In Search of Real Rigidities

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January 29, 2010

A large literature has recently emerged that documents patterns of nominal price stickiness at the very micro level — the good level. The documented nominal durations are significantly shorter than the estimated real effects of money on output (e.g., Christiano, Eichenbaum, and Evans (1999)). The long-lasting real effects of monetary shocks can be reconciled with moderate price stickiness if *real rigidities* are an important phenomena.[1] These real rigidities dampen price responses even when firms adjust prices because of factors such as strategic complementarities in price setting, the dependence of costs on input prices that have yet to adjust, increasing marginal costs at the firm level, among others. It is not surprising then that an important empirical literature has recently emerged that evaluates the question: Are quantitatively important real rigidities present in the data? The answer appears to depend on what data one looks at.

In international economics there is a large and growing literature that estimates exchange rate pass-through from exchange rate shocks into prices. The evidence is used to argue for the presence of important pricing to market effects that arise as firms adjust their mark-ups and pass-through only a small fraction of the shock. This constitutes direct evidence on one of the important sources of real rigidities. Since exchange rate shocks constitute large observable cost shocks for firms that engage in international trade, international pricing data can be used to directly assess the strength of the variable markup channel central to both generating pricing to market and real rigidities. Despite the relevance of this evidence for the importance of real rigidities, the closed economy and open economy literature have rarely

[1] The literature following Taylor (1977) calls it the contract multiplier

been brought together. In this paper we attempt to bring together the closed economy macro literature that focuses on indirect tests of real rigidities (in the absence of well identified and sizeable shocks) with the international pricing literature that uses an observable and sizeable shock, namely the exchange rate shock to evaluate the behavior of prices, with emphasis on real rigidities.

We first review the recent evidence on real rigidities to evaluate if there is a consensus emerging on the importance of real rigidities in the data. There is surprisingly a consistent set of results across studies that emerges despite the fact that these studies use different methodologies and data sets. The evidence in the case of variable mark-ups suggests that they play a less important role at the level of retail prices as compared to at the level of whole-sale prices.

Klenow and Willis (2006) and Bils, Klenow, and Malin (2009) use the retail price micro data that underlies the construction of the U.S. consumer price index and find that these prices display behavior that is inconsistent with calibrated macro models of real rigidity. Klenow and Willis (2006) show this to be the case for the variable mark-up channel and Bils, Klenow, and Malin (2009) extend this to a more general class of real rigidities by evaluating the properties of reset price inflation. In the international price literature that evaluates micro data and where the prices are whole-sale prices and involve business-to-business transactions Gopinath and Rigobon (2008), Gopinath, Itskhoki, and Rigobon (2008) and Gopinath and Itskhoki (2008) find significant evidence of the variable mark-up channel using at-the-dock import prices into the U.S. Fitzgerald and Haller (2008) find similar evidence using micro-data for Irish exporters. This evidence is consistent with a large literature in international economics that finds strong evidence of pricing to market for individual industries as surveyed in Goldberg and Knetter (1997).

Another set of studies are able to combine wholesale and retail prices for individual goods. Eichenbaum, Jaimovich, and Rebelo (2007) use data from a grocery chain and find that conditional on changing prices there is no evidence of variable mark-ups, all of the whole-sale cost change is passed through into retail prices. Using the same data, but for the U.S. and Canada, Gopinath, Gourinchas, Hsieh, and Li (2009), find that in response to an exchange rate shock movements in relative retail prices in a common currency are explained mainly by movements in relative costs and very little by relative mark-ups. Burstein and Jaimovich (2008) also use this data to document the incomplete pass-through into whole-sale costs of exchange rate shocks. Goldberg and Hellerstein (2006) and Nakamura and Zerom (2008) find that for beer and coffee sales (respectively) in a grocery store the pass-through from exchange rate shocks to whole-sale costs is incomplete, but the pass-through from whole-sale costs to retail prices is close to complete. In a recent study, Berger, Faust, Rogers, and Steverson (2009) match goods in the import price index to those in the consumer price index for the period January 1994-July 2007 and find that the overall distribution wedge, which is the percent difference between retail and at-the-dock prices does not vary systematically with the exchange rate. Overall, the evidence suggests an important role for variable mark-ups at the whole-sale level but not at the retail level.

Next we present novel evidence on real rigidities using international price data by performing the following analysis: First, we construct a reset price inflation series for U.S. import prices and evaluate the properties of this series and compare it to the evidence for retail prices in Bils, Klenow, and Malin (2009). Bils, Klenow, and Malin (2009) estimate that for the sample that excludes sales prices the actual inflation series has persistence (as measured by the AR(1) coefficient) of -0.05 and a standard deviation of 0.14%. The reset price inflation series has a persistence of -0.41 and a standard deviation of 0.95%. In contrast, for import prices, the actual inflation series has a monthly persistence of 0.51 and a standard deviation of 0.33%. The reset price inflation series has a persistence of 0.02 and a standard deviation of 1.6%. The reset price inflation series for import prices depicts less negative autocorrelation as compared to the series for retail prices. The persistence of the reset price inflation series suggests very little dynamics in desired price adjustment for import prices. However, in a second set of results we show that in response to a specific shock, namely the exchange rate shock, there is compelling evidence of sluggish adjustment in desired (reset) prices. We show that prices, conditional on a change, respond to exchange rate shocks prior to the last time the price was adjusted and these lagged effects are large and statistically significant. This evidence suggests that evaluating the response to a specific shock can give very different results from evaluating the properties of a series that is subject to many different shocks. We also present the evidence by the "end-use" of the product and find that while medium-run pass-through is low across the end-use categories lagged effects are more prominent for "industrial supplies and materials" and "capital goods (except automotive)" as compared to "consumer goods (non food, except automotive)".

Third, we evaluate the sensitivity of firm pricing to shocks to competitors by measuring the response of prices to movements in the U.S. trade weighted exchange rate that is orthogonal to the bilateral exchange rate for the country. We find the response to be sizeable and significant. In a similar vein we find that exchange rate pass-through is higher in response to a more aggregate shock as compared to more idiosyncratic shocks, when comparing the response to bilateral exchange rate shocks versus trade weighted exchange rate shocks.

Fourth, we relate the incompleteness in pass-through to certain sectoral features that proxy for the level of competition among importers. An important distinction between retail prices and whole-sale prices is that the latter captures business-to-business transactions. Consequently, the strength of bargaining power of the buyer can impact the extent of pass-through. We use unpublished measures of concentration in the import sector provided to us by the BLS-measures of the Hefindahl index and the number of importers that make up the top 50% of trade- to evaluate this. We find some (mild) evidence that import sectors that are more concentrated have a smaller pass-through. This is mainly evident for products that are classified as "differentiated" as one might expect.

We next evaluate the performance of a model with different degrees of real rigidities (different degree of elasticity of mark-ups) at the whole-sale and retail level. We calibrate the model to the micro-evidence on retail and whole-sale prices and allow for separate retail and whole-sale shocks that generate some disconnect between the two prices, as in the data. This will be a closed economy model where we calibrate the parameters for the whole-sale sector using the evidence from international prices. We then examine the size of the contract multiplier that such an environment generates.

Finally, we present a bargaining model of whole-sale price setting that results in variable markups and incomplete pass-through of shocks into whole-sale prices. Specifically, each final good producer bargains with its intermediate good supplier regarding the price of the intermediate goods. Given these bargained prices, the final good producer is free to choose quantities of the intermediate inputs. This model results in variable markups that depend among other things on the relative bargaining power of the final good producer and on the market share of the intermediate good supplier. We then incorporate this bargaining model into a standard dynamic general equilibrium sticky price model to assess the extent of monetary non-neutrality that it can generate.

1 Real Rigidities

We first set-up some notation and spell out the sources of real rigidities that can result in sluggish price adjustment. We define the *desired price* of a firm as the price it would set if it could adjust its price flexibly, given the economic environment. The presence of real rigidities works to slow the response of the desired price to a shock. Real rigidities powered by staggered price adjustment (Taylor, 1980; Calvo, 1983), can be either at the aggregate (industry) level or at the micro (firm) level. Real rigidities at the aggregate level include, among others, intermediate inputs (Basu, 1995), real wage rigidity (Blanchard and Galí, 2007) and firm-specific inputs (Rotemberg, 1996). Real rigidities at the firm-level arise from variable markups (Kimball, 1995; Atkeson and Burstein, 2008) or non-constant marginal cost (Burstein and Hellwig, 2007). The empirical evidence is about determining which of these channels if any is present in the data and the magnitude of these effects. Since the empirical literature has examined this evidence at both the retail and whole-sale level we will present that break-up in our description.

Final good (retail) pricing: The desired log price for a final good i, $\tilde{p}_{it}$ is

$$\tilde{p}_{it} = \tilde{\nu}_{it} + \alpha s_t + (1-\alpha)w_t - z_{it},$$

where $\tilde{\nu}_{it}$ is the log desired mark-up, s_t is the log price of the intermediate input, w_t is the log price of other inputs (like labor), and z_{it} is idiosyncratic marginal cost (or markup) shock. We let $\alpha \in [0,1]$. When $\alpha = 0$, this is the case with no intermediates; when $\alpha = 1$ the final good price level is closely tied to the intermediate good price level.

The final good price level is approximated by a geometric average of individual final good prices, which in logs is simply:

$$p_t = \int_i p_{it} \mathrm{d}i.$$

The strategic complementarity/variable mark-up channel can be captured by the desired mark-up decreasing in the relative price of the firm, that is

$$\tilde{\nu}_{it} \approx -\Gamma^F (p_{it} - p_t)$$

where $\Gamma^F \geq 0$ is the elasticity of the mark-up to the relative price.

$$\tilde{p}_{it} = \frac{\Gamma^F}{1+\Gamma^F} p_t + \frac{\alpha s_t + (1-\alpha) w_t - z_{it}}{1+\Gamma^F},$$

If $\Gamma^F > 0$ the desired price depends on the price set by the competitors. Also the response to shocks such as z will be incomplete. Similarly, sluggishness in $\tilde{p}_{it}$ can arise from slow response of s_t and w_t to shocks.

Intermediate good (wholesale) pricing: The desired log price of an intermediate producer j is

$$\tilde{s}_{jt} = \tilde{\mu}_{jt} + w_t - a_{jt},$$

where $\tilde{\mu}$ is log desired markup, a_{jt} is the log idiosyncratic marginal cost (or markup) shock. The actual intermediate goods price s_{jt} and price index for intermediates s_t are defined similarly to above.

