the good is $\omega \equiv W/z$. Idiosyncratic productivity follows an AR(1) process in logs with infrequent shocks:

$$\log z_t^j = \begin{cases} \rho_z \log z_{t-1}^j + \sigma_z \epsilon_t^j & w.p.\ \ \lambda \\ \rho_z \log z_{t-1}^j & w.p.\ \ 1-\lambda \end{cases}$$

Each firm j posts a nominal price p_j and satisfies the demand associated with that price. The extensive margin of demand is determined by the search process of the household, and their intensive margin is determined by the downward–sloping demand curve. Each firm sells to any captive customers they encounter and to non–captive customers if they have the lower of the two prices the customer faces. The quantity that a firm with real price p sells is then:

$$q(p) = \Big[\underbrace{\alpha}_{\text{captive}} + \underbrace{2(1-\alpha)(1-F(p))}_{\text{Non–captive}}\Big] \underbrace{p^{-\theta}}_{\text{Intensive margin}}$$

Each period, unless it changes its price, a firm's real price depreciates by π. The firm can pay a fixed adjustment cost to change its price. A firm with current price p and next period's price p' must pay the real menu cost ϕ. Given distribution of prices $F(p)$, a firm in market j with last periods' (deflated) price p_{-1} and current value of productivity z^j who cannot change their price for free solves the recursive problem

$$V(p_{-1}, z; F) = \max\{V^A(z^j) - \phi, V^{NA}(z_j)\}$$

$$V^A(z) = \max_p \pi(p, z) + \beta \mathbb{E}_{z',\phi} V(p/(1+\pi), z', \phi)$$

$$V^{NA}(p, z) = \pi(p) + \beta \mathbb{E}_{z',\phi} V(p/(1+\pi), z', \phi)$$

where current period profits are given by

$$\pi(p, z) = \Big[\alpha + 2(1-\alpha)(1-F(p))\Big] p^{-\theta} \left(p - \frac{W}{z}\right)$$

3.3 Equilibrium

A steady state equilibrium is a distribution of real prices F, firm value functions V, V^A, V^{NA} and firm policies p such that:

1. Given the distribution of real prices F, the value function V solves the recursive firm problem, with p the optimal policy.

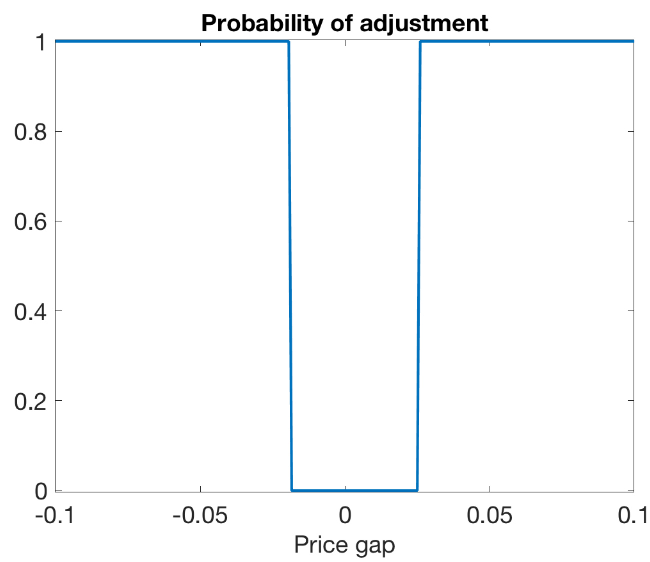
2. The distribution of real prices F is consistent with the law of motion implied by firm optimal policies and the law of motion for idiosyncratic productivity.

The distribution of prices F directly enters the value of the firm through its profit function. This implies that solving for the steady state requires finding a fixed point over the cdf F. This function is an infinite–dimensional object, so to compute the equilibrium, I approximate the function with a finite–dimensional object.

3.4 Firm policy

A firm's optimal policy in this model takes the form of an (s,S) policy: conditional on adjustment and a value of productivity, a firms' value is maximized by a unique price. I denote this price the *reset price*. As in Golosov and Lucas (2007), this price is increasing in marginal cost, and firms with higher productivity set lower prices. Given a reset price policy, a firm will only choose to adjust if the value of adjustment is higher than the value of not adjusting. In general, a firm will not adjust when its price gap, the difference between its current and optimal reset price, is small. Figure 3 depicts such an optimal rule for a given value of productivity. Note that in this model, the width of a firms' inaction region depends on the level of its productivity.

