Global Versus Local Shocks in Micro Price Dynamics*

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Abstract

A number of recent papers point to the importance of distinguishing between the price reaction to micro and macro shocks. We emphasize instead the importance of distinguishing between *global* and *local* shocks. We exploit a panel of 276 micro price levels collected on a semi-annual frequency from 1990 to 2010 in 59 countries around the world, that enables us to distinguish between *different* types (local and global) of *micro* and *macro* shocks. We find that global shocks are associated with a slower response of prices than local shocks. This new fact can be explained by a price-setting model with staggered pricing and strategic complementarity (substitutability) in pricing for firms across (within) countries arising from the international segmentation of labor markets.

Keywords: global shocks, local shocks, price adjustment, micro-macro gap, price-setting models, micro prices.

JEL Classification: E31, F4, C23

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1 Introduction

How fast do prices adjust to changes in economic conditions? The answer is crucial in assessing the real effects of nominal shocks, for instance. The literature provides conflicting answers: whereas aggregate price indices have been found to be very persistent, more recent work starting with Bils and Klenow (2004) showed that individual prices adjust frequently. The implication that monetary policy might as a result be less effective than originally thought has been challenged more recently. Several studies (e.g. Boivin et al. 2009) attempt to resolve this micro-macro puzzle while retaining the importance of monetary policy by distinguishing between the (sluggish) response of individual prices to *macroeconomic shocks* common to every sector or product, and their (rapid) response to *microeconomic shocks* specific to a sector or product. Our paper emphasizes the distinction between *global shocks* common to every location worldwide, and *local shocks* specific to a location. We show that this distinction is much more striking and no less informative for price-setting models, than the macro-micro split considered in previous work.[1]

For both macro and micro shocks alike, local components are associated with much less persistence than global ones.[2] The slow speed of price adjustment to international macro shocks, such as global (US) monetary policy ones, is particularly striking. In order to close the global-local gap we observe, price-setting theory models would need to include some mechanism that leads to a sufficiently high degree of aggregate price rigidity in response to global shocks, and that can generate different price responses to global versus local shocks.

Our analysis relies on a panel of 276 micro price levels collected from 1990 to 2010 at a semi-annual frequency across 88 cities in 59 countries across the world. This dataset is non-standard and was especially compiled for us by the Economist Intelligence Unit (EIU) at a semiannual frequency for the complete untypically large sample of international locations.[3] The March and September dates for gathering these semi-annual data are specifically designed to avoid standard sales seasons. In addition, EIU correspondents are specifically instructed to take regular retail prices and not to take sale prices. These sampling facts suggest that our price data are not as prone to include

[1] The implication that, as a result of frequent price adjustment, monetary policy might be less effective than originally thought has also been challenged by Nakamura and Steinsson (2008) who attribute the Bils and Klenow (2004) finding to temporary sales-induced price reductions, and by Kehoe and Midrigan (2010) who allow for temporary sales in their model to propose that the aggregate price level is sticky and monetary policy effective even as micro prices change frequently. Our dataset is specifically designed to avoid sales so that our findings regarding the speed of price adjustment relate to standard rather than sale prices, and are not exposed to this critique.

[2] Considering only one type of micro or macro shock would thus typically lead to misleading inferences about the persistence of local macroeconomic shocks in micro prices.

[3] The standard EIU city prices edition typically used in the LOP deviations literature, e.g. Crucini and Shintani (2008) or Zachariadis (2012), is at the annual frequency, while the non-standard semi-annual EIU city prices data used in Bergin et al. (forthcoming) ending in 2007, contains 21 cities in 21 industrial countries.

temporary price changes, shown by Nakamura and Steinsson (2008) to bias results towards finding more rapid price adjustment.[4] This is important for the inferences we can draw about the speed of price adjustment in response to local shocks for instance.[5]

The three dimensions of our panel—time, location and individual product—allow us to decompose price dynamics for each product in a given location at a given date into four different components: (1) a *global macro* component common to every good in every location, capturing for example global (US) monetary policy shocks; (2) a *local macro* component specific to a location and common to every good, related for example to monetary or other domestic policies; (3) a *global micro* component specific to a good and common to every location, related for instance to technology shocks specific to a product but common across the globe; and (4) a *local micro* or *idiosyncratic* component specific to a good and a location, capturing for instance the idiosyncrasy of weather conditions facing vineyards in a certain location. We estimate the responses of prices to shocks in each component.

While ignoring the global-local distinction our data then implies that (similar to past research on the micro-macro gap) macro shocks are more persistent than micro ones, decomposing macro and micro shocks into their global and local components reveals a different more precise picture. Local micro shocks are the most rapidly corrected ones, followed by local macro shocks and global micro shocks,[6] with adjustment to the global macro shock being the slowest. Our results confirm that prices react differently to different types of shocks, but stress that sorting shocks by geographic distance (global vs local) leads to more striking differences than sorting shocks by mere economic distance (macro vs micro).

We propose that decomposing macro and micro shocks into finer categories provides new facts that price-setting models should be able to rationalize. In light of the importance of the global

[4] For example, De Graeve and Walentin (2011) use an approach that handles sale prices in the Boivin et al. (2009) data and find persistent micro shocks in contrast to the earlier paper.

[5] That our data is relatively free of temporary price changes presents an important advantage in this matter relative to datasets affected by sale prices. Moreover, our data has relatively low (semi-annual) frequency and again should not be dominated by high-frequency changes over the year. As pointed out by Kehoe and Midrigan (2010), what matters for how the aggregate price level responds to low-frequency changes in monetary policy is the degree of low-frequency micro price stickiness rather than high frequency variation associated with temporary price changes. In their setting, there are two reasons that the aggregate price level is sticky even though micro prices change frequently. First, temporary price changes are highly clustered in time so that they are less able to offset persistent changes in monetary policy i.e. a firm that changes its prices four times in a single month is less able to respond to persistent money supply changes than a firm that spreads these four changes over a year. Second, when a firm changes its price temporarily it can react to changes in monetary policy but these responses are short-lived, and as soon as the price returns to the old one it no longer reflects the monetary policy change.

[6] The latter three components of prices are mean-reverting on average, but this does not apply to all relative prices for all goods or locations. Some of these relative prices are instead characterized by a specific stochastic trend. The absence of a stochastic trend on average, validates the theoretical assumption by Golosov & Lucas (2007) that goods relative prices within a location have no specific trend, ensuring that their time variance is bounded.

or international dimension, it would be useful to have price-setting models that can rationalize differences in the speed of price adjustment to international versus domestic shocks. These models would need to explain why these differences are more striking when shocks are classified with respect to geographic distance (global vs local) rather than mere economic distance (macro vs micro).[7] They should also be able to generate a sufficiently high degree of aggregate price rigidity in response to international shocks, in line with the slow response of prices to such shocks we find.

We illustrate that one can rationalize these facts in a model relying on labor market segmentation arguments in the spirit of Woodford (2003), Benigno (2004), and Carvalho and Lee (2011), from which works we borrow an extensive number of features to synthesize a model consistent with our main findings. The latter paper allows for labor market segmentation across sectors within a country to explain the micro-macro gap in an otherwise standard neo-Keynesian model with Calvo pricing. In our setting, we explain the global-local gap by allowing for labor market segmentation across countries. Since labor market segmentation across countries is plausibly no lower than across sectors within a country, there is no loss of realism in reinterpreting the Carvalho and Lee (2011) model in this manner.[8] In fact, international labor market segmentation being larger than within country segmentation could explain why differences are more striking when shocks are classified with respect to geographic distance (global vs local) rather than mere economic distance (macro vs micro).

More specifically, we introduce a real rigidity in the form of labor market segmentation across space in a basic price staggering model with standard New Keynesian features following Woodford (2003). Pricing decisions for firms in different countries will then be strategic complements associated with slower price adjustment, while pricing decisions within a country for firms that share a common labor market will be strategic substitutes associated with faster price adjustment. As Woodford (2003) points out, the assumption of a common labor market is key in obtaining a high degree of strategic substitutability in pricing decisions and fast price adjustment as a consequence.[9]

The specifics of our model include a finite number of countries and a continuum of firms with each firm producing a differentiated good in one of the countries. Firms, are subject to shocks that are specific to the country they produce in and to global shocks that affect firms in all countries. These shocks affect the marginal cost of a firm differently. We also assume an equal number of households

[7] Kehoe and Midrigan (2007), Atkeson and Burstein (2008), Crucini et al. (2010), and Gopinath and Itskhoki (2010) offer examples of open macro models that consider optimal price-setting and price dynamics. Further emphasis on price-setting theory models in an open economy context would be useful to understand the above differences.

[8] In this, our theoretical structure resembles Benigno (2003) who assumes no migration of labor across regions of an otherwise common market for goods.

[9] For example, in Chari, Kehoe and McGrattan (2000), and in other work that incorporates sticky prices in an otherwise standard RBC setting.

in each country that specialize in the supply of only one type of labor in the country they reside in, and facing competitive financial markets that allow for complete risk sharing so that there is perfect consumption insurance for households across countries with firm profits redistributed lump-sum to households.

Because a local shock, unlike a global shock, affects prices specifically in that country, within country substitutability works to speed up the price response of firms to such shocks as compared to global shocks. Because a global shock, say a positive global monetary shock, affects the global price level, across country complementarity in firms pricing decisions along with price staggering will combine to give rise to a sluggish response of country-specific prices in response to such a shock as higher prices for firms in other countries would reduce the relative price and thus increase demand and the cost of the country-specific input for that country. Price staggering is an essential feature here, since if pricing decisions of firms across countries are strategic complements, the fact that firms in some countries have not yet adjusted prices in response to a global shock leads to a smaller change in the prices of those firms that do adjust in that period as compared to the case of price sychronization, and this in turn restrains the adjustment in a later period of the prices that were sticky in the earlier period. In the presence of a sufficient degree of strategic complementarity which has indeed been shown (e.g. in Woodford, 2003) to be implied by our assumpion of labor market segmentation across countries, this process then creates a form of price persistence that allows for prolonged effects of, say, a global monetary shock on real activity across the globe.

Next, we describe the data and undertake preliminary analysis of these. We then present our statistical model. Following that, we discuss our results and relate them to the existing literature, and then proceed to rationalize these with a price setting model that incorporates a real rigidity. The final section concludes.

2 Data and preliminary analysis

2.1 Description and reliability

The main source of data utilized in our application comes from the Economist Intelligence Unit (EIU). EIU prices were provided to us for 327 items in 140 cities in 90 countries twice a year, where available, from 1990 to 2010. We were able to utilize data that cover 59 countries and 276 goods over the 1990S1-2010S1 period, for all Tables of results shown hereafter. The semiannual (March and September) prices were especially compiled for us by the EIU upon request, as the standard historical data in the EIU "cityprices" publication contains prices gathered only once a year, every September. In the data appendix, we undertake a detailed description of how these prices are collected and put together, meant to help the reader understand the potential advantages and disadvantages of using this dataset to study international prices and to assist future users in appropriately handling these data. Although subsamples of these data have been used previously as described below, the information provided in the data appendix is largely new.

For example, the data appendix sub-section on "Sampling, seasonality, and sales", describes how the March and September dates for gathering data were specifically designed to avoid standard sales seasons, like traditional sales in December, January, May and June which take place in many countries, and that furthermore, correspondents are instructed not to take sale prices but to take standard recommended retail prices. This is an important dimension over which this dataset has an advantage over other price datasets ridden with sale prices that tend to bias estimates towards faster speeds of adjustment while being less suited to assessing the effectiveness of monetary policy.