Further, the desired markup can be decreasing in the relative price of the intermediate:

$$\tilde{\mu}_{jt} = -\Gamma(s_{jt} - s_t),$$

where Γ is the elasticity of markup (that can potentially vary with j). The desired price of the intermediate goods:

$$\tilde{s}_{jt} = \frac{\Gamma s_t}{1+\Gamma} + \frac{w_t - a_{jt} + \phi_j e_t}{1+\Gamma}.$$

Purely idiosyncratic shocks get passed-through immediately (conditional on first price adjustment) with a pass-through coefficient of $1/(1+\Gamma)$. More aggregate shocks have two channels through which they affect the desired price — directly (w_t or e_t) and via the prices of competitors (s_t). Coupled with nominal price stickiness, this generates sluggish adjustment that lasts past the periods of nominal stickiness.

Wages: Assume the following process for wages:

$$w_t = \gamma m_t + (1-\gamma) p_t,$$

where m_t is money supply which follows an exogenous random process and γ is a measure (inverse) of the extent of aggregate real rigidities that are not explicitly modeled.

Slow movement in s_t leads to slow movement in $\tilde{p}_{it}$ if α is sufficiently large. Sluggish adjustment in $\tilde{p}_{it}$ can arise from variable mark-ups at the retail or the whole-sale level, sluggish adjustment in wages or other intermediate inputs prices. We will now evaluate the evidence on these different sources of real rigidities.

2 Evidence of Real Rigidities: Review

Although appealing at the intuitive level, real rigidities are hard to identify and measure in the data. Aggregate real rigidities imply a sluggish response of the marginal costs of the firms to aggregate shocks. Firm-level real rigidities (strategic complementarities) imply a muted response of the firms' prices conditional on price adjustment to the marginal cost shocks.[2] Since the data on marginal costs is usually unavailable, it is hard to test this mechanisms directly. Therefore, the literature either calibrates these mechanisms or uses indirect empirical tests.

Apart from generating a contract multiplier, variable markups are important in explaining pricing to market (Dornbusch, 1987; Krugman, 1987) which is a pervasive feature of international pricing. The international literature has a long-standing tradition of estimating exchange rate pass-through that allows to evaluate the extent of pricing to market. Exchange rate shocks constitute large observable cost shocks for firms trading internationally. Therefore, international pricing data can be used to directly assess the strength of the variable markups channel central to both generating pricing to market and real rigidities. Despite this the pricing to market literature in international economics and the real rigidities literature in the monetary closed economy literature has almost worked in parallel without overlap.

In this paper we bring together the closed economy macro literature that focuses on indirect tests of real rigidities with the international pricing literature centered around pricing to market. As a result, our focus is mainly firm-level real rigidities, or strategic complementarities. We will also focus on the recent evidence on real rigidities that uses micro-price data.

[2]Alternatively, aggregate-level real rigidities imply a sluggish adjustment of the marginal cost to the monetary shocks. This mechanism is equally hard to identify in the data since it requires information on the marginal cost response to underlying shocks.

Closed economy literature

In the domestic prices data sets the evidence on real rigidities usually arises from indirect identification strategies. For example, Klenow and Willis (2006) calibrate a menu cost model with variable markups and argue that the levels of real rigidity sufficient to generate significant monetary non-neutrality has implausible implications for the required size of the menu costs and idiosyncratic productivity shocks in order to match data on frequency and size of price adjustment. Conceptually, significant real rigidities compress price dispersion so that much larger idiosyncratic shocks are required to match the size of price adjustment.[3] At the same time, large menu costs are required to match the average durations of price rigidity given large idiosyncratic shocks.

In a related paper, Burstein and Hellwig (2007) replace Kimball demand with increasing marginal costs at the firm level to generate strategic complementarity in price setting. They calibrate the extent of decreasing returns to scale (elasticity of the marginal cost with respect to output) in order to match the data on the comovement between prices and market shares. This calibration implies a moderate role for strategic complementarities generated via curvature in marginal costs.

Bils, Klenow, and Malin (2009) develop a test to assess a broader class of models with real rigidities. They examine the persistence of actual and reset-price inflation series. Reset-price inflation is defined as an average price change within the group of goods that adjust prices in a given period, while reset prices for all other goods are indexed by reset-price inflation. In other words, this construct approximates desired price inflation. If real rigidities are important, there should be significant persistence both in the actual and reset-price inflation series. The paper find low persistence for actual price inflation and negative persistence for reset price inflation, suggesting that the selection mechanism present in menu costs models (see Caplin and Spulber, 1987) offsets the effects of real rigidities and the real effects of money last less than nominal price durations.

In a different paper, however, Klenow and Willis (2007) find that prices respond to old information known prior to the period of previous price adjustment. They interpret this as evidence of sticky information in the spirit of Mankiw and Reis (2002), nevertheless, this

[3] It is important to stress that this argument applies equally to any type of real rigidity – both at the firm-level and in aggregate. All real rigidities act to compress price dispersion across firms, therefore matching the large sizes of price adjustment would require larger underlying shocks in the presence of real rigidities.

evidence is also consistent with the presence of real rigidities and pricing complementarities that lead to incomplete price adjustment at the micro-level.

As already mentioned, the empirical tests for real rigidities in the literature surveyed above are indirect relying mainly on calibrations or statistical properties of observable prices given that marginal costs and markups are not directly observable.

International prices literature

There exists a vast and long-standing literature that documents markup variability using international prices. Firms that sell the same product across different destinations often set different prices in different markets, a phenomenon referred to as *pricing to market*. This concept is closely related, but not identical to the notion of incomplete exchange rate pass-through, i.e. a partial response of the foreign good's price to exchange rate movement. Both phenomena arise under variable markups. The literature on international prices makes use of exchange rate fluctuations that constitute large and observable cost shocks for exporting firms. As a result, the presence and extent of markup variability can be assessed directly using international prices.

Goldberg and Knetter (1997) summarize a large body of the earlier empirical literature that usually focuses on specific industries and goods and provide both evidence of incomplete pass-through and pricing to market. It is important to distinguish pass-through at the dock (border of the country) from pass-through into consumer prices since the distribution margin plays a very important role for the latter (Campa and Goldberg, 2006).

Fitzgerald and Haller (2008) examine the pricing of Irish manufactures both in the domestic market and of their exports to the U.K. Since the goods come from the same plants, this holds the marginal cost constant across domestic and foreign sales. As a result, the empirically pronounced differential response of prices to exchange rate movements necessarily reflects variation in markups.

Another piece of evidence on the importance of variable markups in international pricing is provided by Gopinath and Itskhoki (2008). Using micro-level import prices they document a positive correlation between the frequency of price adjustment for a good and exchange rate pass-through conditional on price adjustment. They argue this positive correlation is consistent with variation in markup elasticity across firms and cannot be consistent with other sources of firm heterogeneity. Additionally, the evidence on currency choice by exporters and on delayed pass-through of exchange rate shocks provided in Gopinath, Itskhoki, and Rigobon (2008) is also consistent with an important role played by variable markups.

A recent study by Berman, Martin, and Mayer (2009) compares the extent of markup variability across French exporters of different size. It finds that larger exporters have lower exchange rate pass-through, which is consistent with a model in which both the level and the variability of the markup increases with the productivity (and hence) size of the firm. Since exporting firms are typically larger, the implication of this finding is that the extent of markup variability (pricing to market) can be significantly greater in the international data than in the full sample of firms producing for the domestic market.

Evidence on retail and wholesale prices for the same good

Another strand of literature employs data on wholesale and retail prices for the same good and consequently provides the most direct evidence of the importance of variable mark-ups at the two stages of pricing. Eichenbaum, Jaimovich, and Rebelo (2007) use supermarket scanner data from a grocery chain in the U.S. and find that conditional on changing prices there is no evidence of variable mark-ups at the level of retail prices, i.e. all of the whole-sale cost change is passed through into retail prices. Using the same data, but for the U.S. and Canada, Gopinath, Gourinchas, Hsieh, and Li (2009), find that in response to an exchange rate shock movements in relative retail prices in a common currency are explained mainly by movements in relative costs and very little by relative mark-ups. Burstein and Jaimovich (2008) also use this data to document the incomplete pass-through into whole-sale costs of exchange rate shocks. Goldberg and Hellerstein (2006) and Nakamura and Zerom (2008) find that for beer and coffee sales (respectively) in a grocery store the pass-through from exchange rate shocks to whole-sale costs is incomplete, but the pass-through from whole-sale costs to retail prices is close to complete. In a recent study, Berger, Faust, Rogers, and Steverson (2009) match goods in the import price index to those in the consumer price index for the period January 1994-July 2007 and find that the overall distribution wedge, which is the percent difference between retail and at-the-dock prices does not vary systematically with the exchange rate. Overall, the evidence suggests an important role for variable mark-ups at the whole-sale level but not at the retail level.

3 New Empirical Evidence

The empirical evidence on real rigidities has been evaluated using different specifications across the various data sets. In the retail price literature for the U.S., in the absence of well identified large shocks, the approach has been to evaluate the autoregressive process for *reset prices*. In the open economy literature, the evidence relies on the response of prices to exchange rate shocks. In this section, we will present evidence on reset prices for the open economy using import price data for the U.S. First, we show that reset prices are less negatively autocorrelated as compared to that documented for retail prices. This is consistent with the conclusion that international prices depict higher real rigidities as compared to retail prices. Second, we present evidence regarding the sluggish response of price changes to exchange rate shocks. We show that prices, conditional on a change, respond to exchange rate shocks prior to the last time the price was adjusted. This evidence suggests an more important role for real rigidities as compared to the point estimate of the autocorrelation of reset prices. This also implies that evaluating the response to a specific shock can give very different results from evaluating the properties of a series that is subject to many different shocks. Third, we evaluate the sensitivity of firm pricing to shocks to competitors by measuring the response of prices to movements in the U.S. trade weighted exchange rate that is orthogonal to the bilateral exchange rate for the country. We find the response to be sizeable and significant. Fourth, we relate the incompleteness in pass-through to certain sectoral features that proxy for the level of competition among importers.

The data used in this section is the micro price data underlying the construction of the U.S. import price index. This covers the period 1994-2005. For details regarding this data see Gopinath and Rigobon (2008).