Figure 3: A firm's optimal decision to change its price



This optimal strategy is standard in menu cost models but differs from the firm policy in the QSs model of Burdett and Menzio (2017). Adding idiosyncratic productivity purifies the QSs equilibrium so that firms are no longer exactly indifferent over a region of prices. This purifying effect of firm productivity differences is similar to what Kenneth Burdett and Dale Mortensen (1998) find; firms are no longer indifferent over prices.

4 Steady state results

4.1 The Golosov–Lucas Benchmark

The profit function of the firm in this model nests the profit function of Golosov and Lucas (2007). To see why, recall the profit function:

$$\pi(p,z) = \left[\alpha + 2(1-\alpha)(1-F(p))\right]p^{-\theta}\left(p - \frac{W}{z}\right).$$

When every customer is captive, $\alpha = 1$ and firm profits are

$$\pi(p,z) = p^{-\theta}\left(p - \frac{W}{z}\right)$$

When $\alpha = 1$, firms are effectively monopolistic producers of a variety. They set different prices due to differences in productivity, a downward–sloping demand curve, and the menu cost. Throughout this section, I will compare a version of the model with $\alpha \in (0,1)$ to the Golosov and Lucas (2007) benchmark.

4.2 Calibration

Standard menu cost models account for price dispersion entirely through productivity dispersion, the menu cost, and monopolistic competition. The product market frictions in this model are another source of price dispersion. Thus, to calibrate the model, I jointly choose values of the product market frictions, menu cost, and firm productivity dispersion parameters to target three moments of the distribution of firm prices and price changes.

An important moment is the dispersion in store–good prices, as documented in Section 2. At its peak, the standard deviation of store–good prices was 16 %, and at its trough it was 14.2 %. Greg Kaplan, Guido Menzio, Leena Rudanko and Nicholas Trachter (2016) estimate that 36 % of the variance in the store–good component is permanent, the remainder coming from temporary sales. The model is not one of temporary sales, so I target a standard deviation of prices in the model of $\sqrt{.36 \times 16^2\%} = 9.6\%$.

The two other moments of the price distribution that I target are the frequency and average absolute of price adjustment. These moments capture firms' willingness to change their prices in response to idiosyncratic shocks and are thus informative about the degree of dispersion in idiosyncratic shocks and about the degree of menu costs.

While I simultaneously choose the degree of product market frictions, the variance of idiosyncratic shocks, and the level of the menu cost to target these three moments, identification works loosely as follows. I choose the degree of product market frictions to rationalize the degree of price dispersion; this parameter affects the degree of deviation from the Law of One Price. The menu cost and idiosyncratic volatility parameters both affect the frequency and size of price changes. An increase in the menu cost widens the firms' Ss band, which decreases frequency and increases average size. An increase in volatility increases the average size of price changes and could either increase or decrease frequency; it increases the likelihood that a firm hits is adjustment band but also widens them via a "wait–and–see" motive.

Table 1: Parameterization

Parameter		Search economy	Golosov–Lucas	Source
Discount rate	β	$0.95^{\frac{1}{12}}$		Monthly
Demand curve	γ	1/4		CES demand[2]
Wage	ω	0.5		Normalization
Money growth	π	0.0021		Mean inflation
Persistence of tfp	ρ_z	0.62		Vavra (2014)
Prob. of shock	λ	0.13		Vavra (2014)
Captive customers	α	13 %	100 %	Internal calibration
Vol. of tfp	σ_z	5%	5.2 %	Internal calibration
Menu cost	f	0.135	0.02	Internal calibration

Observe that the search economy requires a higher value of the menu cost to target the same value of the frequency of price change. This is because, in the search economy, firms face an extra margin of competition and thus face stronger incentives to keep their price at its optimal level. The volatility of idiosyncratic TFP is roughly the same in each economy.

4.3 The elasticity of demand and markups

Demand elasticities are important for understanding the pass–through of idiosyncratic cost shocks and aggregate monetary shocks. To understand why, note that I can write the log price of firm i at date t as its marginal cost plus a markup:

$$\log p_{it} = mc_{it} + \mu_{it}.$$

In general, the markup a firm sets might depend on past values of its price, its marginal cost, and the prices that other firms set. An increase in marginal cost is then partly passed into prices and partly into markups:

$$\frac{\partial p_{it}}{\partial mc_{it}} = 1 + \frac{\partial \mu_{it}}{\partial mc_{it}}$$

So, when the markup falls with marginal costs, pass–through is less than 1, when the markup rises with marginal costs, pass–through is greater than 1, and when the markup does not depend on marginal costs, pass–through is 1. In the standard CES framework, prices are a constant markup over marginal cost, so that pass–through is equal to 1. Under the Kimball demand framework, markups are falling in marginal costs, so that passthrough is always less than one.