Engel and Rogers (2004), Bergin and Glick (2007), Crucini and Shintani (2008), Bergin et al. (forthcoming), and Zachariadis (2012) have all exploited sub-samples of these EIU prices. The first paper focuses on a sample of prices in 18 European cities for 101 traded and 38 non-traded products for the period from 1990 to 2003, to ask how much more integrated the EU has become after the introduction of the euro. Bergin and Glick (2007) focus on a sample of 101 tradeable goods in 108 cities in 70 countries for the period from 1990 to 2005, to assess global price convergence. Crucini and Shintani (2008) focus on a sample of 90 cities in 63 countries for the period from 1990 to 2005, to assess the rate of price convergence for the relative price of each good. Bergin et al. (forthcoming) study a subset of these data for traded goods price comparisons between the US and 20 cities in 20 industrial countries at a semiannual frequency from 1990 to 2007 in an attempt to resolve the macro-micro disconnect of PPP and the LOP. Finally, Zachariadis (2012) exploits the annual EIU price data for as many as 19 countries for 1990-2006 to investigate the role of international movements of labor in narrowing the gap for LOP deviations across countries.

As compared to the above papers, we have access to semiannual prices for 1990 to 2010 for the great majority of locations. Restricting the sample to goods and locations always present during this period, we end up with price levels for 276 goods and services across 88 cities in 59 countries. Table 1 provides a complete list of goods and locations (cities and countries) present in our sample. It also provides a classification between less developed countries (LDC) with income per capita less than \$12,000 and more developed countries (DEV) in our sample,[10] and a classification of goods between traded (TR) and non-traded (NT). We note that there is a much lower number of NT items available as compared to TR products and a lower number of LDC locations. Most traded

[10] Our classification of less developed countries is based on the PPP adjusted GDP per capita from the Penn World Tables. These are countries with income per capita below \$12000 on average over 1990–2007. This threshold corresponds to the average income per capita in the cross country distribution of the Penn World sample.

goods prices are observed in two types of stores, so that we end up with two price observations per date and location for 100 goods. In Table 1, we also report the type of store (supermarkets, chains, and mid-price or brand stores) each good was sampled in.

For some of our results, we focus on a restricted sample of 49 countries, excluding EMU countries other than Germany, to address the fact that EMU countries do not undertake independent monetary policy so that local macro shocks would not be as related to monetary policy if these were included. Similarly, we have restricted our main analysis to countries rather than cities since the latter cannot undertake independent monetary policy. However, we also consider a more complete sample of 59 countries including EMU ones, as well as a city-level analysis for 88 cities in these 59 country sample.

All prices are converted in a common currency, the US dollar, using exchange rate data assembled by the EIU to match the sampling periods of the city price levels data. We also used the US dollar exchange rates to reconstruct exchange rate data for the British Pound and Yen relative to the national currencies of the locations in the sample, in order to consider the robustness of the results to the numeraire currency. We obtained PPP-adjusted real GDP per worker from the Penn World Tables (up to 2007) and country-level population from the World Development Indicators.

2.2 Descriptive statistics

Summary statistics regarding the EIU price data are presented in Table 2. The data summarized here cover 88 cities in 59 countries and 276 goods over the 1990S1-2010S1 period. More specifically, we provide the mean and other characteristics of the cross-sectional distribution across products and locations in our sample for the average inflation rates over the period, for the standard deviation of inflation rates over the period and for the degree of persistence characterizing these inflation rates. The latter is measured by the sum of dynamic coefficients, $\rho_{il} = \sum_{h=1}^{4} \rho_{il,h}$, in an AR(4) inflation rate process.

The average rate of inflation in these data is 0.014, with fairly large heterogeneity across goods and locations as inflation rates range from negative values to values above 0.045, with a cross-sectional standard deviation of 0.024. The average standard deviation characterizing these inflation rates over time is 0.18, with a standard deviation of 0.15 across goods and locations. Finally, the average value for persistence of these inflation rates over the period is rather low, at -0.13, but again this exhibits large heterogeity across goods and locations in our sample, with values ranging from -0.89 for the 5th percentile to 0.45 for the 95th percentile, and a cross-sectional standard deviation of 0.42.

For illustration and comparison with some related works, we provide a focus of the descriptive statistics for the US. The average inflation rate over the period was 0.013 per semester with a standard deviation of 0.06 over the time period. The volatility of the average inflation is strikingly lower than the cross country average, in line with the Great Moderation episode experienced over this period of time. Finally, average persistence across the different products in our sample is 0.28 for the US, distinctly higher than the cross-sectional average. Overall, average inflation is less volatile and more persistent in the US compared with the average across countries.

3 A statistical model of goods prices in different locations

We first present the statistical model we use to decompose the dynamics of prices into the different components and discuss this framework in comparison to related studies. We then turn to the estimation method. Finally, we also discuss the potential influence of choosing a particular reference currency on estimation results.

3.1 Specification

Let p_{ilt} be the common currency (log) price of product item i in location l at date t. We consider a decomposition of international price inflation rates, $\pi_{ilt} = p_{ilt} - p_{ilt-1}$ into four components: a global macroeconomic one π^{GA}_{ilt}, a local macroeconomic one π^{LA}_{ilt}, a global microeconomic one π^{GI}_{ilt}, and a local microeconomic one π^{LI}_{ilt} so that:

$$\pi_{ilt} = \pi^{GA}_{ilt} + \pi^{LA}_{ilt} + \pi^{GI}_{ilt} + \pi^{LI}_{ilt}.$$

By comparison, the related studies of Boivin et al. (2009) and Maćkowiak et al. (2009) decompose US sectoral inflation rates into two components, a macro one and a micro one, $\pi_{it} = \pi^{A}_{it} + \pi^{I}_{it}$. Ciccarelli & Mojon (2010) decompose OECD aggregate inflation rates into a global component and a local one, $\pi_{lt} = \pi^{G}_{lt} + \pi^{L}_{lt}$. We compound the two dimensions together.[11]

The *global macroeconomic* component of the inflation rate of good i in location l, π^{GA}_{ilt}, is driven by an unobserved component u_t affecting *every price in every location* which is assumed to follow an autoregressive process. Specifically we have:

$$\pi^{GA}_{ilt} = \alpha_{il} u_t \quad \text{with} \quad A(L)u_t = \epsilon_t, \quad \epsilon_t \sim \text{iid}(0, \sigma^2).$$

[11] We could also have considered the intermediate level of regional-specific components, made of geographical subgroups of locations. Kose et al. (2003) do so in their study of cross-country aggregate growth rates. In our case, due to the micro dimension of the data, doing so would entail considering a total of six different components since it would add a regional macro and a regional micro components to the four previous ones. While this additional layer is potentially relevant, in particular in the study of economies made of several countries like the euro area, we deem such extension to be beyond the scope of the present paper.

Typical examples of such global macro factors would be oil prices or global liquidity shocks associated with worldwide money supply. These shocks can have different impact on prices depending on marginal cost or markup determinants. Such heterogeneity in price reactions is captured by the heterogeneity in the parameter α_{il}.

Likewise, the *local macroeconomic* component of good i inflation rate in location l, π_{ilt}^{LA}, is affected by an unobserved component v_{lt} affecting *every price in a given location* which is assumed to follow an autoregressive process, namely:

$$\pi_{ilt}^{LA} = \beta_i v_{lt} \quad \text{with} \quad B_l(L)v_{lt} = \epsilon_{lt}, \quad \epsilon_{lt} \sim \text{iid}(0, \sigma_l^2).$$

Typical examples of such local macro component are monetary or fiscal policies. An aggregate demand shock specific to a location can induce different reactions in the prices of different goods, according to markup determinants such as demand elasticities or the cost of updating prices that are specific to a given product. We allow for such heterogeneous reaction of prices by allowing for heterogeneity in the parameter β_i.

In comparison, the *global microeconomic* component of good i inflation rate in location l, π_{ilt}^{GI}, is influenced by an unobserved component w_{it} affecting *a given good in every location* which is also assumed to follow an autoregressive process, so that:

$$\pi_{ilt}^{GI} = \gamma_l w_{it} \quad \text{with} \quad C_i(L)w_{it} = \epsilon_{it}, \quad \epsilon_{lt} \sim \text{iid}(0, \sigma_i^2).$$

A natural example of such a global microeconomic determinant of prices would be a technological innovation specific to a given product. Such innovations can have different impact on prices depending on the location in which the product is sold, typically due to the distance to the technology frontier of the specific location considered. Such potential differences are captured in the heterogeneity of the parameters γ_l.

Finally, the *local microeconomic* component of good i inflation rate in location l, π_{ilt}^{LI}, results from idiosyncratic unobserved factors summed-up in a component z_{ilt} specific to *a given good in a given location* and described by:

$$\pi_{ilt}^{LI} = z_{ilt} \quad \text{with} \quad D_{il}(L)z_{ilt} = \epsilon_{ilt}, \quad \epsilon_{ilt} \sim \text{iid}(0, \sigma_{il}^2).$$

A typical example of a factor affecting this component would be a strike in a given sector and location.

The statistical innovations, ϵ_t, ϵ_{lt}, ϵ_{it}, ϵ_{ilt}, specific to each of the four components in prices are assumed to be mutually independent.

As in Maćkowiak et al. (2009), each of the components in the panel of price dynamics is described by a specific univariate process. They allow for unrestricted dynamic multipliers for each of their two, i.e. aggregate and sectoral, components. We consider four distinct components but put more restrictions on the heterogeneity of the dynamics that we consider as we assume multipliers that are common either to every good-location pair $A(L)$, or to every good in a location $B_l(L)$, or to every location for a given good $C_i(L)$.

As in Boivin et al. (2009), individual inflation rates are characterized by linear combinations of a set of common factors. Compared to them, we introduce a distinction between global and local common factors. However, we constrain our setup to a single factor to describe each dimension. As a consequence, the factor loadings α_{il}, β_i and γ_l are scalars which only re-normalize the same dynamics of each component in individual inflation rates. Without loss of generality, we can thus normalize the average of the loadings to unity. Namely, letting n be the total number of goods and locations in the sample, n_l the number of locations, and n_i the number of goods items, we postulate that $\frac{1}{n}\sum_{il}\alpha_{il} = \frac{1}{n_i}\sum_i \beta_i = \frac{1}{n_l}\sum_l \gamma_l = 1.$[12]

Our setup allows us to recover estimates of the dynamics of each component from observed prices by applying simple averaging and difference transformations as we detail in the next subsection.