3.1 Reset Price Inflation

We follow Bils, Klenow, and Malin (2009) in estimating the reset price inflation series for U.S. imports. The log price of a good i at time t is denoted by $p_{i,t}$. The log of the reset price at time t for good i is denoted by p^*_{it} and defined as,

$$\begin{aligned} p^*_{it} &= p_{i,t} && \text{if} \quad p_{i,t} \neq p_{i,t-1} \\ p^*_{it} &= p^*_{i,t-1} + \pi^*(t) && \text{if} \quad p_{i,t} = p_{i,t-1} \end{aligned}$$

$\pi^*(t)$ is the average reset price inflation of those goods whose prices change at time t. The inflation of the actual price series will be referred to as "actual price inflation". In a Calvo price adjustment environment, where firms only differ in the exogenous frequency of price adjustment, in response to a shock the behavior of the reset price will capture the extent of real rigidities. In the case where there are no real rigidities reset prices will adjust immediately to their long-run level and reset price inflation will display no persistence. On the other hand, the aggregate actual price series will adjust slowly, as each firm receives its exogenous opportunity to adjust prices. If there exist real rigidities then reset price inflation will display positive autocorrelation, because the firm that adjusts initially will optimally respond only partially to the shock. For instance in the presence of strategic complementarities in price setting, a firm that adjusts early on will not change prices by much given that other firms have not adjusted prices. Eventually as other firms adjust, there will be further rounds of price adjustment.

In the case of state dependent pricing or variations in desired price responses across sectors the behavior of measured reset prices is not as direct. Gopinath and Itskhoki (2008) show that sectors that have a higher frequency of price adjustment also have higher long-run pass-through (less real rigidities). Consequently, the reset price series is affected by those goods that change prices more frequently and pass-through eventually a lot more.

It is important to point out that the sample sizes in the import price data are not as large as in the CPI data, and given the low frequency of price adjustment, the number of actual price changes used to impute the reset price series is low. This would suggest that the import reset price inflation series is more subject to noise as compared to the construction of Bils, Klenow, and Malin (2009) for U.S. CPI.

We now present the details of our results. The results for various specifications are reported in Table 1. In all specifications we exclude petrol classifications. For each series 2002 weights at the 4 digit level are used to aggregate across prices. More precisely, for actual inflation, we estimate mean price change by four digit harmonized code, then we average across the different harmonized codes using weights at the 4 digit level. For the reset price inflation, we assume that in January 1994 all prices were reset prices[4]. Then we follow the formula in equation (3.1). In constructing $\pi^*(t)$ we weight the reset price changes by 4 digit weights. The numbers in the table report the standard deviation of inflation for each series

[4]This is mainly to have an initial condition.

and the persistence parameter estimated from running an AR(1) on the inflation series.

	Regular Inflation	
	AR(1)	SD
All,no petrol	0.51	0.33
	(0.08)	
All, no petrol,dollar	0.56	0.27
	(0.06)	
All, no petrol,dollar, market	0.43	0.3
	(0.07)	
	Reset Inflation	
	AR(1)	SD
All,no petrol	0.02	1.6
	(0.09)	
All, no petrol,dollar	-0.043	1.2
	(-0.08)	
All, no petrol,dollar, market	-0.03	1.7
	(-0.09)	

Table 1: Moments of regular and reset price inflation

In the first specification we include all goods except those in the petrol classifications. This includes the goods priced in dollars and those in non-dollars. All price series refer to the dollar value of prices. The actual inflation series has a monthly persistence of 0.51 and a standard deviation of 0.33%. The reset price inflation series has a persistence of 0.02 and a standard deviation of 1.6%. We can compare these to the numbers in Bils, Klenow, and Malin (2009). Their sample period is longer 1989-2008. They also exclude energy, fresh fruit and vegetables and eggs. For the sample that excludes sales prices the actual inflation series has persistence of -0.05 and a standard deviation of 0.14%. The reset price inflation series has a persistence of -0.41 and a standard deviation of 0.95%. A simple comparison therefore suggests greater persistence (as measured by the simple AR(1) coefficient) for the actual inflation in the import price series as compared to that for the consumer price index (excluding shelter and the other goods listed earlier). The reset inflation series for import prices is close to an i.i.d process unlike the case in Bils, Klenow, and Malin (2009) where it is negatively autocorrelated. As mentioned earlier some part of the difference in results can arise because the reset price inflation series for import prices is estimated using far fewer observations and the noise can be greater.

We present statistics for other sub-samples. In the second specification we restrict the sample to those goods that are priced in dollars. Around 90% of imports are priced in dollars, so this excludes 10% of the sample. As expected the persistence in actual inflation rises. It is now 0.56 as compared to 0.51.This is because with goods that are priced in non-dollars when they do not adjust prices their pass-through into dollar prices is 100%, while when they adjust prices the pass-through is less that 100%. This can be explained theoretically and we document this to be the case empirically in Gopinath, Itskhoki, and Rigobon (2008). This particular behavior lowers the persistence of dollar inflation. One would expect by the same argument that reset price inflation would have higher persistence but it is not evident in the numbers. The third specification excludes intra-firm transactions in addition to excluding non-dollar prices. The persistence is slightly lower at 0.43. Market transactions make up 60% of the sample.

An advantage of the international data is that we can examine the response to a specific shock, namely the exchange rate shock. This has advantages over just looking at reset price inflation that aggregates (imperfectly in small samples) across idiosyncratic, sectoral and aggregate shocks. In the next section we provide evidence of the sluggish adjustment of price to exchange rate shocks.

3.2 Micro-dynamics of Price adjustment

At the good level, we estimate the following regression:

$$\Delta \bar{p}_{i,t} = \beta_1 \Delta_{\tau_1} e_{i,t} + \beta_2 \Delta_{\tau_2} e_{i,t-\tau_1} + Z'_{i,t}\gamma + \ldots + \epsilon_{i,t}, \tag{1}$$

where i indexes the good; $\Delta \bar{p}_{i,t}$ is the change in the log dollar price of the good, *conditional on price adjustment in the currency of pricing*;[5] We will restrict the sample to non-petrol, dollar priced goods and market transactions. $\Delta_{\tau_1} e_{i,t}$ is the cumulative change in the log of the bilateral nominal exchange rate over the duration for which the previous price was in effect (τ_1). τ_2 is the duration of the previous price of the firm so that $\Delta_{\tau_2} e_{t-\tau_1} \equiv e_{t-\tau_1} - e_{t-\tau_1-\tau_2}$ is the cumulative exchange rate change over the previous (the one before the most recent one) period of non-adjustment. $Z_{i,t}$ includes controls for the cumulative change in the foreign consumer price level, the US consumer price level and fixed effects for every BLS defined

[5]In the BLS database, the original reported price (in the currency of pricing) and the dollar converted price are both reported. We use the latter, conditional on the original reported price having changed. Since the first price adjustment is censored from the data, we also perform the analysis excluding the first price change and find that the results are not sensitive to this assumption.

primary strata (mostly 2-4 digit harmonized codes) and country pair. We allow Z_t to include lagged foreign and domestic inflation. The standard errors are clustered at the level of the fixed effects. We allow for lags in the exchange rate changes to affect the current price adjustment to test for the presence of strategic complementarities.

The results are reported in Table 2. This specification requires the goods to have at least two price adjustments during their life. Since there are several goods that have only one price change during their life, we lose about 30% of the goods. We provide evidence for various sub-samples of the data.

	β_1	β_2	Nobs	R2
All	0.11	0.08	69917	0.01
	(0.02)	(0.01)		
hioecd	0.23	0.18	32809	0.02
	(0.02)	(0.02)		
non-hioecd	0.06	0.04	37108	0.01
	(0.02)	(0.01)		
Differentiated	0.14	0.10	21360	0.02
	(0.02)	(0.02)		
Euro	0.22	0.14	5933	0.02
	(0.04)	(0.03)		
Japan	0.26	0.24	4249	0.06
	(0.04)	(0.03)		
Canada	0.28	0.34	14620	0.01
	(0.16)	(0.05)		
All no-jumps	0.10	0.08	45765	0.01
	(0.02)	(0.01)		
Hioecd no-jumps	0.19	0.13	22436	0.01
	(0.03)	(0.02)		

Table 2: Dynamic response to exchange rate shocks

Across all specifications we find that exchange rate shocks that took place prior to the current period of adjustment have a significant effect on current price adjustments. This supports the existence of real rigidities in pricing. The strength of these lagged effects are much stronger than what would be suggested purely by the reset price inflation series. The first row of Table 2 points out that the elasticity of current price changes to lagged exchange rate shocks for dollar priced goods is 0.08, which is only slightly smaller than the response to the contemporaneous exchange rate movement (equal to 0.11). The importance of these lagged effects are documented for the various sub-samples. For the high-income OECD sample (HIOECD) the contemporaneous and lagged responses are 0.23 and 0.18 respectively. For the non high income OECD sample the pass-through rates are overall lower but there are still important lagged effects. This is similarly documented for the Euro, Japan and Canada sample. In the data there can be spells that have missing prices and where the new price follows a missing price. In this case the exact timing of the price change is not known, so lagged effects can arise from getting the timing wrong. The last two rows checks for the robustness of the results by including in the sample only those price changes that were not followed by a missing price. This changes the sample composition, but the lagged responses are still strongly evident.

The results in this section are consistent with the evidence in Gopinath, Itskhoki, and Rigobon (2008) that long-run pass-through is much higher than pass-through conditional on the first adjustment to the exchange rate shock. Here we present explicitly the dynamics and extend the sample to more countries.

We also break the sample down by the "end-use" of the product. In all cases the pass-through conditional on first adjustment is low, but in the case of "industrial supplies and materials" and "capital goods (excluding auto)" the dynamic adjustment is significant. In the case of "consumer goods (non food and excluding auto) the dynamics is less evident. One should be careful about interpreting the results for consumer goods because these goods more often have a fixed price during their life and then get discontinued and replaced. Since we do not observe price changes across discontinuations we might be excluding important adjustments that take place at the time of product replacement.