In this model, because demand elasticities depend on the distribution of prices, optimal markups will vary with marginal costs, and passthrough will vary over the distribution of firms. The demand that a firm with price p pays is equal to

$$D(p, z; F) = \Big[\alpha + 2(1-\alpha)\big(1 - F(p)\big)\Big]p^{-\theta}$$

The elasticity of demand is then

$$\epsilon_p^D = -\frac{2(1-\alpha)f(p)p}{\alpha + 2(1-\alpha)(1-F(p))} - \theta$$

This elasticity is $-\theta$ in two cases: in the Golosov–Lucas case ($\alpha = 1$) and when the mass of firms with a price p is equal to 0 (i.e., $f(p) = 0$). In all other cases, firms face more elastic demand. This implies that optimal markups should be weakly bounded above by the optimal CES markup of $1 - \frac{\theta}{\theta-1}$. This pattern indeed holds in this model.

Figure 4: Markups in the search Golosov and Lucas (2007) economies

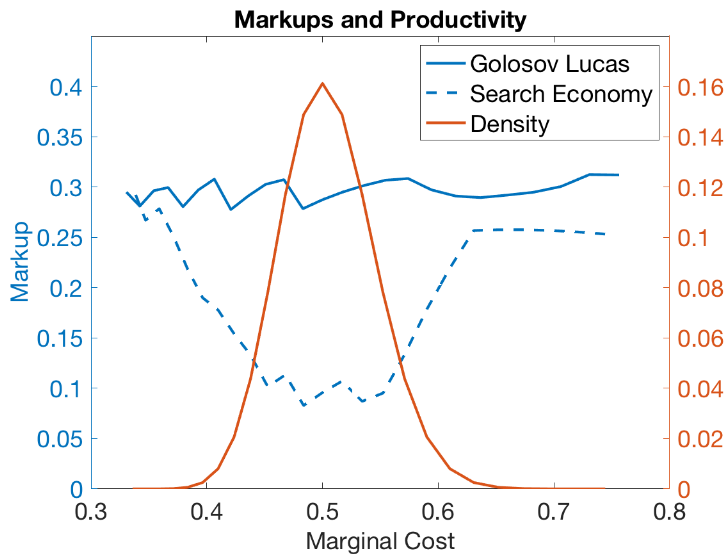
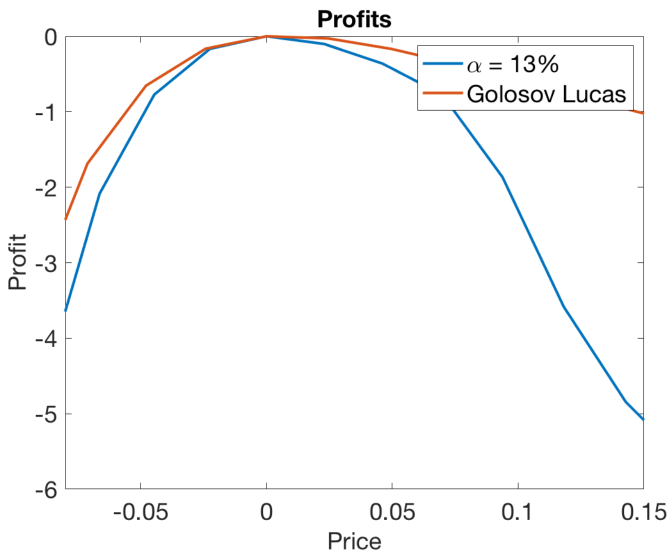


Figure 4 depicts optimal frictionless markups in the two economies as a function of marginal cost, as well as the distribution of marginal costs. Markups are roughly flat in the Golosov and Lucas (2007) economy, implying that pass–through of cost shocks is roughly 1. In the search economy, markups for extreme values of marginal cost are roughly equal to the CES markup. They fall in the middle of the distribution, as firms compete more closely with other firms near them. This is a unique feature of this model: firms here face competition from firms near them, rather than from the aggregate.

Since markups fall, are flat, and then rise again with marginal costs, pass–through is heterogeneous in this economy. Pass–through is less than 1 for the most productive firms, is about 1 for firms near the center of the distribution, and is larger than one for unproductive firms. The intuition is as follows: for a high productivity firm, an increase in costs makes them more similar to the average firm and subjects that firm to more intense competition. For a low productivity firm, an increase in costs makes them more different from other firms so that they face less local competition and can raise their markup.