3.2 Estimation

Under the model specification described above, a consistent estimator of the unobserved global macroeconomic component in international prices is given by the average of individual inflation rates over all goods and locations:

$$\widehat{u}_t = \frac{1}{n}\sum_{il}\pi_{ilt}.$$

Moreover, denoting $n_{l|i}$ as the number of locations good i is sampled at and $n_{i|l}$ as the number of product items sampled in location l, and considering the good specific and location specific price averages, $\overline{\pi}_{it} = \frac{1}{n_{l|i}}\sum_l \pi_{ilt}$ and $\overline{\pi}_{lt} = \frac{1}{n_{i|l}}\sum_i \pi_{ilt}$, estimators of the remaining unobserved components are then given by:

$$\widehat{v}_{lt} = \overline{\pi}_{lt} - \widehat{u}_t, \quad \widehat{w}_{it} = \overline{\pi}_{it} - \overline{\pi}_t, \quad \text{and} \quad \widehat{z}_{ilt} = \pi_{ilt} - \widehat{u}_t - \widehat{v}_{lt} - \widehat{w}_{it}.$$

In the setup of the above model, these simple unobserved component estimators converge to the true ones up to a term that is perfectly correlated with u_t for the local macro one, $\widehat{v}_{lt}$, and the

[12] The fact that common factors are scalars also implies that considering a reaction of prices to local macro shocks which differs only according to goods rather than according to both goods and locations is just a matter of normalization. Indeed, one can always rewrite $\beta_{il}\widetilde{v}_{lt} = \beta_i\beta_l\widetilde{v}_{lt} = \beta_i v_{lt}$ with $v_{lt} = \beta_l\widetilde{v}_{lt}$. The same applies to the term $\gamma_l w_{it}$.

global micro one, $\widehat{w}_{it}$, and up to a term that is a linear combination of u_t, v_{lt} and w_{it} for the local micro one, $\widehat{z}_{ilt}$.

Given these properties, consistent estimates of the lag polynomials, $A(L)$, $B_l(L)$, $C_i(L)$, $D_{il}(L)$, can be obtained by regressing each estimated component on their own lags, controlling for lags of the error term resulting from the first stage approximation of the unobserved component, i.e. for $\widehat{u}_t$ in the auto-regressions of the local macro factor and the global micro factor, and for $\widehat{u}_t$, $\widehat{v}_{lt}$, and $\widehat{w}_{it}$, in the auto-regressions of the local micro factor. This type of auto-regressions augmented with the cross-individuals average of the dependent variable is similar to the procedure developed in the CCEMG estimator of Pesaran (2006, 2007) for panels where errors are cross-correlated due to common factors.[13]

3.3 What is the impact of the reference currency?

As already mentioned, we work with prices converted to the same currency. We thus consider the dynamics of international prices offered to a representative consumer that can freely buy in any location worldwide goods priced in a single numeraire. Consequently, with the exception of the country of the reference currency, the adjustment to shocks we capture is a combination of the internal adjustment of domestic prices and the external adjustment through the exchange rate. We now discuss how the choice of the numeraire affects the estimation of the dynamics of various components of inflation rates. We denote π^*_{ilt} the local currency inflation rate of good i in location l and s_{lt} the (log) exchange rate of the local currency into the chosen reference currency, in our case the USD, so that $\pi_{ilt} = \pi^*_{ilt} + \Delta s_{lt}$.

To start with, we note that the external adjustment does not show up in every component of individual inflation rates. It is indeed not at stake in the dynamics specific to a given good item i. Indeed, by definition, the estimation of the global-micro component of inflation does not depend on the reference currency since

$$\widehat{w}_{it} = \frac{1}{n_{l|i}} \sum_l (\pi^*_{ilt} + \Delta s_{lt}) - \frac{1}{n_i} \sum_i \frac{1}{n_{l|i}} \sum_l (\pi^*_{ilt} + \Delta s_{lt}) = \frac{1}{n_{l|i}} \sum_l \pi^*_{ilt} - \frac{1}{n_i} \sum_i \frac{1}{n_{l|i}} \sum_l \pi^*_{ilt}.$$

This also holds for our estimation of the local-micro component, which after simple algebra can be written as:

$$\widehat{z}_{ilt} = \left(\pi^*_{ilt} - \frac{1}{n_{l|i}} \sum_l \pi^*_{ilt} \right) - \left(\frac{1}{n_{i|l}} \sum_i \pi^*_{ilt} - \frac{1}{n_i} \sum_i \frac{1}{n_{l|i}} \sum_l \pi^*_{ilt} \right).$$

[13] As Pesaran (2006) emphasizes, controlling for common factors through simple averages is a procedure robust to specification error induced by more elaborate methods which in particular require to specify the number of common factors.

By contrast, estimates of macro factors do depend on the reference currency. It is obvious for the estimate of the global-macro component in price dynamics which can be written as:

$$\widehat{u}_t = \frac{1}{n}\sum_{il}(\pi^*_{ilt} + \Delta s_{lt}) = \overline{\pi}^*_t + \Delta \overline{s}_t.$$

This term is thus a combination of factors that affect local currency prices everywhere, and factors that have an effect on the exchange rate of the numeraire currency relative to every other currency. Put differently, aside of local price reaction to global shocks, this price component captures the exchange rate reaction to shocks that are specific to the country of the numeraire currency. So changing the numeraire might affect the dynamic property of this term.

Lastly, simple algebra also makes clear that the estimate of the local-macro component in inflation involves bilateral exchange rates with respect to the reference currency since it can be written as:

$$\widehat{v}_{lt} = \left(\frac{1}{n_{i|l}}\sum_i \pi^*_{ilt} - \frac{1}{n_l}\sum_l \frac{1}{n_{i|l}}\sum_i \pi^*_{ilt}\right) + \left(s_{lt} - \frac{1}{n_l}\sum_l s_{lt}\right).$$

The impact of the external adjustment through the exchange rate increases with the extent to which the location-specific exchange rate, s_{lt}, has a specific dynamic compared to the average one, $\frac{1}{n_{l|i}}\sum_l s_{lt}$. Changing the numeraire currency will change the reference with respect to which location-specific asymmetric shocks are defined, but not the way prices respond to these shocks through the external adjustment mechanism.

In the empirical analysis we start by using the US dollar as the numeraire currency. So, aside of global shocks affecting local prices everywhere, the global component is affected by shocks that are specific to the dollar, for instance US monetary policy shocks. This is a natural choice to make: given the key role of the US dollar in international transactions, shocks that affect the dollar exchange rate worldwide can be considered as global shocks. However, we also check that this particular choice of the reference currency, hence US specific shocks, does not drive our results regarding the dynamics of the different price components, by considering other numeraire currencies.

4 Estimation results

In this section, we first present some properties of the four components in international prices recovered from the estimation of the model presented above. We emphasize the persistence of the global components in comparison to the local ones. We then show that this persistence of the global shocks is robust to several modifications in the estimation method including treating the euro area as a unique entity, considering different numeraire currency, averaging prices for the items that are observed in different stores of the same location, running the analysis at the city level rather than country level, and excluding the years of the Great Recession.

4.1 Persistence and volatility properties of the four components

Table 3 presents some characterization of the four components in micro price inflation rates observed over the 1990S1-2010S1 period allowing each component in prices to follow an AR(4) process.

Inflation average and time variance

The first column of Table 3 presents the average inflation associated with each of the four components, namely $\mathrm{E}(\pi_{ilt}^{GA})$, $\mathrm{E}(\pi_{ilt}^{GI}|i)$, $\mathrm{E}(\pi_{ilt}^{LA}|l)$, $\mathrm{E}(\pi_{ilt}^{LI}|il)$, as well as some measure of their cross-sectional dispersion. The average global inflation rate amounts to 1.42% per semester over the sample period. The table underlines substantial heterogeneity in the average inflation of the various global micro components, as well as of the various local macro and micro components. In particular, some goods but also some countries exhibit negative (USD) average inflation over this period of 20 years. There is more heterogeneity across the global micro components than across the local macro and micro components.

The second column of Table 3 reports the standard deviation over the period for the four price components, $\sigma(\pi_{ilt}^{GA})$, $\sigma(\pi_{ilt}^{GI}|i)$, $\sigma(\pi_{ilt}^{LA}|l)$, and $\sigma(\pi_{ilt}^{LI}|il)$. The results show that the volatility of the local macro and micro price components is on average greater than the volatility stemming from the respective global components. Yet, the global components account for a substantial part of the fluctuations of inflation for a typical good-location inflation. The third column illustrates this by reporting the share of each of the four price components in the total average variance of inflation in these international micro prices, $E[\sigma^2(\pi_{ilt}|il)]$. As we can see from this column, the global components account on average for a quarter of the time-series fluctuation of inflation rates. In particular, global micro shocks account for 22 percent of these fluctuations. Moreover, as we can see in Table 3, for the typical good-location couple, local micro shocks are more volatile than local macro shocks consistent with Boivin et al. (2009). These average figures conceal substantial heterogeneity of the volatility of the different components across goods and locations. This cross-sectional heterogeneity is larger for the micro components and in particular for the global one, than for the macro components.

Persistence of the four components

We now turn to the persistence characterizing each of the components which is reported in the fourth column of Table 3. The measure of persistence presented here is the sum of the coefficients characterizing the dynamics of each of the components, namely $A(1)$, $B_i(1)$, $C_l(1)$, and $D_{il}(1)$ obtained from our estimation exercise. As we can see from this fourth column, the global macro component of the inflation rate exhibits the greatest persistence, thus measured, with a value of 0.42 followed by the global micro component with a mean (median) persistence of 0.10 (0.12). The two local components exhibit a lower degree of persistence with a mean (median) of -0.14 (-0.099) for the local macro and -0.28 (-0.19) for the local micro. Moreover, we note that there is a substantial amount of heterogeneity of the persistence parameters across goods and locations, the heterogeneity being more pronounced for the local micro component.

Response of prices to global and local shocks

The fact that the persistence of the effects of a shock to the various components in international prices differs significantly from each other is further illustrated in Figure 1. More specifically, the figure plots the median impulse response function (IRF) of prices to an innovation in each price component: global-macro, global-micro, local-macro, and local micro. The data used to produce these figures cover 59 countries and 276 goods over the 1990S1-2008S1 period.[14] As we can see, the median IRF of prices to an innovation in the global macro component portrays a permanent response, while the price response to each of the other components eventually reverts to zero. Moreover, as we can see in Figure 1, it takes longer for prices to reach their long-run value in response to an innovation in the global macro component as compared to the time it takes to reach their long-run value (zero in this case) in response to any of the other components. We also see that it takes longer for prices to reach their long-run value in response to an innovation in the global micro component as compared to the time it takes to reach their long-run value in response to innovations in either the local macro or the local micro components. Finally, prices are characterized by a comparable response to innovations in the local macro or micro components. Overall, it clearly takes prices longer to respond to global than to local shocks.

The fifth and last column of Table 3 reports a measure of the speed of adjustment in the response to shocks in each of the four components. More precisely, the measure is the share of the long-term adjustment (that we assume is reached 12 semesters after the shock) completed over the first two years following a shock. Namely, letting IRF(h) being the price response to a shock h periods after it occurred, the column reports [IRF(4)-IRF(0)]/[IRF(12)-IRF(0)]. This measure ranks the global shocks as more persistent than the local ones. More specifically, 39% of the long-term response to a global macro shock is completed over the first two years following the shock, while the ratio equals 57% in response to a global micro shock. The speed of adjustment is faster for the local shocks with 70% (79%) of the long-term response to a local macro (micro) shock completed after two years.

[14] This excludes the "abnormal" crisis period that begins in the second semester of 2008.

Thus, the convergence speeds associated with the global macro, global micro, local macro and local micro components are faster as we descend from the former to the latter.

The reaction of prices to macroeconomic shocks is often discussed in order to assess the effectiveness of monetary policy. However, the shocks that we consider in this section are non structural and thus the results do not exclude the possibility that prices could react rapidly to some global shocks and in particular to monetary policy shocks. In Section 5, we address this issue by looking at the response of prices to both global and local structural monetary shocks. Before that, we consider a number of robustness checks of our main result of the current section that global components in prices are more persistent than local ones.