3.3 Impact of other major exporter currencies

We evaluate the response of each firm's pricing to the its own exchange rate and to movements in the U.S. trade weighted exchange rate that is orthogonal to the bilateral exchange rate for the country. More specifically, we run a first stage regression where we regress the trade weighted exchange rate on the bilateral exchange rate. We calculate the residual and then estimate a second stage regression where we regress the price change conditional on changing

	All countries			
	β_1	β_2	Nobs	R2
Food, feed and beverages	0.05	0.03	17731	0.01
	(0.04)	(0.02)		
Industrial Supplies and Materials	0.13	0.11	22396	0.02
	(0.03)	(0.02)		
Capital Goods, except automotive	0.16	0.17	4220	0.05
	(0.03)	(0.03)		
consumer goods (nonfood) except automotive	0.05	0.03	8222	0.01
	(0.04)	(0.02)		
	High-income OECD			
	β_1	β_2	Nobs	R2
Food, feed and beverages	0.16	0.15	5207	0.03
	(0.04)	(0.03)		
Industrial Supplies and Materials	0.21	0.25	13089	0.01
	(0.05)	(0.03)		
Capital Goods, except automotive	0.21	0.22	2587	0.05
	(0.04)	(0.03)		
Consumer goods (nonfood) except automotive	0.17	0.03	2915	0.02
	(0.06)	(0.04)		

Table 3: Dynamic response to exchange rate shocks: End use sectors

prices on the bilateral exchange rate and the residual.[6] The results are reported in Table 4. The effect of the residual is almost as large as the effect of the bilateral exchange rate and in some cases larger than the impact of the bilateral exchange rate. (We will also include a table for the lagged effects)

3.4 Pass-through and import sector concentration

In this section we relate the incompleteness in pass-through to certain sectoral features that proxy for the level of competition among importers. An important distinction between retail prices and whole-sale prices is that the latter captures business-to-business transactions. Consequently, the strength of bargaining power of the buyer can impact the extent of pass-through. We use unpublished measures of concentration in the import sector provided to

[6]The coefficient on the residual will be equivalent to the coefficient obtained from regressing the price change on the bilateral and the trade weighted exchange rate, but the coefficient on the bilateral will be different across the two specification.

	bilateral	residual	Nobs	R2
All	0.11	0.19	83064	0.01
	(0.01)	(0.02)		
hioecd	0.22	0.17	32809	0.02
	(0.02)	(0.05)		
non-hioecd	0.07	0.18	46420	0.01
	(0.02)	(0.02)		
Differentiated	0.12	0.17	21360	0.02
	(0.01)	(0.03)		
Euro	0.27	0.31	7856	0.03
	(0.03)	(0.07)		
Japan	0.21	0.17	5733	0.02
	(0.04)	(0.06)		
Canada	0.23	0.12	16221	0.01
	(0.12)	(0.10)		

Table 4: Impact of other major exporter currencies

us by the BLS-measures of the Hefindahl index and the number of importers that make up the top 50% of trade- to evaluate this. We find some (mild) evidence that import sectors that are more concentrated have a smaller pass-through. This is mainly evident for products that are classified as "differentiated" as one might expect. We present this evidence both for medium run pass-through, which is pass-through conditional on the first adjustment to the exchange rate shock and to long-run pass-through that is pass-through after multiple rounds of price adjustment.

	All Goods			
	Ψ_0	Ψ_1	N	R2
Herfindahl index	0.13	-0.01	71757	0.01
	0.01	0.01		
Num. importers in top 50 percentile	0.11	0.004	71757	0.01
	-0.02	0.006		
Broda-Weinstein elasticities	0.12	0.01	83892	0.01
	0.01	0.01		
	Differentiated Goods			
Herfindahl index	0.157	0.012	26968	0.02
	-0.016	0.007		
Num. importers in top 50 percentile	0.11	0.013	26973	0.02
	0.03	0.006		
Broda-Weinstein elasticities	0.139	0.02	29384	0.02
	0.019	0.021		

Table 5: Medium-run pass-through and sector characteristics

	All Goods			
	ψ_0	ψ_1	N	R2
Herfindahl index	0.295	-0.021	12432	0.06
	(0.01)	(0.01)		
Num importers in top 50 percentile	0.231	0.016	12435	0.06
	(0.037)	(0.009)		
Broda-Weinstein elasticities	0.23	0.039	14008	0.06
	(0.02)	(0.009)		
	Differentiated Goods			
Herfindahl index	0.278	-0.013	7164	0.02
	(0.022)	(0.011)		
Num importers in top 50 percentile	0.214	0.017	7167	0.02
	(0.042)	(0.009)		
Broda-Weinstein elasticities	0.242	0.031	7862	0.02
	(0.024)	(0.018)		

Table 6: Long-run pass-through and sector characteristics

4 Model

In this section we present a model with a retail sector and a whole-sale sector. As in the data, the whole-sale sector will have real rigidities in the form of variable mark-ups while the retail sector will have constant mark-ups. Price setting in both sectors follows Calvo pricing. We calibrate the parameters of the model to moments of the data. Here we introduce only the log-linearized equilibrium conditions of the model, while the appendix provides the detailed derivation of the model.

4.1 Whole-sale sector

The whole-sale sector produces an intermediate good used in the production of the final good. The only factor used in the production of intermediate good is labor. We hence assume that the marginal cost of an intermediate good producer j is

$$mc_{jt} = w_t - a_{jt},$$

where w_t is the wage rate and a_{jt} is the productivity of firm j. Individual productivity may have an aggregate component that we denote by $\bar{a}_t = \mathbb{E}_j a_{jt}$.

The desired price of an intermediate good producer equals his desired markup over the marginal cost:

$$\tilde{s}_{jt} = \tilde{\mu}_{jt} + mc_{jt}.$$

We assume that the first-order approximation to the desired markup is given by:

$$\tilde{\mu}_{jt} = -\Gamma(s_{jt} - s_t),$$

where $s_t = \mathbb{E}_j s_{jt}$ is (an approximation to) the price index of the intermediate good producers. This approximation can be derived from a number of models discussed in the appendix. It emerges with infinitesimal firms and Kimball demand as in Klenow and Willis (2006) and Gopinath and Itskhoki (2008), as well as with large firms and nested CES demand as in Atkeson and Burstein (2008).

Intermediate goods producers reset prices with a Calvo probability $(1 - \theta_m)$. As a result, the first-order approximation for their reset price is

$$\begin{aligned} \bar{s}_{jt} &= (1 - \beta\theta_m) \sum_{\ell=0}^{\infty} (\beta\theta_m)^{\ell} \mathbb{E}_t \tilde{s}_{j,t+\ell} \\ &= (1 - \beta\theta_m) \sum_{\ell=0}^{\infty} (\beta\theta_m)^{\ell} \mathbb{E}_t \left\{ \frac{1}{1+\Gamma} s_{t+\ell} + \frac{\Gamma}{1+\Gamma} (w_{t+\ell} - a_{j,t+\ell}) \right\}, \end{aligned}$$

where β is the discount factor. The dynamics of the price index of intermediate goods producers is given by

$$s_t = \theta_m s_{t-1} + (1-\theta_m)\mathbb{E}_j \bar{s}_{jt},$$

since the firms that adjust prices are a representative sample of all firms under the Calvo assumption.

Combining the two above equations, we can derive a Phillips curve for the intermediate goods price index:

$$\Delta s_t = \beta \mathbb{E}_t \Delta s_{t+1} + \frac{\lambda_m}{1+\Gamma}\big(w_t - s_t - \bar{a}_t\big), \tag{2}$$

where the slope of the Phillips curve is given by $\lambda_m = (1-\theta_m)(1-\beta\theta_m)/\theta_m$. Note that Γ measures the elasticity of the markup, a parameter central for incomplete pass-through and pricing to market. The greater is Γ, the flatter is the Phillips curve implying a more sluggish adjustment to the shocks.

4.2 Retail sector

The retail sector produces a final good combining the intermediate good and labor as inputs. We assume constant markup pricing in this sector so that the desired price is proportional to the marginal cost. Specifically, the desired price of the final good producer i is

$$\tilde{p}_{it} = \alpha s_t + (1-\alpha) w_t - z_{it},$$

where α is the expenditure share on intermediate goods and z_{it} is a productivity shock which again may admit an aggregate component $\bar{z}_t = \mathbb{E}_i z_{it}$.

The final good price setting is also subject to the Calvo friction with the probability of adjusting prices given by θ_f. As a result, the optimal preset price is given by

$$\bar{p}_{it} = (1-\beta\theta_f)\sum_{\ell=0}^{\infty} \mathbb{E}_t \left\{\alpha s_{t+\ell} + (1-\alpha) w_{t+\ell} - z_{i,t+\ell}\right\}.$$

The final good price index dynamics is given by

$$p_t = \theta_f p_{t-1} + (1-\theta_f)\mathbb{E}_i \bar{p}_{it},$$

which results in the following Phillips curve for the final good price dynamics:

$$\Delta p_t = \beta \mathbb{E}_t \Delta p_{t+1} + \lambda_f \big(s_t - p_t - \bar{z}_t \big) \tag{3}$$

with $\lambda_f = (1-\theta_f)(1-\beta\theta_f)/\theta_f$.

4.3 Equilibrium dynamics

To close the model we introduce two aggregate equations standard in the literature, an exogenous process for money supply and the wage rate determination equation. For money supply, we assume an AR(1) process in differences:

$$\mu_t = \rho_m \mu_{t-1} + \varepsilon_t^{\mu}, \qquad \text{where} \qquad \mu_t \equiv \Delta m_t. \tag{4}$$

Further, we assume that the wage rate is given by

$$w_t = \gamma m_t + (1-\gamma) p_t. \tag{5}$$

When γ is large, the wage rate adjusts quickly to monetary shocks. Smaller values of γ are a stand in for various unmodeled aggregate real rigidities including real wage rigidity, segmented labor markets, and round-about production. Therefore, the strength of real rigidities in our model is a combination of aggregate real rigidities measured by γ and firm-level real rigidities measured by Γ. Additionally, α determines the role of intermediate inputs in the production of the final good, the channel through which variable markups at the whole-sale level effects final good prices. Finally, θ_f and θ_m measure the extent of nominal rigidities.

Equation (2)-(5) fully describe the equilibrium dynamics of the model subject to exogenous productivity shocks $\{\bar{a}_t, \bar{z}_t\}$. The parameters of the model include $\{\beta, \rho_m, \theta_f, \theta_m, \alpha, \gamma, \Gamma\}$. We now calibrate the parameters of the model and discuss the results of the simulation.

4.4 Simulation results

We calibrate the model to monthly data. This implies a discount factor $\beta = 0.96^{1/12}$, which corresponds to an annualized 4% rate. The Calvo parameters are set to $\theta_f = 0.75$ and $\theta_m = 0.9$ respectively corresponding to 4 and 10 months durations of retail and wholesale prices respectively, consistent with the micro-level evidence. This corresponds to substantial nominal rigidity at the wholesale level, but highly flexible prices at the retail level.