More elastic demand implies that profit functions exhibit stronger curvature in the search economy than in the Golosov and Lucas (2007) economy. Figure 5 depicts profits around an optimal value for both economies. It shows that profits decline more sharply around their optimal value for price deviations in the search framework. The intuition is that, for a firm in the search economy, having too high a price means that they lose sales to other firms, and having too low a price means selling to too many consumers at too low a markup. The curvature of a firm's profit function depends on mass of firms with prices near that firm's price.

Figure 5: Markups in the search Golosov and Lucas (2007) economies



5 Imperfect competition, volatility, and monetary non–neutrality

In this section, I study the behavior of output in this economy to an unexpected shock to the growth rate of money. The experiment is as follows: at date $t = 1$, the economy is in steady state. Then, inflation is unexpectedly 2% larger for one period, after which it returns to its steady state value. Firms are surprised by the initial increase in inflation but perfectly anticipate the return of the economy to its steady state thereafter.

Figure 6: The experiment in the search and Golosov and Lucas (2007) economies

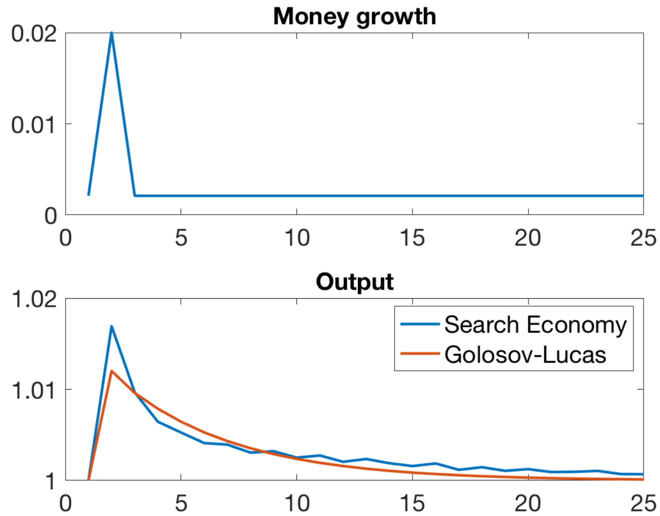


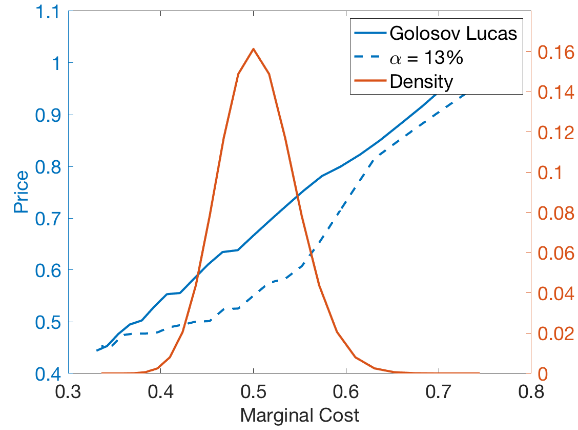
Figure 6 depicts the results of the experiment, and Table 2 presents summary statistics. The peak response in the search economy is 41 % larger than in the Golosov–Lucas economy. The total response is 19 % larger in the search economy. Output remains elevated in the search economy for longer than in the Golosov Lucas economy, remaining above its steady state level even after 20 months.

Table 2: Summary of the experiment

Statistic	Search economy	GL economy	% difference
Peak response	1.69%	1.20%	41%
Total response	7.70%	6.45%	19%

Why is the response of output larger in the search economy than in the Golosov Lucas economy? To understand the difference in the effect of a monetary shock on output, it is useful to understand how firms pass cost shocks into their optimal reset prices, and then how an aggregate shock pushes firms to adjust their prices to those new reset prices.

Figure 7: Marginal cost and optimal reset prices in two economies



5.1 Pass–through

A monetary shock leads real prices to fall relative to the real wage, which is fixed at ω. Effectively, it acts like a cost shock, depreciating firms' markups. So, to understand the response of prices to an aggregate monetary shock, it is useful to study how firms respond to idiosyncratic cost shocks.

In the Golosov–Lucas economy, markups are constant and do not depend on the actions of any other firms. So, the pass–through of marginal cost shocks into reset prices is complete and immediate. In the search economy, however, markups are not constant in marginal cost, and they do depend on the actions of other firms. To see why, recall the expression for the elasticity of demand I derived in a previous section:

$$\epsilon_p^D = -\frac{2(1-\alpha)f(p)p}{\alpha + 2(1-\alpha)(1-F(p))} - \theta$$

The elasticity of demand at a price p, and therefore the optimal reset markup, depends on the mass of firms who set a price near p. When the first term in the expression for the elasticity is large, firms face very elastic demand and want to set low markups. The first implication of this relationship is that, if the distribution of prices is unimodal, pass–through is increasing in price. Figure 7 depicts the optimal reset price as a function of marginal cost in these two economies.