4.2 Robustness

We now consider a number of robustness checks and report results in Table 4. In Table 4, with the exception of column (7), we consider again countries rather than cities for comparability to the previous literature investigating macro shocks at the national level, and in line with the fact that monetary policy is typically undertaken at the national rather than city level. In addition, in columns (1) and (2) of Table 4, we treat the EMU as a single entity since EMU nations do not undertake independent monetary action. Thus, we restrict our sample to 49 countries, capturing the EMU entity by Germany in column (1) and by the EMU average in column (2). In effect, this restricted sample treats Euro area countries as a single entity. Even though we do not exactly identify monetary policy shocks in Table 4, accounting for the fact that some locations do not exercise independent monetary policy ensures that our local macro shocks will be more closely related to monetary shocks than otherwise.

As compared to the 59 country sample in Table 3 that includes all available EMU nations, persistence estimates are not that different: persistence associated with the global macro shock remains at 0.42, while the persistence measure value for the global micro is 0.106 as compared to 0.104 in Table 3. Moreover, the persistence estimates associated with the local macro and local micro shocks are almost unchanged: these are respectively equal to -0.144 and -0.299 in column (1) of Table 4 as compared to the respective values of -0.139 and -0.283 in Table 3. Finally, considering an average over EMU nations rather than capturing the EMU entity using Germany, does not really affect the results as can be seen in column (2) of Table 4.

Next, we consider the issue of converting prices to a common currency other than the US dollar. More specifically, in columns (3) and (4) of Table 4 we consider the conversion of local currency prices into British Pound and Yen prices respectively. Using the British Pound, persistence estimates of prices in response to the different types of shocks and their relative ranking are similar to those in Table 3 that utilize the US dollar. As we can see in column (3) of Table 4, persistence associated with global macro and global micro shocks equals 0.35 and 0.148 respectively, as compared to 0.42 and 0.104 for the respective persistence estimates in Table 3. The persistence estimates associated with the local macro and local micro shocks are now closer to each other than previously, with values respectively equal to -0.185 and -0.233 as compared to the respective values of -0.139 and -0.283 in Table 3 or to estimates reported in columns (1) and (2) of Table 4. Overall, the ranking in terms of the relative persistence of global macro, global micro, local macro, and local micro shocks does not change.

Persistence estimates based on the Japanese Yen reported in column (4) of Table 4 are very similar to those based on the British Pound reported in column (3) for the global micro, local macro, and local micro shocks: persistence estimates are respectively equal to $0.138, -0.169$, and -0.257 as compared to $0.148, -0.185$, and -0.233 in column (3). However, persistence associated with the global macro shock is now very fast, at -0.01, and spectacularly different than what we got previously based on the British Pound or the US dollar. As discussed earlier, conversion to the same numeraire currency introduces to the global price component (i) the external adjustment to shocks via the exchange rate, and (ii) shocks specific to the reference currency country. When these happen to dominate the internal adjustment of domestic prices to the global macro shock, estimation of the speed of price adjustment to that shock is not robust to the choice of reference currency. In this case, the global component appears to be affected by shocks that are specific to the Japanese yen.

The EIU samples only one price per good per type of store in a given city and period, which could lead to measurement error if this single price is used as the basic unit of analysis. To alleviate this source of measurement error, we now average prices across types of stores for a given good, city, and time period, which is possible since prices are available for two types of stores for most goods as shown in Table (1). In column (5) of Table 4, we report persistence estimates that utilize this average price as the basic unit of analysis while still including goods and services with only one available observation thus restricting the sample down to 178 distinct goods and services. The persistence values now obtained for the global macro, global micro, local macro, and local micro shocks are respectively equal to 0.42, 0.15, -0.14, and -0.19 as compared to 0.42, 0.104, -0.14, and $-.28$ in Table 3. As we can see, while the persistence associated with the global and local macro components is virtually unchanged, the global and local micro components are now more persistent than in Table 3.

To more closely consider the issue of measurement error, in column (6) of Table 4 we restrict the sample to only goods with two available observations and consider the average price for each such good. This restricts the sample to only 100 distinct goods. The persistence values associated with the global macro, global micro, local macro, and local micro shocks in column (6) of Table 4 are respectively equal to 0.42, 0.17, −0.14, and −0.27 as compared to 0.42, 0.15, −0.14, and −.19 in column (5) and 0.42, 0.104, −0.14, and −.28 in Table 3. These results suggest that the only important change relative to Table 3, is the increase in persistence of the global micro component when we restrict the sample to goods with two averaged observations.

Next, we consider city-level analysis for the complete sample of locations, exploiting the full spatial dimension of our dataset across 88 cities in 59 different countries. In column (7) of Table 4, we show that the persistence values associated with the global macro, global micro, local macro, and local micro shocks are respectively equal to 0.42, 0.106, −0.104, and −0.31 which are similar to the respective estimates (0.42, 0.104, −0.14, and −.28) in Table 3 which reports estimates based on the same 59 countries, averaging prices for each good across cities for countries with more than one city price observation. Once again, the relative ranking of persistence estimates for the different components remains exactly the same.

Finally, in column (8) of Table 4 we consider the time period 1990-2008S1 before the onset of the Crisis, for comparability to the IRFs shown in Figures 1, 2 and 3 that also omit the Crisis period. The persistence values associated with the global macro, global micro, local macro, and local micro shocks are respectively equal to 0.598, 0.16, −0.14, and −0.32 as compared to the respective estimates of 0.42, 0.104, −0.14, and −.28 in Table 3 which shows results based on the time period 1990-2010S1. While local components are relatively unchanged, the two global components are associated with more persistence as compared to results based on the complete sample period that includes the Crisis. This suggests that the Crisis era might be regarded as a global tendency for reversion to the mean for these components, associated with reduced persistence. Yet again, the relative ranking of persistence estimates for the different types of components remains the same.

5 Price response to structural monetary shocks

In this section, we investigate the following three questions. First, we assess whether differences in the persistence of the global and local components documented above stem from differences in the response of prices to the various shocks underlying them or from differences in the persistence of these underlying shocks. We answer this by identifying the response of prices to unpredictable global and local monetary shocks using structural VARs. In this analysis, we consider that US monetary policy has a leading impact on liquidity supplied worldwide and can thus be seen as a global monetary shock. This assumption is also convenient to compare our results with previous studies which investigated the response of US sectoral prices to a US monetary policy shock. Second, we look at how our global shock, *i.e.* US monetary policy, affects the US local specific component of price dynamics. The answer is obtained as a subcase of the previous SVAR exercise and allows us to compare our results with the recent studies investigating the effect of US monetary policy on US sectoral prices. Third, we study the persistence of macro and of micro components when one does not separate their global and local components as has been done in related previous studies of the US economy.

5.1 Price response to global and local monetary shocks

We first show that the differences in the persistence of price components documented in the previous section is also related to prices reacting differently to different types of shocks. More precisely, we investigate the response of prices to two types of unpredictable structural shocks: a global monetary shock and a local one. Those two shocks are identified by means of structural VARs. The global monetary policy shock is identified as an unpredictable increase in the US Federal Fund rate controlling for current US output growth, oil prices, global inflation and US specific inflation. Local monetary policy shocks are identified as an unpredictable increase in the money market short term interest rate of each country in the sample, controlling for current local output growth and local inflation as well as for the US growth rate, the global inflation rate and the average short term interest rate as a way to take into account country specific monetary policy reactions to these global variables. Data are obtained from the IMF. The need of money market interest rates restricts our sample to 41 countries. We consider the years of the Great Recession as an outlier in our sample and thus focus on the pre-crisis period of our sample, that is 1990S1-2008S1.

Figure 2 plots the IRF of the global component of prices to an unexpected unitary increase in the US monetary policy and the median response of local prices to a local unitary increase in the money market interest rate. As we can see in Figure 2, in response to a global monetary shock, prices reach their long-run value much slower as compared to the time it takes for prices to reach their long-run value in response to a local monetary shock. In response to a global (adverse) monetary shock, prices fall steadily for several periods, remaining below their original level for a sustained period of time. On the other hand, prices fall fast upon impact of a local adverse monetary shock and then tend to revert to their original level reaching that by the 7th period. We note that the two monetary shocks (local/global) that we identify both lead to a transitory increase of comparable length of the federal funds rate. Thus, we can state that our local/global IRFs show that *(i)* the reaction of prices to a transitory increase in the local interest rate is transitory, reaching a peak after 4 periods and then starting to go back to its initial value, and not as persistent, while *(ii)* the reaction of prices to a transitory hike in the global (US) interest rate is very persistent and comparable to that shown in previous work.

5.2 Relevance to the existing literature

Boivin et al. (2009) found that US sectoral prices react slowly to US macroeconomic (typically monetary policy) shocks.[15] We underline that, for the average country, the persistence is due to global and not country specific macroeconomic shocks. The two results can be reconciled as US monetary policy shocks can be considered as global ones and US monetary policy could have a persistent effect on US prices via its effect on the global component of US prices.

A question is then to know whether Boivin et al. (2009) mainly capture the global reaction of prices to a US monetary policy shock, or a US specific reaction of prices to US monetary shocks, or both. Figure 3 provides an answer to this question. It shows the IRF of the US specific price component to the US, hence global, monetary policy shock we identified in the previous subsection. As the figure shows, the US specific price reaction to this US monetary policy shock is only slightly more persistent than the reaction of the average country to its domestic monetary policy shocks. We can thus conclude that the reaction of US prices to the US monetary shock previously identified is mostly related to the reaction to the global component of prices worldwide.

We also need to address the concern that our results could be due to our methodology implying lower persistence of US specific macro components as compared to previous studies. This is not the case as results in Table 5 indicate. To start with, as we can see from the first panel of Table 5, the local macro component for the US using our methodology is much more persistent than that for the average country in our sample, which can then reconcile our results with previous work. Our persistence measure for the local macro component for the US in Table 5 is 0.35 as compared to -0.14 for the sample average shown in Table 3. The local macro component for the US is also much more persistent than the local micro component for the US. The persistence measure for the latter is shown to be -0.24 in Table 5, in-between the sample mean and median shown in Table 3.

We go further by implementing a decomposition of prices in our sample into two components, a macro and a micro one, and looking at their properties.[16] The second panel of Table 5 gives the

[15] In their own words, their "main finding is that disaggregated prices appear sticky in response to macroeconomic and monetary disturbances, but flexible in response to sector-specific shocks" and that "many prices fluctuate considerably in response to sector-specific shocks, but only sluggishly to aggregate macroeconomic shocks such as monetary policy shocks". This result has in turn spurred a debate on what theoretical model of price-setting could rationalize such different response of individual prices to different types of shocks.

[16] We consider a price dynamics model given by $\pi_{ilt} = a_{il}\pi^{A}_{ilt} + \pi^{S}_{ilt}$, instead of our four component model introduced

results we obtain for the US. We obtain a persistence of the macro component of US aggregate inflation of 0.81 much above the one for the local US specific macro component of 0.35 and broadly in line with the results obtained in Boivin et al. (2009) or Maćkowiak et al. (2009). Moreover, in Table 5, and also in line with these previous studies, we can see that the macro component for the US is way more persistent than the micro component for the US which is associated with a persistence value of -0.05.