Next we set $\alpha = 0.7$ corresponding to a 70% share of intermediate goods in the cost of the final good that is well within the range often used in the literature. We vary the autocorrelation of the money supply process between 0 and 0.8; the latter corresponds to an AR(1) coefficient of 0.5 at a quarterly frequency often used in the literature. We set $\gamma = 0.75$ implying a moderate level of aggregate real rigidities. Finally, the baseline level of markup elasticity is $\Gamma = 1$, consistent with the empirical findings in Gopinath, Itskhoki, and Rigobon (2008) and Gopinath and Itskhoki (2008). In the baseline line simulation we also shut down the aggregate productivity shocks, $\bar{a}_t = \bar{z}_t \equiv 0$.

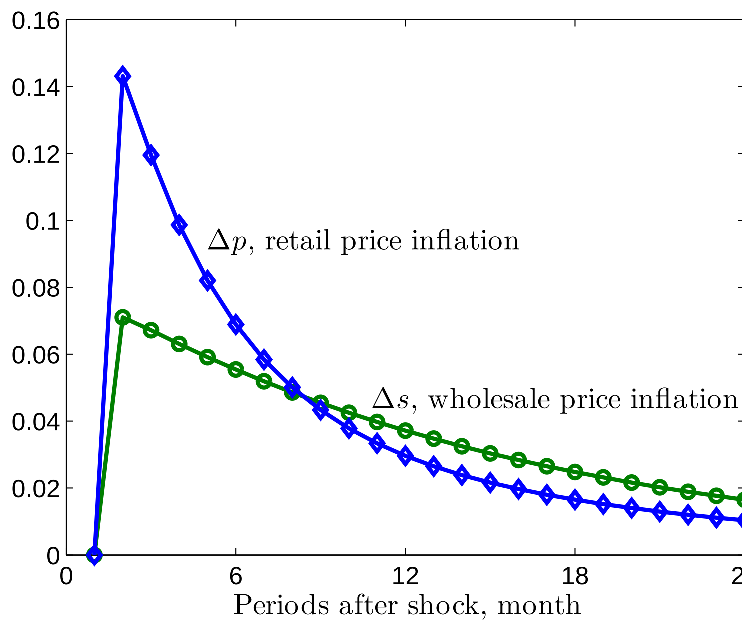

Figure 1: Impulse response of retail and wholesale price inflation

Figure 1 illustrates a much greater persistence in the wholesale prices relative to retail price, consistent with our empirical findings. Despite this fact, both series exhibit considerable persistence, as further described in Table 7.

	Baseline	$\Gamma = 0$	$\Gamma = 3$	$\gamma = 0.5$	$\alpha = 0.5$
	$\rho_m = 0.001^{1/3} = 0.1$				
AR(1) Δp	0.886	0.883	0.884	0.909	0.847
AR(1) Δs	0.938	0.914	0.956	0.948	0.937
HL y, month	10.5	8.1	14.1	13.2	8.3
	$\rho_m = 0.5^{1/3} = 0.8$				
AR(1) Δp	0.939	0.935	0.941	0.948	0.925
AR(1) Δs	0.956	0.944	0.966	0.962	0.956
HL y, month	80.0	58.2	111.7	98.7	67.2

Table 7: Simulation results: persistence of retail and wholesale price inflation and half-life of output. Baseline calibration: $\Gamma = 1$, $\gamma = 0.75$, $\alpha = 0.7$, $\theta_f = 0.75$, $\theta_m = 0.9$.

Table 7 shows that the difference in the persistence between retail and wholesale price inflation can be as large as 0.85 versus 0.94, which at a quarterly frequency corresponds to 0.61 versus 0.82. Note however that both series always exhibit very significant persistence, much greater than that in the data. To match the persistence in the data, one needs to introduce transitory aggregate productivity shocks.

Further note that both types of real rigidities, γ and Γ, lead to longer-lasting output gaps, however, γ mainly tends to increase the persistence of retail prices, while Γ mainly tends to increase the persistence of wholesale prices. Therefore, this allows us to calibrate the relative importance of the two types of real rigidities.

Lower share of intermediates, α, allows to increase the gap in the persistence between the two inflation series at the cost of reducing the contract multiplier.

Finally, overall monetary non-neutrality (measured by the half-life of output) responds strongly to the autocorrelation of monetary shocks. When money follows nearly a random walk, the contract multiplier varies between 2 and 3.5 depending on the parametrization, while when autocorrelation of ε^μ is 0.5 at the quarterly frequency, the contract multiplier is an order of magnitude greater.

Note that in our calibration retail prices exhibit little nominal stickiness with average duration of 4 months. At the same time the half-lives of output are around 10 months even when money follows a random walk. This is achieved in a large part due to nominal and real rigidities at the wholesale level.

Next steps: We plan to introduce aggregate productivity shocks, $\bar{a}_t$ and $\bar{z}_t$, in order to match the persistence of retail and wholesale price inflation. We then simulate a panel of firm-level prices, given idiosyncratic marginal cost shocks a_{it} and z_{jt}, in order to study the properties of reset price inflation.

[TO BE COMPLETED]

5 Bargaining Model of Price Setting

We now consider a setup in which the final good producer bargains with a number of intermediate goods suppliers. This is a reasonable setup for thinking about price setting in business-to-business transactions in the data. We first derive desired wholesale prices and markup elasticities in a static bargaining framework and then incorporate this bargaining game into a dynamic general equilibrium model of the previous section.

Consider a final goods producer i. In what follows, we omit the final good producer's identifier i where it leads to no confusion. The final good producer uses intermediate inputs to assemble the final good according to a CES technology

$$y = \left[\sum_{j=1}^{N} q_j^{\eta}\right]^{1/\eta}, \qquad \eta \in (0,1) \tag{6}$$

where η controls the elasticity of substitution between the intermediate varieties, N is the number of intermediate varieties used for assembly and q_j is the quantity of intermediate variety j. Note that labor is not used for the production of the final good, which is produced using only intermediates. This corresponds to the special case of $\alpha = 1$ in the previous section.

The revenue of the final goods producer is given by

$$R = py = Ay^{\zeta}, \qquad \zeta \in (0,1),$$

where p is the final good price, A is a demand shifter and ζ is a parameter that controls the elasticity of demand. This revenue function specification arises from CES preferences over the final good with the elasticity of substitution equal to $1/(1-\zeta)$. Finally, the intermediate good producer j has a constant marginal cost of c_j. Therefore, the total surplus that can be shared between the final good and intermediate good producers is

$$Ay^{\zeta} - \sum_{j=1}^{N} c_j q_j, \tag{7}$$

where y is given in (6).

The surplus in (7) is divided according to bilateral Nash bargaining between the final goods producer and each of the intermediate good suppliers. Specifically, we assume that the prices are determined through bargaining, while given prices the final good producer is free to choose any quantity of the intermediate goods supply. Denote by v_j the prices of the intermediate goods determined via bargaining. The the final goods supplier will maximize his revenues minus cost given by $\sum_{j=1}^{N} v_j q_j$ when choosing the quantities. As a result, the quantities lie on the demand curves given by

$$\zeta A y^{\zeta-\eta} q_j^{\eta-1} = v_j. \tag{8}$$

This implies that the final good's price is a constant markup over the cost index of the intermediate goods:

$$p = Ay^{\zeta-1} = \frac{v}{\zeta}, \qquad \text{where} \qquad v \equiv \left[\sum_{j=1}^{N} v_j^{-\frac{\eta}{1-\eta}}\right]^{-\frac{1-\eta}{\eta}}.$$

Therefore, the final good's quantities and prices respond to the manner in which the intermediate goods prices, v_j, are set.

The Nash bargaining between the final good's producer and supplier j determines the price v_j. We assume that the bargaining power of the final good's producer is $\phi \in (0,1)$ and we denote his relative bargaining power by $\lambda \equiv \phi/(1-\phi)$. If bargaining breaks down, the supplier receives zero, while the final good's producer has to assemble the final good without the input of this supplier. Therefore, the surplus of the supplier is $(v_j - c_j)q_j$.

From (8) it follows that the profit of the final good's producer equals $(1-\zeta)Ay^{\zeta}$, where $y = \left(\zeta A/v\right)^{1/(1-\zeta)}$ is his optimal output of the final good given intermediate prices v_j. If bargaining with supplier j breaks down, the cost index of the intermediates becomes

$$v_{-j} = \left[\sum_{k \neq j} v_k^{-\frac{\eta}{1-\eta}}\right]^{-\frac{1-\eta}{\eta}} > v.$$

As a result, the optimal output of the final good is $y_{-j} = \big(\zeta A / v_{-j}\big)^{1/(1-\zeta)} < y$ and therefore profit of the final good producer is $(1-\zeta)Ay_{-j}^{\zeta}$. Under these circumstances, the incremental surplus of the final good producer from supplier j is given by

$$(1-\zeta)A\big[y^{\zeta} - y_{-j}^{\zeta}\big] = (1-\zeta)\zeta^{\frac{\zeta}{1-\zeta}} A^{\frac{1}{1-\zeta}} \left[v^{\zeta} - v_{-j}^{\zeta}\right]$$

With this in mind, we can write the Nash bargaining problem formally as:

$$\max_{v_j} \left\{ \Big[(v_j - c_j)q_j\Big]^{1-\phi} \left[(1-\zeta)\zeta^{\frac{\zeta}{1-\zeta}} A^{\frac{1}{1-\zeta}} \left(v^{\zeta} - v_{-j}^{\zeta}\right)\right]^{\phi} \right\},$$

where q_j is subject to (8) and v and v_{-j} are the cost indexes defined above.

The appendix provides a detailed solution to this bargaining game. Here we present the main results. The bargaining price is the solution to the following equation:

$$\frac{v_j}{v_j - c_j} = \frac{1}{1-\eta} + \frac{\zeta}{1-\zeta} s_j \left[\frac{\lambda}{1-(1-s_j)^{\kappa}} - \frac{\eta - \zeta}{1-\eta}\right], \tag{9}$$

where

$$\kappa \equiv \frac{\zeta}{1-\zeta}\frac{1-\eta}{\eta}$$

and s_j is the cost (market) share of supplier j equal to

$$s_j = \frac{v_j q_j}{v y} = \left(\frac{v_j}{v}\right)^{-\frac{\eta}{1-\eta}}.$$

Note that (9) implies a markup pricing rule in which the markup depends on the market share s_j, the relative bargaining power λ and the parameters of the model ζ and η. We have the following properties:

1. When $s_j = 0$ (infinitesimal supplier), then markup is constant and given by:

   $$\mu_j \equiv v_j / c_j = \phi + (1-\phi)\frac{1}{\eta},$$

   which is a convex combination of 1 and $1/\eta$ weighted by bargaining power.