As Figure 7 depcits, pass–through is 100% in the Golosov–Lucas economy, while it is low for high productivity firms and increases with marginal cost for firms in the search economy. For most firms in the economy, and for those who sell the most, pass–through is less than 100 % in the search economy. This suggests that firms do not completely pass–through an aggregate shock into prices.

5.2 Real rigidities

Because customers can switch between stores, firms in the search model are more strongly penalized for setting high prices. This feature introduces stronger curvature in the profit function above the optimal price, as depicted in Figure 5. Following Emi Nakamura and Jon Steinsson (2010), in the Golosov–Lucas model, we can write a firm's profit function as $\Pi(p_t/P_t, S/P_t, \tilde{A}_t)$, where p_t/P_t is a firm's price relative to the price index (this is "real price" in my model), S/P_t is nominal output relative to the price level, and $\tilde{A}_t$ are idiosyncratic factors that affect a firm's profits. In that case, one can show that

$$\frac{\partial p}{\partial P} = 1 + \frac{\Pi_{12}}{\Pi_{11}}$$

An increase in the curvature of the profit function with respect to p, i.e., an increase in $-\Pi_{12}$, makes a firm's price less responsive to the aggregate price index. This implies that an increase in the curvature of the profit function will make firms hesitant to respond completely to the changes of their competitors' prices. To understand why, consider the decision of a firm who has decided to change its price. It knows that eventually, it will have to respond fully to the monetary shock. However, in the short run, some of its competitors will not change their prices, and it will lose demand to those firms.

The search economy incorporates an additional margin of adjustment that is ignored in the Golosov–Lucas economy. In the Golosov–Lucas economy, consumers are entirely captive to retailers. In the search economy, consumers can switch between stores, which penalizes stores with high prices. This feature makes prices stickier in the search economy and leads monetary policy to have stronger effects on output.

5.3 A useful decomposition

A change in optimal reset prices leads firms to respond in two ways: first, firms who would have changed their prices absent the shock will now change their prices by more, and second, the change in optimal reset prices will push some firms who would not have changed their prices to their adjustment bands and lead them to respond. The first margin is typically denoted the *intensive margin* and the second margin is denoted the *extensive margin* or the *selection effect*.

Ricardo J. Caballero and Eduardo M.R.A. Engel (2007) formalizes this intuition. Define the log difference between optimal reset price and current price, $x \equiv \log p^* - \log p$ the price gap, and denote its distribution $f(x)$ and the probability of adjustment conditional on a value of the price gap $\Lambda(x)$. Inflation is given by

$$\pi = \int \Lambda(x) x f(x) dx.$$

Consider then a small aggregate shock to price gaps given by ΔS. A first–order Taylor approximation implies that the response of inflation to a small shock is equal to the intensive plus the extensive margins:

$$\lim_{\Delta S \to 0} \frac{\Delta \pi}{\Delta S} = \int \Lambda(x) f(x) dx + \int x \Lambda'(x) f(x) dx$$

The first term is the intensive margin and it is exactly the frequency of adjustment. Since both the search model and the Golosov–Lucas model are calibrated to the same frequency of price change, this term is the same in both models. The second term is the extensive margin. It captures the idea that a change in price gaps pushes some firms to adjust their prices who would not have otherwise. If the firms who are pushed to change their prices have large price gaps, then inflation responds strongly to the aggregate shock.

Table 3 summarizes the results of the Caballero and Engel (2007) decomposition in the search and Golosov–Lucas economies. As I find in the experiment, prices are stickier in the search economy. The intensive margin is equal to the frequency of price adjustment and is the same in each economy. Prices are more flexible in the Golosov–Lucas economy because the extensive margin is larger. Because their incentives to pass through cost shocks are heterogeneous, firms in the search economy change their prices more due to idiosyncratic reasons than in the Golosov–Lucas economy.