Finally, the last panel of Table 5 gives the results we obtain when one applies the mere macro/micro decomposition to the whole sample of countries. It shows that, unlike that for the US, the macro component for the average country (-0.02) is not persistent. The micro component for the complete country sample is even less persistent (-0.18). The lower persistence of both the macro and micro components in the average country compared to the US stems from the fact that local components are much more volatile in the average country than in the US. Hence, this aggregation conceals the properties of the global components much more for the average country than for the US.

Papers by Clark (2006), Boivin et al. (2009), and Maćkowiak et al. (2009) bridge the gap between measured persistence of macro price indices and the frequent adjustment observed in micro prices.[17] In their setup, a macro shock is common to every sector in the US, potentially encompassing a shock common to every country worldwide (our global macro shock) and a shock specific to the US (our local macro shock). Likewise, their sectoral shock can be made of a worldwide sectoral shock (our global micro shock) and a US sector-specific one (our local micro shock). Our results on the differential response of prices to different types of shocks extend these papers to a global environment. More specifically, our work points to the importance of disentangling global and local components to understand price dynamics. No study of micro price levels has looked at this global/local decomposition of micro and macro shocks.[18]

Our results suggest that the global versus local distinction is crucial in order to uncover the reaction of prices to different types of shocks. They also suggest that distinguishing between global and local components is useful in discriminating between different models of price setting. According to these results, price setting models should be able to rationalize differences between the price response

in Section 3.

[17] They show that sectoral prices react rapidly to US sectoral shocks and sluggishly to US macro shocks, arguing that as the latter account for such a low share of sectoral price variance it is not surprising to observe sectoral prices that on average adjust rapidly. Altissimo et al. (2009) find similar results for the euro area. Reis and Watson's (2010) related contribution emphasizes the importance of common factors to understand fluctuations in US sectoral prices.

[18] Using sectoral price indices, Beck et al. (2010) also emphasize the variance of geographical components as an important part of what was previously thought to be micro shocks. The related literature on global shocks has found a large common component in international aggregate inflation indices in OECD countries (Ciccarelli & Mojon, 2010) or in disaggregated inflation at the CPI product level in OECD countries (Monacelli & Sala, 2008). As compared to these, we use a large number of micro-prices and global locations to further decompose the common component into macro and micro global components, stressing that the micro part accounts for a greater share of in-sample variance.

to global versus local shocks that are more pronounced than between macro and micro shocks. Explaining such differences in the rate of price adjustment to different types of shocks, could be achieved by resorting to models of endogenous imperfect perception of shocks, in the spirit of the recent contributions of Reis (2006), Maćkowiak and Wiederholt (2009), Woodford (2009) or Alvarez et al. (2010), where geography matters due to relative loss of information processing capacity so that the relative cost of observing global conditions would be greater than the one associated with monitoring local ones, in the same manner (but more strikingly so) in which the relative cost of observing macro conditions is normally assumed to be greater than the one associated with monitoring micro ones. Another possibility would be to rely on labor market segmentation arguments, in the spirit of Carvalho and Lee (2011), with segmentation being greater between countries than within them in the same manner (but more strikingly so) that labor segmentation is greater across sectors than within sectors. We exploit this theoretical possibility next.

6 Theoretical Interpretation

We now illustrate how theoretical models of price setting can explain the relatively slow adjustment of prices to global shocks and their relatively fast adjustment to local shocks. We rely on labor market segmentation arguments in the spirit of Carvalho and Lee's (2011) multi-sector model. More specifically, we consider the price reaction to two types of demand shocks, a global and a local one, in a stylized multi-country version of the basic New-Keynesian sticky price model with cross-country labor market segmentation.[19]

Labor market segmentation across countries makes a firm's marginal cost depend on its relative price: a higher relative price implies lower demand for the country's output which translates into lower demand for the country-specific labor input and lower wage and marginal costs in that country.[20] As we illustrate below, the negative dependence of a firm's marginal cost on its own country price level and positive dependence on the global price level, produces a strategic substitutability in price setting within countries and a strategic complementarity in price setting across countries. These differences in strategic interactions generate a price adjustment in response to global shocks that is slow in comparison to the price adjustment in response to local shocks.

[19] Woodford (2003) Ch3 section 2.5 points to the link between multi-country and multi-sectoral New-Keynesian models. In addition to labor market segmentation, Carvalho and Lee's model also features input-output linkages, endogenous monetary policy, and aggregate preference shocks as well as aggregate and sector specific technology shocks. We do not include all these ingredients in this illustrative version to keep the argument of why prices react differently to different types of shocks as simple as possible.

[20] Without labor market segmentation, workers migrate out of countries where firms offer a relatively lower wage leading to a drop in labor supply hence upward pressure on wages in these countries and eventually wage equalization across locations.

6.1 Economic structure

The economy is made of a finite number of countries indexed by $l \in \{1, 2, ..., L\}$. There is a continuum of agents indexed by $i \in [0, 1]$ with each agent consuming all goods produced in the L countries, while producing a differentiated good item i in one of the L countries and specializing in the supply of a single type of labor in the country they reside in. We note I_l the set of agents in country l and $n_l = \int_{I_l} di$ the measure of goods produced in each country l so that $\sum_{l=1}^{L} n_l = 1$. For simplicity, we assume that each country has the same size $n_l = 1/L$.

As in Benigno (2004), goods are traded across the L countries with zero trade cost and prices for the final goods are set taking into consideration all L markets so that the law of one price holds: prices for the same good are the same across all L countries. There is an equal number of agents in each country and each agent specializes in the supply of only one type of labor in the country they reside in without the possibility of migrating to an other country. We assume a cashless economy as in Woodford (2003). Moreover, there exist competitive financial markets where complete risk sharing occurs so that there is perfect consumption insurance across countries, with firm profits redistributed lump-sum to households.

6.2 Households

The household maximization problem is described by

$$\max_{\{B_{t+1}, N_{lt}\}} E_0 \left[\sum_{t=0}^{\infty} \beta^t \left(\log C_t - \frac{N_{lt}^{1+\varphi}}{1+\varphi} \right) \right], \tag{T1}$$

subject to a budget constraint given by

$$C_t + \frac{E_t[Q_{t,t+1} B_{t+1}]}{P_t} = \frac{B_t}{P_t} + \left(\frac{W_{lt}}{P_t} \right) N_{lt} + \sum_{l=1}^{L} \int_{I_l} \left(\frac{\Pi_{lt}(i)}{P_t} \right) di, \tag{T2}$$

where β is a subjective discount factor, φ is the inverse of the elasticity of labor supply, C_t denotes the aggregate consumption index, N_{lt} is the labor supply of a household residing in country l which offers disutility as described in the above function, W_{lt} is the wage rate in country l, $\Pi_{lt}(i)$ are nominal profits for firm i in country l resulting from the firm's optimization problem described below and taken as given in the constrained household maximization problem described above, $Q_{t,t+1}$ is the nominal stochastic discount factor, and B_{t+1} is a one-period internationally-traded state contingent bond consistent with complete asset markets within and across countries.

The above household maximization problem gives the following two first-order conditions:

$$Q_{t,t+1} = \beta \frac{C_t}{C_{t+1}} \frac{P_t}{P_{t+1}}, \tag{T3}$$

and

$$\frac{W_{lt}}{P_t} = N_{lt}^{\varphi} C_t. \tag{T4}$$

We note that, as the labor market for each country l is segmented, labor supply and the wage rate can differ across locations and are thus indexed by l, while perfect risk sharing across all states of nature implies that consumption, C_t, is identical in all countries l.

The consumption index C_t that enters the utility function of each household is a CES aggregate of L sub-indices

$$C_t \equiv \left[\sum_{l=1}^{L} (n_l D_{lt})^{1/\eta} C_{lt}^{(\eta-1)/\eta} \right]^{\eta/(\eta-1)}, \tag{T5}$$

with η the elasticity of substitution between consumption composites produced in different countries, and D_{lt} a relative demand shock that satisfies $D_{lt} > 0$ and $\sum_{l=1}^{L} n_l D_{lt} = 1$ so that the variation in the D_{lt} is a shift in the relative demand of the L final goods and represents a single shock each period. The sub-indices, C_{lt}, are themselves CES aggregates of the continuum of differentiated goods produced in each of the L countries, namely:

$$C_{lt} \equiv \left[n_l^{-1/\theta} \int_{I_l} C_{lt}(i)^{(\theta-1)/\theta} di \right]^{\theta/(\theta-1)}, \tag{T6}$$

for $l = 1, 2, ..., L$, with η the elasticity of substitution between consumption varieties produced within country l.[21] The minimum expenditure of obtaining one unit of the consumption composite C_t is given by the overall price index

$$P_t \equiv \left[\sum_{l=1}^{L} n_l D_{lt} (P_{lt})^{1-\eta} \right]^{1/(1-\eta)}, \tag{T7}$$

and, similarly, the minimum cost of obtaining one unit of the composite good C_{lt} produced in country l is

$$P_{lt} \equiv \left[n_l^{-1} \int_{I_l} [P_{lt}(i)]^{1-\theta} \, di \right]^{1/(1-\theta)}. \tag{T8}$$

Given zero trade costs, country l's output is sold at the same price, P_{lt}, in all L countries.

Given C_t, P_{lt} and P_t, the optimal demand for country l's composite good which minimizes total expenditure $P_t C_t$ subject to the constraint given by equation (T5) is

$$C_{lt} \equiv n_l D_{lt} C_t [P_{lt}/P_t]^{-\eta} \tag{T9}$$

[21] One could extent the model to the case where this elasticity within a country differs from the one across countries as is done in Carvalho and Lee (2011).

Then, given the decision on C_{lt}, the optimal allocation of demand in country l across the various differentiated goods which minimizes expenditure $P_{lt}C_{lt}$ subject to the constraint given by equation (T6) is

$$C_{lt}(i) \equiv n_l^{-1} C_{lt}[P_{lt}(i)/P_{lt}]^{-\theta} = D_{lt}C_t[P_{lt}(i)/P_t]^{-\theta} \tag{T10}$$

for each good i in country l.

6.3 Firms

Firms are assumed to use country-specific labor as the only input to production. More specifically, the production function for a good item i produced in country l takes the simple linear form[22]

$$Y_{lt}(i) = N_{lt}(i). \tag{T11}$$

Price-setting is staggered so that a fraction α of prices remain unchanged each period whereas the remaining $1-\alpha$ firms adjust prices, with the probability that any given price will be changed in any given period given by the latter constant fraction irrespective of how much time has elapsed since the last price was set.[23] Thus, country l's price level evolves according to

$$P_{lt} = \left[\alpha P_{lt-1}^{1-\theta} + (1-\alpha)\left(P_{lt}^*\right)^{1-\theta}\right]^{1/(1-\theta)}, \tag{T13}$$

where P_{lt}^* is the optimal price chosen by all firms in country l who can reset their price at date t.