2. When all bargaining power is with the final good producer (i.e., $\phi = 1$ or $\lambda = \infty$), bargaining results in marginal cost pricing $v_j = c_j$.

3. In the opposite case, when full bargaining power is with intermediate goods producers ($\phi = \lambda = 0$), markup depends on the market share:

$$\frac{v_j}{v_j - c_j} = \frac{1}{1-\eta} - s_j \frac{\zeta}{1-\zeta} \frac{\eta - \zeta}{1-\eta} \qquad \Rightarrow \qquad \mu_j = \frac{1/\eta - \kappa s_j \frac{\eta-\zeta}{1-\zeta}}{1 - \kappa s_j \frac{\eta-\zeta}{1-\zeta}}.$$

   Note that when $\eta > \zeta$ (the baseline case), the markup is increasing in market share.

4. In general, when $s_j \in (0,1)$ and $\lambda < \infty$, the markup is variable and pass-through is incomplete. Moreover, pass-through is not necessarily monotonic in the market share.

We have proposed here a bargaining model of variable markups. We are now working on incorporating this bargaining model into a dynamic general equilibrium model of Section 4.[TO BE COMPLETED]

A Details of the Model for Section 4

A.1 Consumers

The utility is defined over consumption aggregate C, labor L and real money balances M/P.[7] The consumer solves

$$\max_{\{C(\cdot),L(\cdot),B(\cdot),M(\cdot)\}} \sum_{t=0}^{\infty} \beta^t \sum_{s^t} \pi(s^t) U\big(C(s^t), L(s^t), M(s^t)/P(s^t)\big) \tag{10}$$

subject to the budget constraint:

$$P(s^t)C(s^t) + M(s^t) + \sum_{s_{t+1}} Q(s^{t+1}|s^t)B(s^{t+1}) \leq W(s^t)L(s^t) + M(s^{t-1}) + B(s^t) + \Pi(s^t) + T(s^t),$$

initial conditions B_0 and M_{-1} and no Ponzi schemes which are ruled out by $B(s^{t+1}) \geq \bar{B}$. All notation is standard (follows CKM), Π denotes firms' profits and T is the money transfer from the government (which is the only source of money injections into the model).

First order conditions for consumer maximization are:

$$-\frac{U_L(s^t)}{U_C(s^t)} = \frac{W(s^t)}{P(s^t)},$$

$$Q(s^{t+1}|s^t) = \beta\pi(s^{t+1}|s^t)\frac{P(s^t)}{P(s^{t+1})}\frac{U_C(s^{t+1})}{U_C(s^t)},$$

$$\frac{U_M(s^t)}{U_C(s^t)} = 1 - \frac{1}{R(s^t)},$$

where $R(s^t) = \left[\sum_{s_{t+1}} Q(s^{t+1}|s^t)\right]^{-1}$ is the nominal risk-free interest rate.

A.2 Equilibrium Conditions

The money transfer equals

$$T(s^t) = M(s^t) - M(s^{t-1}) = \big(1 + \bar{\mu} + \mu(s^t)\big)M(s^{t-1}),$$

[7] An alternative specification is cash in advance which just imposes $M = PC$

where $\mu(s^t)$ is the stochastic money growth rate:

$$\mu(s^t) = \rho_m \mu(s^{t-1}) + \epsilon^m(s_{t+1}).$$

Here we imposed equilibrium in the money market by using M to denote both money supply here and money demand in (10).

The equilibrium in the bonds market requires $B(s^t) = 0$ for all s^t since bonds are in zero net supply.

Using these equilibrium requirements allows us to transform the budget constraint into something like a resource constraint:

$$P(s^t)C(s^t) = W(s^t)L(s^t) + \Pi(s^t) = P(s^t)Y(s^t),$$

where the right-hand side is the nominal GDP (and Y is to be defined below).

A.3 Production

Labor is used in the production of intermediate goods. Than intermediate goods are combined to produce final goods which are aggregated into the consumption aggregate C.

A.3.1 Final Goods

Final consumption C is a CES aggregate of final goods (we drop s^t notation as all expressions are static and hold state-by-state):

$$C = Y = \left[\int_0^1 Y_i^{\frac{\eta-1}{\eta}} \mathrm{d}i\right]^{\frac{\eta}{\eta-1}}.$$

The price of the final good i is P_i so that the aggregate price index equals

$$P = \left[\int_0^1 P_i^{1-\eta} \mathrm{d}i\right]^{\frac{1}{1-\eta}}.$$

Final good i is produced from an aggregate of intermediate goods which costs S and with productivity Z_i. Therefore, the marginal cost of production is S/Z_i. Desired price, as a result, is a constant markup over this marginal cost:[8]

$$\tilde{P}_i = \frac{\eta}{\eta - 1}\frac{S}{Z_i}.$$

The model can be generalized to labor inputs at the final goods stage,[9] as well as to local labor markets or local intermediate goods market. At the moment, all final goods producers face a common intermediate goods price.

A.3.2 Intermediate Goods

Individual intermediate goods denoted by j are produced from labor with a productivity A_j so that the marginal cost is W/A_j. The output equals

$$X_j = A_j L_j$$

and the labor resource balance is

$$L = \int_0^1 L_j \mathrm{d}j.$$

Denote by μ_j the log markup of the intermediate goods produce (desired with tilde), so that the j's price can be written as:

$$S_j = \exp(\mu_j)\frac{W}{A_j}.$$

Finally, we use the Kimball aggregator of the intermediate inputs into the aggregate intermediate good:

$$\int_0^1 \Psi\left(\frac{X_j}{X}\right)\mathrm{d}j = 1, \qquad \Psi(1) = 1,\ \Psi'(\cdot) > 0,\ \Psi''(\cdot) < 0.$$

This implicitly defines demand

$$\frac{X_j}{X} = \psi\left(D\frac{S_j}{S}\right), \qquad \psi(\cdot) \equiv \Psi'^{-1}(\cdot),$$

[8] Alternatively, we can consider the Cobb-Douglas case ($\eta = 1$) with marginal-cost pricing (no markups). This would be especially useful if there is no price stickiness at the final goods stage.

[9] In this case the marginal cost becomes $S^\alpha W^{1-\alpha}/Z_i$.

where $D \equiv \int_0^1 \Psi'(X_j/X)X_j/X\mathrm{d}j$ and the price index for intermediates:

$$SX = \int_0^1 S_j X_j \mathrm{d}j.$$

A.4 Equilibrium

- Given wages W and facing demand (and prices of competitors $\{S_{-j}\}$), intermediate goods producers choose price S_j and satisfy demand;
- Given price of intermediates S, final goods producers choose P_j and satisfy demand;
- Given wages W and prices P consumers optimally choose C and L;
- W is such that labor market is in balance;
- Qs are such that bonds market is in balance;
- P is such that money market is in balance.

Remark 1: All of the above is in real terms, except for the money market. As a result, it is useful to scale all nominal variables by M.

Remark 2: With flexible prices, all equilibrium is static (interest rates and inflation are such to ensure no dynamic links through B and M). With sticky prices, the firms decisions become intra-temporal and money shocks have dynamics effects.

Remark 3: Note that the total profits in the economy is:

$$\Pi = [PY - SX] + [SX - WL] = PY - WL.$$

Therefore, $PY = \Pi + WL$ is indeed nominal GDP. Up to the first order approximation around symmetric equilibrium $Y = L$ so that the resource constraint becomes $C = L$.

A.5 Calvo Price Setting

Denote by θ_f and θ_m the Calvo probabilities of non-adjustment for final and intermediate goods respectively.

A.5.1 Price Setting for Final Goods

The firm's problem is:

$$\bar{P}_i(s^t) = \arg\max_{\bar{P}_i} \sum_{\ell=0}^{\infty} \theta_f^{\ell} \sum_{s^{t+\ell}|s^t} Q(s^{t+\ell}|s^t) Y_i(s^{t+\ell}) \left[\bar{P}_i - S(s^{t+\ell})/Z_i(s^{t+\ell})\right],$$

subject to

$$Y_i(s^{t+\ell}) = C(s^{t+\ell}) \left(\frac{\bar{P}_i}{P(s^{t+\ell})}\right)^{-\eta}$$

and where we recursively define $Q(s^{t+\ell}|s^t) = Q(s^{t+\ell}|s^{t+1})Q(s^{t+1}|s^t)$.

The first order condition for this profit maximization can be written as

$$\sum_{\ell=0}^{\infty} \theta_f^{\ell} \sum_{s^{t+\ell}|s^t} Q(s^{t+\ell}|s^t) C(s^{t+\ell}) P(s^{t+\ell})^{\eta} \left[\bar{P}_i - \frac{\eta}{\eta-1} \frac{S(s^{t+\ell})}{Z_i(s^{t+\ell})}\right] = 0.$$

Therefore, the price is an appropriately weighted average of static desired prices. After log-linearization (around a symmetric non-stochastic steady state) this yields the following pricing formula (small letters denoting log deviations, t replacing s^t and $\mathbb{E}_t$ denoting a conditional expectation):

$$\bar{p}_{it} = (1-\beta\theta_f) \sum_{\ell=0}^{\infty} (\beta\theta_f)^{\ell} \mathbb{E}_t\{s_{t+\ell} - z_{i,t+\ell}\}.$$

Log-linear expression for the price index is

$$p_t = \int_0^1 p_{it} \mathrm{d}i.$$

Since only fraction $(1-\theta_f)$ of (randomly chosen) firms adjust, we can rewrite it as:

$$p_t = \theta_f p_{t-1} + (1-\theta_f) \mathbb{E}_{i \in I_t^A} \bar{p}_{it},$$

where I_t^A denotes the set of firms that adjust at t. Denote by $\bar{z}_t \equiv \mathbb{E}_i z_{it}$ the aggregate component of the productivity shock of the final goods production. Then we can rewrite the price level dynamics (using standard Calvo model tricks) as

$$\Delta p_t = \beta \mathbb{E}_t \Delta p_{t+1} + \lambda_f (s_t - p_t - \bar{z}_t), \tag{11}$$

where $\lambda_f \equiv (1-\theta_f)(1-\beta\theta_f)/\theta_f$.