Table 3: The Caballero and Engel (2007) Decomposition

Calibration	Intensive	Extensive	Total
Search	11.2%	14.4%	25.6%
GL	11.1%	17.8%	29.0%

5.4 Kurtosis and the selection effect

Fernando Alvarez, Herve Bihan and Francesco Lippi (2016) show that in a class of menu cost models, the cumulative effect of an unexpected monetary shock on output, $\mathcal{M}$, can be summarized in terms of steady state statistics. The effect is proportional to the ratio of kurtosis of price changes to the frequency of price changes

$$\mathcal{M} \propto \frac{Kur(\Delta p_i)}{N(\Delta p_i)}.$$

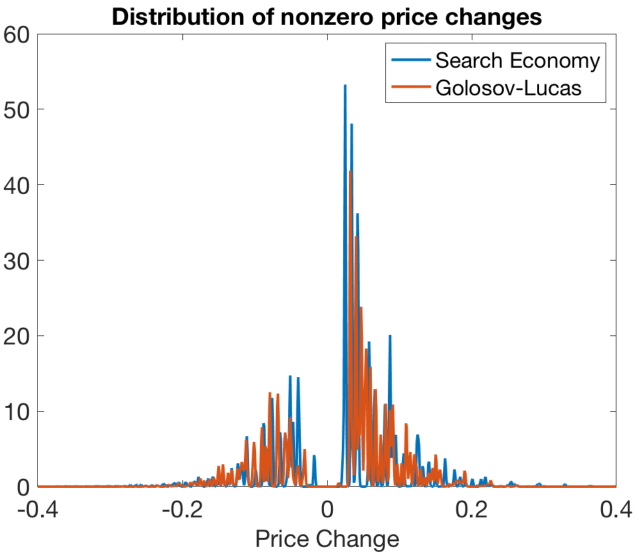
The intuition for this result is relatively straightforward. High frequency of price adjustment implies that prices are sticky and output responds by little to a monetary shock. The kurtosis of price changes summarizes the selection effect. When kurtosis is high, there are many large and many small price changes. This implies that firms respond largely to idiosyncratic shocks, not to keep up with inflation. Because firms primarily change prices for idiosyncratic reasons, a surprise monetary shock does not induce firms with large price gaps to change their prices.

Table 4 summarizes the components of the Alvarez, Bihan and Lippi (2016) statistic in these two economies. Figure 8 depicts the distribution of price changes in each economy. Kurtosis is higher in the search economy than in the Golosov–Lucas economy. This increased kurtosis can be partly explained by heterogeneous pass–through. Firms in each economy are roughly subject to the same volatility of shocks, but in the search economy, some firms change their prices by little and some by a lot in response to those shocks. This drives up the number of both small and large price changes and increases the kurtosis of price changes. The increase in the kurtosis means that firms change prices more for idiosyncratic reasons than in the Golosov–Lucas economy.

Table 4: The Alvarez, Bihan and Lippi (2016) sufficient statistic in two economies

Calibration	Frequency	Kurtosis	Kurtosis/Frequency
Search	1.31	4.32	3.20
GL	1.34	2.76	2.07

Figure 8: The distribution of price changes in each economy



6 Time–varying non–neutrality

In the first section of this paper, I document that price dispersion rises in recessions. This model can account for this fact through a rise in customer captivity. In this section, I study the impact of a rise in customer captivity on monetary non–neutrality in this model. I find that a rise in customer captivity consistent with the rise in price dispersion in recessions decreases the total response of output to a monetary shock by 50 %.

6.1 Calibration

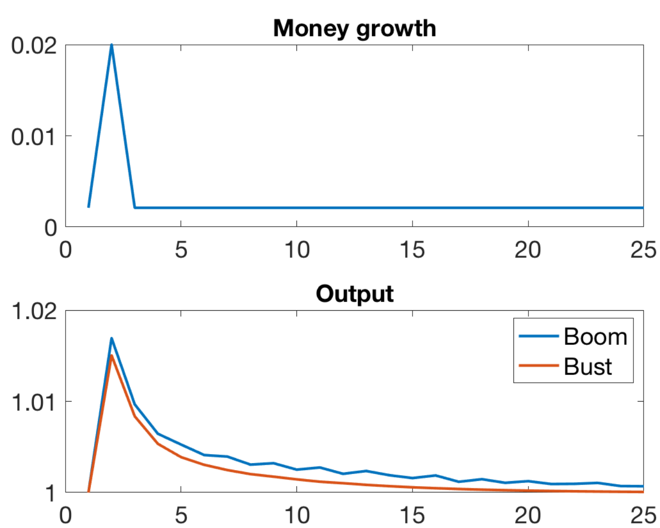
I use the calibration from the previous section as a "normal times" calibration and vary the measure of captive customers α to target the increase in price dispersion observed in the data. Table 5 depicts the parameter values in the normal times and the recession. To account for increased price dispersion, the model requires a larger measure of captive customers. This is due to the fact that, when the measure is low, firms compete intensively with each other and do not want to have prices that deviate strongly from their competitors' prices. The increase in the measure of captive customers drives the frequency of price change down and the average size of a price change up. The decline in frequency is inconsistent with data on price changes in recessions; Joseph Vavra (2014) documents that firms adjust their prices more frequently and by more in recessions.