Firms that adjust their prices in period t maximize expected discounted profits

$$\max_{P_{lt}(i)} E_t \sum_{s=0}^{\infty} \alpha^s Q_{t,t+s} \Pi_{lt+s}(i),$$

where $Q_{t,t+s} = \beta^s \frac{C_t}{C_{t+s}} \frac{P_t}{P_{t+s}}$ is the stochastic discount factor between periods t and $t+s$, and $\Pi_{lt+s}(i) = P_{lt}(i)N_{lt+s}(i) - W_{lt+s}N_{lt+s}(i)$ is the nominal profit of firm i in country l at $t+s$ given that the price chosen at t is still being charged. The first order condition of the firm's problem is:

$$E_t \sum_{s=0}^{\infty} \alpha^s Q_{t,t+s} \left(\frac{P_{lt}^*}{P_{lt+s}}\right)^{-\theta} \left(\frac{P_{lt+s}}{P_{t+s}}\right)^{-\eta} Y_{t+s} \left[P_{lt}^* - \left(\frac{\theta}{\theta-1}\right) MC_{lt+s}\right] = 0. \tag{T14}$$

where the marginal cost of country l's firms is $MC_{lt+s} = W_{lt+s}$.

[22] We could easily extend the analysis to a production technology affected by both worldwide and country-specific technology disturbances.

[23] As Carvalho and Lee (2011) do for different sectors, we could also consider Calvo parameters, α_l, that differ across countries.

6.4 Equilibrium

At the equilibrium, the households optimality condition and budget constraint as well as firms optimality condition are satisfied. Moreover, the following market clearing conditions for respectively the asset market, the goods market, and the country specific labor market also hold:

$$\begin{aligned} B_t &= 0 \\ C_t &= \sum_{l=1}^{L} \int_{I_l} Y_{lt}(i) di, \\ N_{lt} &= \int_{I_l} N_{lt}(i) di \quad \forall l. \end{aligned}$$

We close the model by an assumption on nominal demand which is assumed to be determined exogenously by the money supplied globally

$$P_t C_t = M_t.$$

6.5 Log-linear approximation and solution

As usual in this literature, we consider a linearized version of the model around a zero inflation symmetric steady-state.[24]

As usual, the log-linearized approximation of the model leads to the following country price dynamics equation:

$$p_{lt} = \alpha p_{lt-1} + (1-\alpha) p_{lt}^{*} = \alpha p_{lt-1} + (1-\beta\alpha) E_t \sum_{s=0}^{\infty} (\beta\alpha)^s \, mc_{lt+s}, \tag{1}$$

where we use the usual notation convention of lowercase letters for the log of the corresponding uppercase letter variable (expressed in deviations from the steady state). This equation shows that price adjustment at the country level is a function of the probability of updating a price, α and the reaction of the marginal cost mc_l to the shocks. The first parameter obviously does not depend on the type, global or local, of shocks. However, this is not the case for the marginal cost. Indeed, global and local shocks, move the relative price of firms updating their price differently. Hence, when labor markets are segmented across countries, the two types of shocks produce a different impact on local wages, hence a different price adjustment to them.

[24] The symmetry of the steady state is ensured by the assumption of equal size of every country and that there is no long-run differences in country specific labor productivity. [[See Appendix B for details.]]

More specifically, and as Carvalho and Lee (2011) show, in our case the price dynamics at the country level verifies:

$$p_{lt} = \lambda_1 p_{lt-1} + \frac{(1-\alpha)}{\alpha(1-\alpha\beta)^{-1}} \frac{1}{\lambda_2} E_t \sum_{s=0}^{\infty} \left(\frac{1}{\lambda_2}\right)^s \left[(1+\varphi)m_{t+s} + \varphi d_{lt+s} + \varphi(\eta-1)p_{t+s}\right], \qquad (2)$$

with $0 < \lambda_1 < 1 < \lambda_2$ the roots of the characteristic polynomial:

$$f(\lambda) = \beta\lambda^2 - \left[\beta + 1 + \frac{(1-\alpha)}{\alpha(1-\alpha\beta)^{-1}}(1+\varphi\eta)\right]\lambda + 1.$$

In reaction to a positive local demand shock, $\Delta d_{lt} > 0$, local producers who can update their prices increase them. There is then an "expenditure switching" effect: the relative price of local firms who do not update their prices decreases, which increases the demand for their varieties and thus drives the local wage up. Firms which update their price, factor in this increase in their marginal cost and react by augmenting their prices by an even greater amount. So the reaction of marginal cost to local shocks contribute to speed up price adjustment.

The transmission of global shocks involves the reaction of the global price level p. In reaction to a positive global demand shock, $\Delta m_t > 0$, producers who can update their prices increase them in every location, which thus increases the global price level. However, price staggering makes this increase in the global price level lower than it would be under perfect perfect price flexibility. Had other firms adjusted their prices upwards in response to this shock, this would have reduced the relative price of the initial non-adjusters thus increasing their relative demand leading them to produce and sell more and thus demand more labor which would then increase the country specific wage for firms in the same country, inducing them to increase prices. Thus, to the extent that other firms do not adjust their prices upwards in response to a positive global demand shock, a firm will have less of an incentive to increase its price as compared to the scenario just described. The positive dependence of country level price dynamics to the global price level contributes to slow down the reaction of marginal cost hence prices in reaction to global shocks.

Note that the intuition offered here is entirely analogous to the intuition in Carvalho and Lee (2011) albeit for the fact that they consider within sector and across sectors pricing interactions rather than interactions within and across countries. Price staggering is an essential feature here, since the fact that some prices are not yet adjusted in response to a global shock leads to a smaller change in the prices of those firms that do adjust in that period as compared to the case of price synchronization, and this in turn restrains the adjustment in a later period of the prices that were sticky in the earlier period. In the presence of a sufficient degree of strategic complementarity as is implied by our assumpion of labor market segmentation[25] across countries, this process then creates a form of price persistence that allows for prolonged effects of global shocks on real activity.

[25] See the discussion in Woodford (2003) e.g. in page 172.

7 Conclusion

We have used a unique global microeconomic dataset of semiannual prices observed over two decades ending in March 2010, to consider how fast prices respond to different types of shocks. Previous work has emphasized the difference between the reaction of prices to macro and micro shocks. We have shown that macro shocks are not all alike and that different types of micro shocks do not necessarily resemble each other either. More precisely, we have emphasized the distinction between global and local shocks, and found that for both macro and micro shocks alike, global components are associated with much more price persistence than local ones. The difference is much more striking when decomposing between global and local shocks rather than merely considering macro versus micro shocks. Finally, we have shown that the differences in the persistence of price components we find is also related to prices reacting differently to different types of shocks. For example, we find that the speed of adjustment of prices to global monetary shocks is slower than the speed of adjustment to local ones.

Our findings support price-setting models that can explain differences in the speed of adjustment of prices in response to global versus local shocks, where local shocks are associated with faster adjustment than global ones. This new fact points towards the need of developing price-setting models with a spatial dimension. Geography could matter due to a higher degree of labor market segmentation across as compared to within locations, as in the theoretical model we have constructed in the previous section.

Overall, our work is suggestive of price-setting models consistent with fast price adjustment in response to local shocks and persistent price effects of international shocks. Dynamic price-setting models have typically been constructed in a closed economy setting, which is understandable in as far as, until recently, there had not been as much evidence for prices responding differently to international as compared to local shocks. Our paper provides evidence that this is actually the case, pointing to the need for futher research in open macroeconomy dynamic price-setting models that can rationalize differences in the speed of adjustment of prices in response to different types of international and local shocks.

A Data

The discussion below has benefitted greatly from systematic direct communication with the EIU office over the past few years, and in particular, from the insights and detailed explanations offered to us by Jon Copestake, Editor of the Worldwide Cost of Living Surveys.

Selection of stores and goods

Considerable care is taken by the EIU team to assess accurately the normal or average prices international executives and their families can expect to encounter in the cities surveyed. Survey prices are gathered from three types of stores: supermarkets, medium-priced retailers and more expensive specialty shops. Only outlets where items of internationally comparable quality are available for normal sale are visited. While the majority of cities provide a wide selection of goods and stores at different price levels, this range narrows considerably at several locations. In some cities the entire range of prices has to be collected at the few stores where goods of internationally comparable quality are found. Local markets and bazaars are visited only if the goods available are of standard quality and if shopping in these areas does not present any danger.

For certain items like monthly rent and clothing, there are many subjective factors, questions of personal preferences and taste at play, as well as a wide variety of choice. Therefore, price data given for certain items should be considered to be merely an indication of the general level of prices in these categories. In general, the degree of comparability across locations is high but varies with the general availability of goods in a given city. Given that the survey takes place in 140 cities worldwide, it is not always the case that an identical product is taken in all cities for all items. For example, it is more likely that while London has a quality Burberry raincoat available, Brussels does not have the same item or brand and the correspondent has taken a price based on the designer raincoats that are available. For such products, prices will reflect the general availability and local demand conditions in a location. Given these concerns, one would want to consider subsamples that exclude products likely to be less homogeneous across locations. The latter category includes pretty much all clothing items, automobiles, and a number of other products. As a result, we felt the need to create a sub-sample of goods that are more likely to be comparable across locations. This restricted sample of homogeneous goods excludes more than one third of our complete sample of goods and services, such as "Women's raincoat Burberry type", "personal computer", "family car", and "Furnished residential apartment: 1 bedroom, moderate". However, convergence rates obtained (not reported in the Tables) based on this more highly comparable sub-sample of goods are very similar to what we obtain when using the full sample of goods and services.

The price range presented in the survey utilized in the current study is for supermarkets or chains, and for mid-priced outlets. The EIU takes one representative price per store, sampling only one price from each of two type of stores, and generally surveys two stores per item for most products. As shown in Table 1, we use 100 distinct products that are reported at both a supermarket (or chain) and a mid-priced store and an additional 76 distinct products and services that are only sampled once, for a total of 276 price observations in each location and year.

In all cases, the EIU aims to keep the same stores and the same brands and sizes in obtaining the price for each item, so as to ensure ongoing consistency between surveys in each location. Store and product consistency has been an aim of the survey since its inception. The aim of sampling the same stores has remained consistent and the ability to do so has varied based on specific events in certain years relating to availability or specific situations affecting correspondents, like being refused entry to a store under new management. However, such consistency depends on and varies within individual markets. The surveyors seek to keep to the same stores, brands and weights between surveys. However, given that the survey takes place simultaneously in 140 cities over a period of twenty years, there may be substitutions or changes. This can occur in an evolutionary sense as certain brands or stores or sizes overtake others as the popular interpretation of a particular item changes over time. Alternatively, there may be sudden changes in brand, store or item based on availability in the market during a particular period. For example, a store may close and a certain brand may become temporarily or permanently unavailable. In these cases, substitutes are sought to reflect the price of obtaining the item in question at that particular time. This is more common in less developed markets where availability and price can fluctuate on a day to day basis, but even mature markets are prone to pricing or availability shocks and other changes of this kind especially over longer periods. We note that while the BLS adapts its basket of goods regularly and also changes the weighting system based on consumption trends, the EIU seeks to be more generally representative and has for the most part not changed in this manner, in an attempt to ensure a consistent dataset of like for like products going back over time.

The general conclusion from the discussion in this sub-section is that the EIU city-level prices are highly comparable across both space and time, and are thus suitable for the study of LOP deviations and their evolution over time. That is, one can use these prices to understand both the degree of market segmentation at any given point in time, and the process of market integration over time. The data appear less suitable for overall cost of living comparisons across locations since the goods sampled do not necessarily reflect local preferences as much as the shopping basket of executives and other multinational employees and their families.