A.5.2 Price Setting for Intermediate Goods

Log-linearized equation for the intermediate goods price setting is

$$\bar{s}_{jt} = (1-\beta\theta_m) \sum_{\ell=0}^{\infty} (\beta\theta_m)^{\ell} \mathbb{E}_t \{\tilde{\mu}_{j,t+\ell} + w_{t+\ell} - a_{j,t+\ell}\}.$$

The desired markup $\tilde{\mu}_{jt}$ can be recovered from demand given s_t. Up to the first approximation we again have

$$s_t = \int_0^1 s_{jt} \mathrm{d}j$$

and

$$s_t = \theta_m s_{t-1} + (1-\theta_m)\mathbb{E}_{j \in J_t^A} \bar{s}_{jt}.$$

The expression equivalent to (11) for s_t hence is

$$\Delta s_t = \beta \mathbb{E}_t \Delta s_{t+1} + \lambda_m (\bar{\mu}_t + w_t - s_t - \bar{a}_t),$$

where $\bar{\mu}_t$ is the average markup log deviation for firms resetting price in t.

We now solve for the behavior of the desired markup. We denote by Γ the elasticity of the desired markup with respect to the relative price of the firm ($\Gamma = \varepsilon/(\sigma-1)$, where σ is the demand elasticity and ε is the superelasticity, both evaluated in the symmetric equilibrium). Therefore, the log-linearized (first order approximation) to the desired markup is

$$\tilde{\mu}_{jt} = -\Gamma(s_{jt} - s_t).$$

We can then rewrite the Calvo price setting equation as

$$\bar{s}_{jt} = (1-\beta\theta_m)\sum_{\ell=0}^{\infty}(\beta\theta_m)^{\ell}\mathbb{E}_t\left\{\frac{\Gamma}{1+\Gamma}s_{t+\ell} + \frac{1}{1+\Gamma}[w_{t+\ell} - a_{j,t+\ell}]\right\}.$$

That is, now the firm puts some weight on the dynamics of the intermediate price index and not all weight entirely on the dynamics of own marginal cost. Using this expression and similar steps as above, we recover the dynamic equation for s_t:

$$\Delta s_t = \beta\mathbb{E}_t\Delta s_{t+1} + \frac{\lambda_m}{1+\Gamma}(w_t - s_t - \bar{a}_t), \tag{12}$$

where $\lambda_m \equiv (1-\theta_m)(1-\beta\theta_m)/\theta_m$.

A.5.3 Discussion

Note that (11) and (12) characterize the dynamics of wholesale and retail prices in the economy given the exogenous process for $\bar{z}_t$ and $\bar{a}_t$ (which we can set to equal zero for simplicity) and the dynamics of the wage rate w_t. The parameters of these dynamic equations are the two Calvo parameters θ_f, θ_m and the markup elasticity Γ. Note that $\Gamma > 0$ amplifies the amount of stickiness at the wholesale level. When $\theta_m = 0$ (flexible wholesale prices), $s_t \equiv w_t - \bar{a}_t$ and the model is equivalent to the one without the intermediate sector (variable markups there have no effect). When $\theta_f = 0$ (flexible retail prices), $p_t \equiv s_t - \bar{z}_t$, but stickiness at the wholesale level is still important and markups still have bite. The relevant case empirically is $\theta_m > \theta_f \geq 0$ and $\Gamma > 0$.

A.6 System Dynamics

Equation (11) and (12) determine the joint dynamics of p_t and s_t given the process for w_t. It is natural to set $\bar{a}_t \equiv \bar{z}_t \equiv 0$ for now. What remains to close the model with a dynamic equation for w_t as a function of monetary shocks m_t. One simple way of closing the model is as in Burstein and Hellwig by imposing:

$$w_t = \gamma m_t + (1-\gamma)p_t, \tag{13}$$

where γ is an inverse measure of real rigidities. This equation is derived from the two consumer first order conditions – for money demand and labor supply. Labor supply is a static condition, while money demand in general is a dynamics condition (with the exception of cash-in-advance models). Therefore, the static nature of (13) is a simplification (although it can be derived under the above mentioned assumptions). Below we derive a more general version of (13) which follows from the model described in the beginning of this note.

Note that (11)-(13) fully describes the aggregate equilibrium dynamics where the only exogenous shocks are to money supply. From this system we recover directly the dynamics of p_t, s_t, w_t. This allows us to solve for consumption, labor and output: the first order approximation implies $c_t = y_t = l_t$ and the first order condition $-U_C/U_L = W/P$ pins down the levels of consumption and labor given w_t and p_t. Finally, individual prices can be obtained from optimal pricing policy given aggregate price level and idiosyncratic shocks.

A.6.1 Endogenous Wage Equation

The labor supply FOC can be log-linearized as:

$$w_t - p_t = \varphi_\ell l_t + \varphi_c c_t = \varphi y_t, \qquad \varphi \equiv \varphi_\ell + \varphi_c,$$

where $1/\varphi_\ell$ is the elasticity of labor supply and φ_c is the elasticity of the intra-temporal utility with respect to consumption. From here on we replace c_t and l_t by y_t, which is a result of the first order approximation to the resource constraint.

Next we log-linearize the money demand FOC:

$$\varphi_m(m_t - p_t) - \varphi_c y_t = -\zeta i_{t+1},$$

where i_{t+1} is an appropriately-defined interest rate deviation from steady state and $1/\varphi_m$ is the elasticity of money demand.

Finally, the log-linearized expression for the Euler equation (integral of FOCs for arrow-debreu securities) is

$$y_t = \mathbb{E}_t y_{t+1} - \frac{1}{\varphi_c}(i_{t+1} - \mathbb{E}_t \Delta p_{t+1}),$$

where $1/\varphi_c$ is the IES.

Combining these three equations allows to solve for a dynamic equation linking w_t to m_t and p_t. The simplest special case with $\zeta = 0$ results exactly in (13), where $\gamma = (1+\varphi_\ell/\varphi_c)\varphi_m$. When $\zeta > 0$, the expression is dynamics and is given by

$$w_t = \gamma m_t + (1-\gamma)p_t + \zeta\left[\mathbb{E}_t\Delta w_{t+1} + \frac{\varphi_\ell}{\varphi_c}\mathbb{E}_t\Delta p_{t+1}\right], \tag{13'}$$

where γ is as defined above.

A.6.2 Normalization

Note that m_t is integrated, so are other nominal variables (s_t, p_t and w_t). Therefore, we need to normalize nominal variables. We switch to growth rates which are stationary and work with the 5 equation first-order dynamic system:

$$\begin{cases} \pi_t &= \beta\mathbb{E}_t\pi_{t+1} + \lambda_f x_t, \\ \sigma_t &= \beta\mathbb{E}_t\sigma_{t+1} + \frac{\lambda_m}{1+\Gamma}[\gamma y_t - x_t], \\ y_t &= y_{t-1} + (\mu_t - \pi_t), \\ x_t &= x_{t-1} + (\sigma_t - \pi_t), \\ \mu_t &= \rho\mu_{t-1} + \varepsilon_t^\mu, \end{cases} \tag{14}$$

where the new notation from now on is $x_t \equiv s_t - p_t$, $y_t \equiv m_t - p_t$, $\sigma_t \equiv \Delta s_t$, $\pi_t \equiv \Delta p_t$. We used the fact that $w_t - s_t = \gamma(m_t - p_t) - (s_t - p_t) = \gamma y_t - x_t$. All variables are stationary in this formulation. Note that y_t is a measure of output gap and the extent of monetary non-neutrality. We now need to use some software to solve (14).

B Solution to the Bargaining Model[10]

B.1 Special cases

To develop intuition, we consider first two simple special cases:

[10]Notation in this appendix differs from the notation in the text: parameter β stands for η, derived parameter α stands for κ, index i stands for j, intermediate price is denoted by p_i instead of v_j, and intermediate price index is denoted by P instead of v.

B.1.1 One input (or equivalently $\zeta = \beta$)

In this case $y = q_i$ (or $y^\zeta - y^\zeta_{-i} = q_i^\zeta$) and the demand for intermediate good is given by

$$\zeta A q_i^{\zeta-1} = p_i. \tag{15}$$

Note that this implies the final good producer surplus equal to

$$Ay^\zeta - p_i q_i = (1-\zeta) A q_i^\zeta,$$

while the intermediate good producer surplus is simply

$$(p_i - c_i) q_i.$$

The Nash bargaining solution is given by

$$p_i = \arg\max_{p_i} \left(Aq_i^\zeta - p_i q_i\right)^\phi \left((p_i - c_i) q_i\right)^{1-\phi} = \arg\max_{p_i} \left\{(p_i - c_i)^{1-\phi} q_i^{\zeta\phi + (1-\phi)}\right\},$$

where q_i is subject to (15) and we have used the expression for equilibrium final good producer surplus above. Using (15), we can rewrite:

$$p_i = \arg\max_{p_i} \left\{(p_i - c_i)^{1-\phi} p_i^{-\frac{\zeta\phi + (1-\phi)}{1-\zeta}}\right\}.$$

This problem is equivalent to setting monopolistic price under demand with constant elasticity:

$$\frac{\zeta\phi + (1-\phi)}{(1-\zeta)(1-\phi)}.$$

Therefore, the pricing is constant markup over the marginal cost:

$$p_i = \left[\phi + (1-\phi)\frac{1}{\zeta}\right] c_i.$$

When $\phi = 1$ (full bargaining power of final good producer), then $p_i = c_i$; when $\phi = 0$ (full bargaining power of intermediate good producer), then $p_i = c_i/\zeta$; for $\phi \in (0, 1)$, the markup is a weighted combination of 1 and $1/\zeta > 1$.

To summarize, there is double-marginalization, and bargaining is more efficient the closer is ϕ to 1 and least efficient when $\phi = 0$. There is constant markup pricing of intermediate goods which is consequential for allocations.

B.1.2 Perfect substitutes: $\beta = 1$

In this case only the good with minimal c_i is used, while the second best good c_{-i} determines the surplus and pricing. We still have $y = q_i$, demand given by (15), but the surplus is now:

$$(1-\zeta)Aq_i^{\zeta} - (1-\zeta)Aq_{-i}^{\zeta},$$

where we assume limit pricing for the second-best good, i.e.

$$\zeta A q_{-i}^{\zeta-1} = c_{-i}.$$

The NBS hence becomes:

$$p_i = \arg\max_{p_i} \left\{ \left(p_i^{-\frac{\zeta}{1-\zeta}} - c_{-i}^{-\frac{\zeta}{1-\zeta}} \right)^{\phi} \left(p_i - c_i\right)^{1-\phi} p_i^{-\frac{1-\phi}{1-\zeta}} \right\}.$$

We can solve this to yield:

$$p_i = \frac{c_i}{\zeta} - \frac{\phi}{1-\phi} \frac{p_i - c_i}{1 - \left(\frac{c_i}{c_{-i}} \frac{p_i}{c_i}\right)^{\zeta/(1-\zeta)}} \qquad \text{for} \quad p_i < c_{-i}$$

and limit pricing $p_i = c_{-i}$ otherwise. Alternatively, one can substitute c_{-i} with p_{-i} instead, where in order to determine p_{-i} one needs the price for the next best good.