Table 5: Calibrating the model to a recession

	Normal times	Recession	Data
Variance of productivity shock	0.05	–	–
Menu cost	0.135	–	–
Measure of captive customers	13%	25%	–
Frequency of price change	11.2%	10.4%	11%
Average size	7.1%	8.3%	7.5%
Price dispersion	8.5%	9.7%	(8.5%, 9.6%)

I subject each economy to the same experiment as before. At time $t = 1$, each economy is in its steady state. Inflation is then unexpectedly 2% for one period, after which, it returns to its steady state value. Figure 9 depicts the results of the experiment. Output increases by more and remains elevated for longer in the boom.

Figure 9: The experiment in the boom and bust



This result is intuitive: increasing the measure of captive customers moves the economy closer to the

Golosov and Lucas (2007) benchmark and reduces monetary non–neutrality. In recessions, the decline in competitiveness (or an increase in α) reduces the curvature of the profit function and makes firms more willing to fully respond to the monetary shock. It also reduces the kurtosis of the price change distribution (from 4.3 to 3.7) by reducing the degree of heterogeneity in pass–through, which, through a reduction in the selection effect, drives down monetary non–neutrality.

6.2 Comparison with Vavra (2014)

This assessment of the time–varying effects of monetary policy are clearly not model invariant. I rationalize increased price dispersion in recessions through a rise in firm market power. In recessions, firms are penalized less by deviating from their optimal price, and so prices are stickier and monetary policy is more effective.

Vavra (2014) rationalizes increased price dispersion in recessions in a different way, using increased productivity dispersion and draws opposite conclusions about monetary policy effectiveness. In his model, firms in recessions face larger idiosyncratic productivity shocks, which pushes them to their adjustment bands and makes them more likely to adjust prices in response to a monetary policy shock. This effect leads monetary policy to be less effective at stimulating output in recessions.

A piece of evidence in favor of the mechanism in this paper is that changes in the competitive environment can rationalize the increase in the dispersion in store–good dispersion, while an increase in productivity dispersion cannot, since store–good price dispersion abstracts from store productivity differences.

6.3 Evidence on the decline in competitiveness in recessions

This paper rationalizes increased price dispersion in recessions through a decline in the competitiveness of retail markets. This mechanism generates counter–cyclical markups. It is consistent with observable trends in the retail market.

Several papers have documented time–variation retail competition. Greg Kaplan and Guido Menzio (2016) document in the American Time Use Survey (ATUS) that employed people spend 30 percent less time shopping than nonemployed people and around 15 percent less time shopping than unemployed people. Mark Aguiar, Erik Hurst and Loukas Karabarbounis (2013) find similarly that time spent on shopping decreases with hours worked.

Nicolas Petrosky-Nadeau, Etienne Wasmer and Shutian Zeng (2016) dispute the claim that shopping effort is counter–cyclical. Using the ATUS, they show that time spent shopping in the goods market declined during the last recession, and that states with the largest declines in per capita output experienced the largest declines in time spent shopping. They also show that time spent shopping is increasing in household income. Consistent with Kaplan and Menzio (2016), they find that shopping effort is declining in hours worked, but they show that in the last recession, the income effect dominated the time allocation effect and the unemployed actually shopped less than the employed. This suggests that shopping effort declined in the recession, consistent with an increase in customer captivity.

Retail entry and exit is another margin of adjustment that might affect the competitive environment in recessions. To study this channel, I study the response of grocery establishments to local economic conditions. I measure the number of grocery establishments, by metropolitan statistical area (MSA) in the County Business Patterns Data from the US Census. Those data provide annual measures of the number of establishments by NAICS code in each county, and I count the number of establishments in each county with NAICS code 445110, which corresponds to grocery stores.

To measure local economic conditions, I use house prices, instrumented by local house price elasticity. The measure of local house prices is the Federal Housing Finance Agency's all–transaction index[3]. Since house price movements are endogenous, I instrument for them with the Albert Saiz (2010) measure of the local elasticity of housing supply. This is a measure of how difficult it is to build houses and is a good proxy of the sensitivity of house prices to local economic conditions.

I regress 3–year changes in the log number of establishments on the log 3–year change in the house price index over two periods:

$$\Delta^3 \log \#establishments_\ell = \alpha + \beta \Delta^3 \log hpi_\ell + \epsilon_\ell$$

Table 6 depicts the results of the estimation. The pooled regression shows that CBSAs that experienced higher house price growth between 2002–2005 or larger falls in house prices between 2006–2009 experienced more dramatic changes in the number of stores.