Sampling, seasonality, and sales

The fieldwork for the Worldwide Cost of Living Surveys is carried out on location by the EIU researchers during the first week of March for the Spring edition and during the first week of September for the Autumn edition. These data was especially compiled for us, since the standard historical data in the "cityprices" EIU publication is only available at the annual frequency. Since the data overwrites old data each year, the standard data typically made available historically by the EIU is September data. There are two types of exception to this. First, are cities surveyed annually and only in March. These are: Baku, Bratislava, Calgary, Douala, Harare, Port Moresby, San Juan, and Tunis. For these cities, data is gathered since 2001 during the first week of March. Second, are cities where there are problems or delays in gathering data. These are individual cases and are not tracked, but it would generally be the case that such data is still gathered within a month or two, so that prices can still be relevant and comparable to other cities. Moreover, no such lags are allowed in high inflation locations.

The March and September dates for gathering data are specifically designed to avoid standard sales seasons, like traditional sales in December, January, May and June which take place in many countries. Correspondents are instructed not to take sale prices for items, but to take standard recommended retail prices. There is an element of common sense here as well though. That is, correspondents may take sales prices for general promotions if they feel the price reflects the "true worth" of an item. This might be the case for some items since retailers commonly use tactics of promoting an item by describing it as on "sale" when in fact they have previously artificially inflated the retail price of the item in order to later reduce it to a more reasonable price and make consumers think they are purchasing a bargain. This is true of items like CDs, wine, certain fresh food items, and other consumer goods. A few adjustments of the survey prices have been made in some cases where seasonal discount sales and changes in brand names, package sizes, and quality would have unduly distorted the index results. This procedure is limited to cases where it would not entail misrepresentation of actual prices in the EIU team's judgement.

The conclusion from the above paragraph is that the astonishing price differences for specific items across cities observed by the EIU team, are not due to sales or discounting, as the EIU does not seek to include such seasonal data in the price survey.

Reliability of data

Given the above discussion, we have opted to be extremely conservative in removing entries that at first might appear to be price outliers. Moreover, we never opt to adjust prices for what might at first appear to be "obvious" mistakes, like misplacing a digit or otherwise using a wrong unit, or misplacing part of a price entry in previous or subsequent entries. In this respect, our treatment of the data is very different than Crucini and Shintani (2008).

We opted to treat the data as a rather reliable representation of actual prices since in our discussions with the EIU office it was convincingly explained to us that specifying for instance the price variance between surveys not to be less than half or more than twice the CPI rate would be an extremely narrow margin for highlighting outliers, as the EIU team has historically observed prices that regularly change by as much as four times or more the CPI rate, while other prices remain unchanged year after year or even move down. It was also explained to us, that every survey price is "sense checked" as it comes in compared to those returned six months ago and those returned one year ago. Sense checking is simply to ensure that prices look broadly comparable to those returned previously. However, the final prices reported in the EIU surveys are based on actual ones as returned from field correspondents in each city, and are never a calculation based on a ratio of expected price movement to reported inflation levels. As a result, prices of individual items in the basket the EIU surveys can fluctuate wildly based on the basket snapshot that is taken.

For instance, a seemingly wrong but actually correct price entry comes from Casablanca in the case of bread. The figures for years 1992 to 1995 seem to be missing the initial digit "1". This example of bread in Casablanca between 1992 and 1996 is a prime example of how EIU prices should be considered valid even if they look peculiar relative to general price trends. Between 1992 and 1995, Morocco suffered from a period of drought which caused three harvests to fail (1992, 1993, and 1995). This had an impact on economic growth and prompted a recession. In response, the government will have extended price controls on staples. In the Moroccan diet, bread is considered to be the staple food of the poor and would have been the first and most heavily price-regulated item. Upon recovery and under external pressure the government pledged to relax such controls in 1996. In the case of the survey, we can clearly see this reflected. Lower priced bread in line with the 1992-1995 prices may have been widely available before and after this period, but during this period shortages, economic stagnation, suppressed demand for more expensive consumer goods, and price controls may have meant that these were the only prices available for bread. This situation was rectified as Morocco emerged from this period. Similarly, many prices could be flagged in developing countries during times of instability as these experience massive fluctuations in prices dependent on localized supply and demand factors. Thus, the EIU suggests that users consider reasons why a particular price may deviate from expectation based on the political, social and economic market context, globally, nationally or at city level before removing a price entry.

Errors that emerge may be a currency issue where back-rates are recalculated to cater to currency redenominations caused by inflationary spikes, or where devalued/alternative exchange rates are in operation. It is possible that some prices might be entered in a sub-unit of currency (e.g. in pence or cents) then reported in standard units (e.g. in pounds, euros or dollars). However, this is something the EIU generally seeks to rectify on a rolling basis. Still, the EIU cannot double-check many of the prices since the citydata feed automatically takes from the source files. These are taken from surveys based on manually collected data by correspondents in each location. The price dataset is built as the accumulation of decades of data submitted from a variety of sources in a variety of formats. Any data collected before 1998, for example, would have been returned in paper format and manually input into the base files eventually used, and the original paper versions have long since been disposed of. Thus, the EIU may only be able to check sources for items after 1998 but such a process would be time-consuming and unnecessary according to the EIU office, since most of the price entries that appear at first to be errors are actually valid price entries.

Where a user has serious concerns, the EIU recommends removing a price rather than guessing at its original value. For instance, if we suspect that certain prices were simply misinput in error then this price would need to be removed from consideration as an outlier rather than tweaked into something resembling what it "should be". While it is completely valid that a tiny proportion of the reported prices may include errors, the vast majority of prices are arguably valid snapshots at the time of the survey and most prices that vary disproportionately with the CPI can be explained simply by looking at the context in which the prices were taken. Finally, even if all prices that move very differently than the CPI were assumed to be errors, these would represent a proportion below 0.5% of the available data points.

Nominal exchange rate issues

Spot exchange rates are applied to the city data surveyed by the EIU, and are available along with the price data for each year. The post rates are FT rates taken on the Friday of the first week of each month of the survey. For the standard Cityprices data typically made available by the EIU, data overwrites old data each year, thus most of the exchange rate data supplied historically is September data except in a few instances where a city is only surveyed every March in which case prices and exchange rates are from the first week of March. The exchange rate reported is the spot rate for the survey date when the data was gathered.

For pre-1999 price series, the conversion from legacy currencies to euros is made using the appropriate legacy currency, i.e. Ecu exchange rates prevailing at the time. Like Eurostat, the EIU has chosen to use the Ecu exchange rates because there is no universally agreed methodology for calculating a synthetic euro exchange rate. One Ecu was worth exactly one euro when the euro was launched at the beginning of 1999. The EIU used the September end-period rate from Eurostat to convert the legacy prices. Although surveys were completed for Euro cities at slightly different times in September, the EIU applied a standard rate to maintain relative prices between cities and also maintain distances between published Cost of Living indices.

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Table 1: Description of sample: list and classification of goods and locations

List of Countries

Less Developed Countries	More Developed Countries	
Bangladesh	Argentina	Singapore
Brazil	Australia	Spain
China	Austria	Sweden
Colombia	Bahrain	Switzerland
Ecuador	Belgium	Taiwan
Egypt	Canada	UK
Guatemala	Chech Republic	US
India	Chile	
Indonesia	Denmark	
Iran	Finland	
Kenya	France	
Mexico	Germany	
Nigeria	Greece	
Pakistan	Hong Kong	
Panama	Hungary	
Paraguay	Israel	
Peru	Italy	
Philippines	Japan	
Poland	Korea	
Russia	Luxembourg	
Serbia	Malaysia	
South Africa	Netherlands	
Thailand	New Zealand	
Turkey	Norway	
Uruguay	Portugal	
Venezuela	Saudi Arabia	

Notes: Less developed countries have PPP-adjusted income per capita below the world mean ($12000) for 1990–2007.

Table 1: Description of sample: list and classification of goods and locations

List of Cities

In Less Developed Countries	In More Developed Countries		
ASUNCION	ADELAIDE	LOS ANGELES	TOKYO
BANGKOK	AL KHOBAR	LUXEMBOURG	TORONTO
BEIJING	AMSTERDAM	LYON	VANCOUVER
BELGRADE	ATHENS	MADRID	VIENNA
BOGOTA	ATLANTA	MELBOURNE	WASHINGTON DC
CAIRO	AUCKLAND	MIAMI	WELLINGTON
CARACAS	BAHRAIN	MILAN	ZURICH
DHAKA	BARCELONA	MONTREAL	
GUATEMALA CITY	BERLIN	MUNICH	
ISTANBUL	BOSTON	NEW YORK	
JAKARTA	BRISBANE	OSAKA / KOBE	
JOHANNESBURG	BRUSSELS	OSLO	
KARACHI	BUDAPEST	PARIS	
LAGOS	BUENOS AIRES	PERTH	
LIMA	CHICAGO	PITTSBURGH	
MANILA	CLEVELAND	PRAGUE	
MEXICO CITY	COPENHAGEN	RIYADH	
MONTEVIDEO	FRANKFURT	ROME	
MOSCOW	GENEVA	SAN FRANCISCO	
NAIROBI	HAMBURG	SANTIAGO	
NEW DELHI	HELSINKI	SEATTLE	
PANAMA CITY	HONG KONG	SEOUL	
QUITO	HOUSTON	SINGAPORE	
RIO DE JANEIRO	JEDDAH	STOCKHOLM	
SAO PAULO	KUALA LUMPUR	SYDNEY	
TEHRAN	LISBON	TAIPEI	
WARSAW	LONDON	TEL AVIV	

Notes: Less developed countries have PPP-adjusted income per capita below the world mean ($12000) for 1990–2007.

Table 1: Description of sample: list and classification of goods and locations

List of goods: Non traded

Annual premium for car insurance (high)	Laundry (one shirt) (mid-priced outlet)
Annual premium for car insurance (low)	Laundry (one shirt) (standard high-street outlet)
Babysitter's rate per hour (average)	Maid's monthly wages (full time) (average)
Business trip, typical daily cost	Man's haircut (tips included) (average)
Cost of a tune up (but no major repairs) (high)	Moderate hotel, single room, one night including breakfast (average)
Cost of a tune up (but no major repairs) (low)	One drink at bar of first class hotel (average)
Cost of developing 36 colour pictures (average)	One good seat at cinema (average)
Daily local newspaper (average)	Simple meal for one person (average)
Dry cleaning, man's suit (mid-priced outlet)	Taxi rate per additional kilometre (average)
Dry cleaning, man's suit (standard high-street outlet)	Taxi: airport to city centre (average)
Dry cleaning, trousers (mid-priced outlet)	Taxi: initial meter charge (average)
Dry cleaning, trousers (standard high-street outlet)	Three-course dinner at top restaurant for four people (average)
Dry cleaning, woman's dress (mid-priced outlet)	Telephone line, monthly rental (average)
Dry cleaning, woman's dress (standard high-street outlet)	Telephone, charge per local call from home (3 mins) (average)
Electricity, monthly bill for family of four (average)	Two-course meal for two people (average)
Fast food snack: hamburger, fries and drink (average)	Unfurnished residential apartment: 2 bedrooms (high)
Four best seats at cinema (average)	Unfurnished residential apartment: 2 bedrooms (moderate)
Four best seats at theatre or concert (average)	Unfurnished residential apartment: 3 bedrooms (high)
Furnished residential apartment: 1 bedroom (high)	Unfurnished residential apartment: 3 bedrooms (moderate)
Furnished residential apartment: 1 bedroom (moderate)	Unfurnished residential apartment: 4 bedrooms (high)
Furnished residential apartment: 2 bedrooms (high)	Unfurnished residential apartment: 4 bedrooms (moderate)
Furnished residential apartment: 2 bedrooms (moderate)	Unfurnished residential house: 3 bedrooms (high)
Furnished residential house: 3 bedrooms (high)	Unfurnished residential house: 3 bedrooms (moderate)
Furnished residential house: 3 bedrooms (moderate)	Unfurnished residential house: 4 bedrooms (high)
Hilton-type hotel, single room, one night including breakfast (average)	Unfurnished residential house: 4 bedrooms (moderate)
Hire car, weekly rate for lowest price classification (average)	Water, monthly bill for family of four (average)
Hire car, weekly rate for moderate price classification (average)	Woman's cut & blow dry (tips included) (average)
Hourly rate for domestic cleaning help (average)	Yearly road tax or registration fee (high)
Gas, monthly bill for family of four (average)	Yearly road tax or registration fee (low)