Denote by $\mu_i \equiv p_i/c_i$ the proportional markup. Then we can rewrite the previous expression as:

$$\mu_i = \frac{1}{\zeta} - \frac{\phi}{1-\phi}(\mu_i - 1)\frac{1}{1 - \left(\frac{c_i}{c_{-i}}\mu_i\right)^{\zeta/(1-\zeta)}}.$$

We have the following properties: (1) $1 \leq \mu_i \leq 1/\zeta$ with $\mu_i = 1$ for $\phi = 1$, $\mu_i = 1/\zeta$ for $\phi = 0$ and strict inequality in between; (2) It is straightforward to see that μ_i falls in c_i/c_{-i}, i.e.

$$\frac{\partial \mu_i}{\partial (c_i/c_{-i})} < 0.$$

That is, we have variable markups and strategic complementarity with implications for real allocations.

B.2 General Case

Note that when q_i is on the demand schedule, the profits of the final good producer are $\pi = (1-\zeta)Ay^{\zeta}$, where

$$y = \left(\frac{\zeta A}{P}\right)^{\frac{1}{1-\zeta}}, \qquad P = \left[\sum_{i=1}^{N} p_i^{-\frac{\beta}{1-\beta}}\right]^{-\frac{1-\beta}{\beta}}.$$

If bargaining fails, we assume that output equals y_{-i}, where we substitute P with

$$P_{-i} = \left[\sum_{\substack{j=1\\ j\neq i}}^{N} p_i^{-\frac{\beta}{1-\beta}}\right]^{-\frac{1-\beta}{\beta}}.$$

Note that this fails to internalize the response of p_j for $j \neq i$ when i leaves, as in Stole and Zweibel.

Therefore, the surplus of the final good producer from intermediate i is $(1-\zeta)A\big[y^{\zeta} - y_{-i}^{\zeta}\big]$, while the surplus of the intermediate good producer is $(p_i - c_i)q_i$, where

$$q_i = \big(\zeta A\big)^{\frac{1}{1-\beta}} y^{\frac{\zeta-\beta}{1-\beta}} p_i^{-\frac{1}{1-\beta}}.$$

Hence the Nash bargaining allocation solves:

$$\max_{p_i} \left\{ \big(y^{\zeta} - y_{-i}^{\zeta}\big)^{\phi} \big(p_i - c_i\big)^{1-\phi} q_i^{1-\phi} \right\},$$

or substituting in for y, y_{-i} and q_i we have:

$$\max_{p_i} \left\{ \left(P^{\frac{-\zeta}{1-\zeta}} - P_{-i}^{\frac{-\zeta}{1-\zeta}}\right)^{\phi} \big(p_i - c_i\big)^{1-\phi} p_i^{-\frac{1-\phi}{1-\beta}} P^{\frac{-\zeta}{1-\zeta}\frac{\zeta-\beta}{1-\beta}} \right\}.$$

Note that

$$\frac{\partial \ln P}{\partial \ln p_i} = \left(\frac{p_i}{P}\right)^{-\frac{\beta}{1-\beta}} = s_i$$

is the expenditure share on intermediate i and

$$\left(\frac{P_{-i}}{P}\right)^{-\frac{\zeta}{1-\zeta}} = (1-s_i)^{\alpha}, \qquad \alpha \equiv \frac{\zeta}{1-\zeta}\frac{1-\beta}{\beta}.$$

Solving for NBS p_i, we obtain the following condition:

$$\frac{p_i}{p_i - c_i} = \frac{1}{1-\beta} + \frac{\zeta}{1-\zeta}s_i\left[\frac{\lambda}{1-(1-s_i)^{\alpha}} - \frac{\beta-\zeta}{1-\beta}\right], \qquad \lambda \equiv \frac{\phi}{1-\phi}.$$

One can study various special case using this formula. Note that $\mu_i \equiv p_i/c_i$ is a proportional markup, so that the left hand side defines $\mu_i/(\mu_i - 1)$. Therefore, markup is determined by the demand and technology parameters β and ζ, bargaining power λ and market share s_i. With $\beta > 0$, higher price implies lower market share, which tends to reduce markup (but might also increase it under some special cases). Therefore, a typical case is incomplete pass-through. We have the following properties:

1. When $s_i = 0$ (infinitesimal intermediate suppliers), then markup is constant and given by:
$$\frac{p_i}{p_i - c_i} = \frac{1+\lambda\beta}{1-\beta} \qquad \Rightarrow \qquad \mu_i = \phi + (1-\phi)\frac{1}{\beta},$$
i.e. a convex combination of 1 and $1/\beta$ weighted by bargaining power/

2. When all bargaining power is with the final good producer (i.e., $\phi = 1$ or $\lambda = \infty$) there is marginal cost pricing and efficient allocation: $p_i = c_i$.

3. In the opposite case with full bargaining power with intermediate good producers ($\phi = \lambda = 0$), markup depends on the market share:
$$\frac{p_i}{p_i - c_i} = \frac{1}{1-\beta} - s_i\frac{\zeta}{1-\zeta}\frac{\beta-\zeta}{1-\beta} \qquad \Rightarrow \qquad \mu_i = \frac{1/\beta - \alpha s_i\frac{\beta-\zeta}{1-\zeta}}{1-\alpha s_i\frac{\beta-\zeta}{1-\zeta}}.$$
Note that when $\beta > \zeta$ (the baseline case), the markup is increasing in market share. As a result, there is incomplete pass-through. Moreover, pass-through does not have to be monotonic in the market share.

4. We need $s_i \in (0,1)$ and variable and $\lambda < \infty$ for non-constant markup.

References

Atkeson, A., and A. Burstein (2008): "Trade Costs, Pricing-to-Market, and International Relative Prices," *American Economic Review*, 98(5), 1998–2031.

Basu, S. (1995): "Intermediate Goods and Business Cycle: Implication for Productivity and Welfare," *American Economic Review*, 85(3), 512–31.

Berger, D., J. Faust, J. H. Rogers, and K. Steverson (2009): "Border Prices and Retail Prices," Board of Governors of the Federal Reserve, International Finance Discussion Paper No. 972.

Berman, N., P. Martin, and T. Mayer (2009): "How do different exporters react to exchange rate changes? Theory, empirics and aggregate implications," CEPR Discussion Paper 7493.

Bils, M., P. Klenow, and B. Malin (2009): "Reset Price Inflation and the Impact of Monetary Policy Shocks," NBER Working paper No. 14787.

Blanchard, O. J., and J. Galí (2007): "Real Wage Rigidities and the New Keynesian Model," *Journal of Money, Credit and Banking*, 39, 35–65.

Burstein, A., and C. Hellwig (2007): "Prices and Market Shares in a Menu Cost Model," Working Paper.

Burstein, A., and N. Jaimovich (2008): "Understanding Movements in Aggregate and Product-level Real Exchange rates," Working paper, UCLA.

Calvo, G. (1983): "Staggered Prices in a Utility-Maximizing Framework," *Journal of Monetary Economics*, 12(3), 383–398.

Campa, J., and L. Goldberg (2006): "Distribution Margins, Imported Inputs, and the Sensitivity of the CPI to Exchange Rates," Federal Reserve Bank of New York.

Caplin, A. S., and D. F. Spulber (1987): "Menu Costs and the Neutrality of Money," *Quarterly Journal of Econmics*, 102(4), 703–26.

Christiano, L. J., M. Eichenbaum, and C. L. Evans (1999): "Monetary policy shocks: What have we learned and to what end?," in *Handbook of Macroeconomics*, ed. by J. Taylor, and M. Woodford, vol. 1 of *Handbook of Macroeconomics*, chap. 2, pp. 65–148. Elsevier.

Dornbusch, R. (1987): "Exchange Rate and Prices," *American Economic Review*, 77(1), 93–106.

Eichenbaum, M., N. Jaimovich, and S. Rebelo (2007): "Reference Prices and Nominal Rigidities," mimeo, Stanford.

Fitzgerald, D., and S. Haller (2008): "Exchange Rates and Producer Prices: Evidence from Micro Data," Working Paper, Stanford University.

Goldberg, P., and R. Hellerstein (2006): "A Framework for Identifying the Sources of Local-Currency Price Stability with an Empirical Application," Yale University and Federal Reserve Bank of New York.

Goldberg, P., and M. Knetter (1997): "Goods Prices and Exchange Rates: What Have We Learned?," *Journal of Economic Literature*, 35(3), 1243–1272.

Gopinath, G., P.-O. Gourinchas, C.-T. Hsieh, and N. Li (2009): "Estimating the Border Effect: Some New Evidence," NBER Working Paper 14938.

Gopinath, G., and O. Itskhoki (2008): "Frequency of Price Adjustment and Pass-through," *Quarterly Journal of Economics*, forthcoming.

Gopinath, G., O. Itskhoki, and R. Rigobon (2008): "Currency Choice and Exchange Rate Pass-through," *American Economic Review*, forthcoming.

Gopinath, G., and R. Rigobon (2008): "Sticky Borders," *Quarterly Journal of Economics*, 123(2).

Kimball, M. (1995): "The Quantitative Analytics of the Basic Neomonetarist Model," *Journal of Money, Credit and Banking*, 27, 1241–77.

Klenow, P., and J. Willis (2006): "Real Rigidities and Nominal Price Changes," Stanford Mimeo.

——— (2007): "Sticky Information and Sticky Prices," *Journal of Monetary Economics*, 54(1), 79–99.

Krugman, P. (1987): "Pricing to Market when the Exchange Rate Changes," in *Real Financial Linkages among Open Economies*, ed. by S. Arndt, and J. Richardson, pp. 49–70. MIT Press, Cambridge.

Mankiw, N. G., and R. Reis (2002): "Sticky Information versus Sticky Prices: A Proposal to Replace the New Keynesian Phillips Curve," *Quarterly Journal of Economics*, 117(4), 1295–328.

Nakamura, E., and D. Zerom (2008): "Accounting for Incomplete Pass-through," Working Paper, Columbia University.

Taylor, J. B. (1980): "Aggregate Dynamics and Staggered Constracts," *Journal of Political Economy*, 88(5), 1–24.