I find that areas with faster growth in house prices over the period 2002–2005 experienced significantly

[3]Available at https://www.fhfa.gov/DataTools/Downloads/Pages/House-Price-Index.aspx

larger increases in the number of establishments. The elasticity is 25 % under OLS and 35 % using the Saiz (2010) instrument. Results are not significant in either the pooled or 2006–2009 sample. This suggests that the entry margin is more responsive to local economic conditions than the exit margin. Further research could investigate this relationship.

Table 6: Local demand and establishment entry

	OLS		IV	
Sample	β	se	β	se
pooled	0.221	0.028	11.173	62.18
2002 – 2005	0.256	0.059	0.354	0.122
2006 – 2009	-0.165	0.046	-0.176	0.088

To summarize, I find evidence of higher competitive pressure before the last recession than during the crisis. I document that households visited fewer stores during the recession, and that the number of establishments in a given CBSA responds significantly to local economic conditions. These reduced form findings are consistent with the model calibration, which accounts for increased price dispersion in recessions through a fall in competitive pressure.

7 Relationship to the literature

This paper contributes to a literature on price stickiness in models with search frictions. My model closely resembles that in Kenneth Burdett and Guido Menzio (2018), which study a model in which price dispersion arises due to frictional search and argue that, because their models require lower menu costs to match moments of the data, they imply lower levels of monetary non–neutrality. They do not verify this claim directly by studying the response of the economy to a nominal shock. In this paper, I directly assess this claim.

My paper contributes to a theoretical literature studying models with infrequent price adjustment. Virgiliu Midrigan (2011) and Golosov and Lucas (2007) study monetary non–neutrality in quantitative menu costs models. Golosov and Lucas (2007) argued that money could be nearly neutral in a menu costs model. In their model, the "selection effect" dominates: an increase in the money supply increases the amount by which firms adjust, and pushes more firms with positive price gaps to adjust. This means that the price level reacts quickly to absorb a change in the money supply. Midrigan (2011) argues that Golosov and Lucas (2007) is inconsistent with key features of the price change distribution and presents a modified version of their model in which money is non–neutral.

The degree of monetary non–neutrality implied by these models is still lower than aggregate studies suggest. Klenow and Willis (2016) study models with "real rigidities" that amplify price stickiness. However, they find that a model with micro–level real rigidities requires counterfactually large productivity dispersion in order to account for observed movements in prices. Essentially, firms change their prices a lot for idiosyncratic reasons but not much in response to aggregate shocks. If firms face real rigidities that make them want to keep their prices close to their competitors' prices, then they must face counterfactually large idiosyncratic productivity shocks in order to reconcile these two joint phenomena.

Imperfect competition in the QSs model provides a source of idiosyncratic price dispersion beyond productivity dispersion. In the analytic version of the model, firms had identical productivity but still set different prices. In the quantitative version of the model firms face heterogeneous productivity. And, as in Burdett and Mortensen (1998), the frictional market means that firms with small differences in productivity set very different prices.

Vavra (2014) uses a quantitative menu cost model to argue that monetary policy is more neutral in recessions. He documents counter–cyclical dispersion in the distribution of price changes and frequency of adjustment and rationalizes these facts through counter–cyclical dispersion in firm–level shocks. Increased dispersion in productivity leads prices to be more flexible in recessions. I also use micro–data and a quantitative menu costs model to study time–variation in monetary non–neutrality. In contrast to Vavra (2014), I study a mechanism that leads prices to be less flexible in recessions.

Each of these menu costs models uses some form of monopolistic competition. Mongey (2018) studies a quantitative menu costs model with a continuum of sectors, each of which comprises two strategically engaged firms. In the model, strategic complementarities amplify price rigidity and imply larger output fluctuations due to monetary policy than a standard monopolistic competition model. Like Mongey (2018), I study the implications of alternative market structure for monetary non–neutrality in a menu costs model. Unlike Mongey (2018), I find that increases in the competitiveness of markets decreases price flexibility.

8 Conclusion

The ability to purchase the same good from different stores is a key feature of retail markets. In this paper, I quantify the effect of this feature of competition on monetary non–neutrality by incorporating frictional search into an otherwise standard quantitative menu costs model. I find that incorporating this feature increases price rigidity and the effect of monetary policy on output relative to a monopolistic benchmark. The reason is that increased competition between firms means that firms wish to keep their prices close to their competitors' prices, and so firms are reluctant to respond to a monetary shock. I use the model to study how changes in competitiveness over the business cycle could lead to changes in the effectiveness of monetary policy over the business cycle. Viewed through the lens of the model, the data are consistent with a fall in competitiveness and a fall in price rigidity in recessions. Future work could investigate whether the implications for heterogeneous pass–through in this model are consistent with microdata.

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