Table 1: Description of sample: list and classification of goods and locations

List of goods: Traded

Available at both a supermarket and a mid-priced store

Apples (1 kg)	Flour, white (1 kg)	Peas, canned (250 g)
Aspirins (100 tablets)	Fresh fish (1 kg)	Pork: chops (1 kg)
Bacon (1 kg)	Frozen fish fingers (1 kg)	Pork: loin (1 kg)
Bananas (1 kg)	Frying pan (Teflon or good equivalent)	Potatoes (2 kg)
Batteries (two, size D/LR20)	Gin, Gilbey's or equivalent (700 ml)	Razor blades (five pieces)
Beef: filet mignon (1 kg)	Ground coffee (500 g)	Scotch whisky, six years old (700 ml)
Beef: ground or minced (1 kg)	Ham: whole (1 kg)	Shampoo & conditioner in one (400 ml)
Beef: roast (1 kg)	Hand lotion (125 ml)	Sliced pineapples, canned (500 g)
Beef: steak, entrecote (1 kg)	Insect-killer spray (330 g)	Soap (100 g)
Beef: stewing, shoulder (1 kg)	Instant coffee (125 g)	Spaghetti (1 kg)
Beer, local brand (1 l)	Lamb: chops (1 kg)	Sugar, white (1 kg)
Beer, top quality (330 ml)	Lamb: leg (1 kg)	Tea bags (25 bags)
Butter (500 g)	Lamb: Stewing (1 kg)	Toilet tissue (two rolls)
Carrots (1 kg)	Laundry detergent (3 l)	Tomatoes (1 kg)
Cheese, imported (500 g)	Lemons (1 kg)	Tomatoes, canned (250 g)
Chicken: fresh (1 kg)	Lettuce (one)	Tonic water (200 ml)
Chicken: frozen (1 kg)	Light bulbs (two, 60 watts)	Toothpaste with fluoride (120 g)
Cigarettes, local brand (pack of 20)	Liqueur, Cointreau (700 ml)	Veal: chops (1 kg)
Cigarettes, Marlboro (pack of 20)	Margarine (500g)	Veal: fillet (1 kg)
Coca-Cola (1 l)	Milk, pasteurised (1 l)	Veal: roast (1 kg)
Cocoa (250 g)	Mineral water (1 l)	Vermouth, Martini & Rossi (1 l)
Cognac, French VSOP (700 ml)	Mushrooms (1 kg)	White bread (1 kg)
Cornflakes (375 g)	Olive oil (1 l)	White rice (1 kg)
Dishwashing liquid (750 ml)	Onions (1 kg)	Wine, common table (750 ml)
Drinking chocolate (500 g)	Orange juice (1 l)	Wine, fine quality (750 ml)
Eggs (12)	Oranges (1 kg)	Wine, superior quality (750 ml)
Electric toaster (for two slices)	Peaches, canned (500 g)	Yoghurt, natural (150 g)
Facial tissues (box of 100)	Peanut or corn oil (1 l)	

Table 1: Description of sample: list and classification of goods and locations

List of goods: Traded (continued)

Available at both a chain and mid-priced/branded stores	Available only once
Boy's dress trousers	Compact car (1300-1799 cc) (high)
Boy's jacket, smart	Compact car (1300-1799 cc) (low)
Child's shoes, sportswear	Compact disc album (average)
Child's shoes, dresswear	Deluxe car (2500 cc upwards) (high)
Child's jeans	Deluxe car (2500 cc upwards) (low)
Girl's dress	Family car (1800-2499 cc) (high)
Lipstick (deluxe type)	Family car (1800-2499 cc) (high)
Men's business shirt, white	Family car (1800-2499 cc) (low)
Men's business suit, two piece, medium weight	Heating oil (100 l) (average)
Men's raincoat, Burberry type	International foreign daily newspaper (average)
Men's shoes, business wear	International weekly news magazine (Time) (average)
Socks, wool mixture	Kodak colour film (36 exposures) (average)
Women's cardigan sweater	Low priced car (900-1299 cc) (high)
Women's dress, ready to wear, daytime	Low priced car (900-1299 cc) (low)
Women's raincoat, Burberry type	Paperback novel (at bookstore) (average)
Women's shoes, town	Paperback novel (at bookstore) (average)
Women's tights, panty hose	Pipe tobacco (50 g) (average)
	Regular unleaded petrol (1 l) (average)
	Television, colour (66 cm) (average)

Log-price inflation, π_{ilt}	average	std-dev (ts)	persistence
WHOLE SAMPLE			
Mean	.0141	.1819	−.1317
Median	.0148	.1404	−.0747
95^{th}	.0451	.4318	.4465
5^{th}	−.0135	.0728	−.8938
Std-Dev. (CS)	.0241	.1478	.4190
US			
Mean	.0133	.0615	.2756
Std-Dev. (CS)	.0181	.1095	.3697

Table 2: Cross-section distribution of log price average inflation, time-variance and persistence. Prices are expressed in USD. The sample covers 88 cities in 59 countries and 276 goods over the 1990S1–2010S1 period. The columns report the cross section distribution of good items i in the locations l for the time average of the inflation rate $E(\pi_{ilt}|il)$ (AVERAGE), the standard deviation of the inflation rate $\sigma(\pi_{ilt}|il)$ (STD-DEV), and the persistence of the inflation rate as measured by the sum of dynamic coefficients of a fitted AR(4) model $\rho_{il}(1) = \sum_{h=1}^{4} \rho_{il,h}$ (PERSISTENCE).

Log-price inflation, π_{ilt}	average	std-dev (ts)	share in variance	persistence	conv. speed
Global macro component					
	.0142	.0420	.0326	.4178	.3953
Global micro component					
Mean	.0000	.0376	.2209	.1042	.5743
Median	.0010	.0206		.1214	
95^{th}	.0127	.0905		.7117	
5^{th}	−.0099	.0137		−.6300	
Std-Dev. (CS)	.0172	.1027		.3980	
Local macro component					
Mean	.0000	.0841	.2401	−.1394	.7035
Median	−.0001	.0606		−.0994	
95^{th}	.0136	.1955		.7547	
5^{th}	−.0115	.0396		−.8969	
Std-Dev. (CS)	.0095	.0770		.5190	
Local micro component					
Mean	.0000	.1334	.5006	−.2832	.7977
Median	.0000	.1098		−.1940	
95^{th}	.0221	.3028		.5736	
5^{th}	−.0218	.0410		−1.4401	
Std-Dev. (CS)	.0136	.0965		.6534	

Table 3: Cross-sectional distribution of the average inflation, time-variance and persistence of each of the four components in international prices.

Prices are expressed in USD. The sample covers 59 countries and 276 goods over the 1990S1–2010S1 period. The four components of prices are estimated as decribed in Section 3. For each of the four components of individual inflation rates π_{ilt}, the columns report the cross-sectional distribution of the time average, the standard deviation (STD-DEV) over the period, and the persistence as measured by the sum of dynamic coefficients of a fitted AR(4) model $\rho_{il}(1) = \sum_{h=1}^{4} \rho_{il,h}$ (PERSISTENCE). In addition, the third column reports the share of total variance of inflation attributed to each component, $E[\sigma^2(\pi_{ilt}|il)]$, and the last column reports the convergence speed implied by our measure of persistence.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
PERSISTENCE of								
Global macro component								
	.4178	.4178	.3486	−.0112	.4178	.4178	.4178	.5978
Global micro component								
Mean	.1056	.1056	.1484	.1381	.1502	.1718	.1061	.1607
Std-Dev (CS)	.3986	.3986	.3912	.3954	.3968	.3386	.3965	1.4494
Local macro component								
Mean	−.1439	−.1474	−.1847	−.1692	−.1405	−.1440	−.1042	−.1412
Std-Dev (CS)	.5993	.6009	.4076	.6153	.5308	.5067	.5139	.4799
Local micro component								
Mean	−.2987	−.3004	−.2333	−.2573	−.1903	−.2675	−.3120	−.3167
Std-Dev (CS)	.6683	.6665	.6220	.6462	.6395	.6347	.6525	.7318
SPECIFICATION								
Currency unit	USD	USD	STG	JPY	USD	USD	USD	USD
# Locations	49	49	59	59	59	59	88	59
# Goods	278	278	278	278	178	100	278	278
Sample period	1990S1-2010S1	1990S1-2010S1	1990S1-2010S1	1990S1-2010S1	1990S1-2010S1	1990S1-2010S1	1990S1-2010S1	1990S1-2008S1

Table 4: Robustness checks: Cross-section distribution of persistence under various specifications. The table reports the persistence of the four components in prices when considering several modifications to the baseline case. Column (1): the sample is made of 49 countries, with euro area members other than Germany excluded. Column (2): the sample is made of 49 countries, taking the average across euro area members. Column (3): prices are converted into sterling pound. Column (4): prices are converted into Japanese Yen. Column (5): prices of items observed in different types of stores in the same location are averaged. Column (6): the sample of goods is limited to averaged prices of items observed for more than one type of store in the same location. Column (7): the analysis is conducted at the city level. Column (8): the analysis is conducted over the pre-crisis sample.

Log-price inflation, π_{ilt}			
	average	std-dev (ts)	persistence
US			
Local macro component			
	−.0005	.0406	.3466
Local micro component			
Mean	-.0001	.0420	−.2376
Std-Dev. (CS)	.0059	.0241	.6289
US			
Macro component			
	.0137	.0175	.8058
Micro component			
Mean	−.0003	.0588	−.0513
Std-Dev. (CS)	.0181	.1097	.4033
WHOLE SAMPLE			
Macro component			
Mean	.0141	.0962	−.0185
Std-Dev. (CS)	.0095	.0756	.3845
Micro component			
Mean	.0000	.1446	−.1838
Std-Dev. (CS)	.0222	.1365	.5178

Table 5: Cross-section distribution of price inflation, time-variance and persistence of the macro and micro components in international prices.

Prices are expressed in USD. The sample covers 59 countries and 276 goods over the 1990S1–2010S1 period. The columns report the cross section distribution of the time average, the standard deviation (STD-DEV), and the persistence as measured by the sum of dynamic coefficients of a fitted AR(4) model $\rho_{il}(1) = \sum_{h=1}^{4} \rho_{il,h}$ (PERSISTENCE) of various micro price components both for the US and for the whole sample of 59 countries. Local macro and micro components are estimated as described in Section 3. Macro and micro components subsume both local and global factors and are estimated as described in Section 5.