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KÓLVER HERNÁNDEZ AND ASLI LEBLEBICIOGLU

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Abstract

We investigate the stability of the pricing policies of exporters. This includes the stability in the exchange rate pass-through coefficient as well as the stability in the response to variables that affect the firm's markup. The model assumes that in every period exporters set prices by following either a "high pass-through" or a "low pass-through" pricing policy. The transition from one policy to the other is governed by a Markov process whose transition probabilities depend on economic fundamentals. For the choice of the economic fundamentals we rely on the theoretical literature on determinants of the optimal choice of the exchange rate pass-through. We estimate the model using collected data on 35 lines of imported cars to the US from seven exporting countries for the 1980-2004 period. Our estimations suggest that the "low passthrough" regime is characterized by: a low exchange rate pass-through; a low response to misalignments in the firm's relative price; a low volatility of technology and preference shocks; and a higher duration than the high pass-through regime. We identify three significant factors behind the switching of pricing policies: the US inflation relative to that of the exporter country, the volatility of the exchange rate and the market concentration. Everything else constant, the inflation differential explains abut 20% of the year-to-year variations in the exchange rate pass-through coefficient; the volatility of the exchange rate explains 36% and the market concentration about 38%.

Resumen

Investigamos la estabilidad de las políticas de precios de exportadores. Esto incluye estabilidad en la elasticidad del precio en el mercado importador con respecto al tipo de cambio, así como estabilidad en otras elasticidades que afectan el margen de ganancias. El modelo supone que en cada periodo el exportador fija sus precios siguiendo ya sea una política de precios con una elasticidad de tipo de cambio "alta", o bien, "baja". La transición de una política de precios a la otra esta gobernada por un proceso Markov cuya matriz de probabilidades transicionales dependen de los fundamentos económicos sugeridos por la literatura teórica. Estimamos el modelo usando datos de 35 modelos de autos importados por Estados Unidos de siete países exportadores en el periodo 1980-2004. Nuestras estimaciones sugieren que el régimen de elasticidad "baja" está caracterizado por: una elasticidad baja con respecto al tipo de cambio; una baja respuesta del precio del exportador a cambios en precios relativos; baja volatildad de choques tecnológicos y de preferencias; y una duración mayor que el régimen de elasticidad "alta". Identificamos tres factores significantes

detrás de cambios en régimen: la inflación de Estados Unidos con respecto a la del país exportador, la volatidad del tipo de cambio y la concentración del mercado. Todo lo demás constante, los diferenciales de inflación entre países explican el 20% de las variaciones anuales en la elasticidad promedio con respecto al tipo de cambio; la volatilidad del tipo de cambio explica el 36% y la concentación del mercado el 38%.

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Kólver Hernández
CIDE & University of Delaware

Aslı Leblebicioğlu
North Carolina State University

This Draft: February 2008

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1 Introduction

There is a growing body of empirical literature that documents a decline in the exchange rate pass-through elasticity in various industries and for a number of countries—Campa and Goldberg (2005) for OECD countries, Frankel, Parsley and Wei (2005) for several developing countries, Ihrig et al. (2006) for G-7 countries, and Marazzi and Sheets (2007) for the US economy. While the important implications of the decline in the pass-through for adjustments of external imbalances and monetary policy can be drawn from the theoretical literature, the sources of the instability in the pass-through elasticity are not fully established by the empirical literature.

Theoretical studies suggest a number of economic fundamentals that determine an exporting firm's optimal degree of exchange rate pass-through[1]; while some of the studies focus on product or industry specific characteristics, others highlight the role of macroeconomic conditions. Some of the product and/or industry specific factors that have been studied are substitutability of the export good—e.g., Giovannini (1988), Donnenfeld and Zilcha (1991), Friberg (1998), Goldberg and Tille (2005)—, strategic complementar-

[1]The two theoretical polar cases of exchange rate pass-through are producer currency pricing (PCP) and local currency pricing (LCP). If all exporting firms choose set their prices in their home currencies (PCP) and prices are preset, then they will be passing on all the fluctuations in the exchange rates onto the consumers; therefore, the pass-through will be complete. If, on the other hand, all the firms choose the importing country's currency (LCP), then there will be no pass-through.

ities and the market share of the exporting country—e.g., Feenstra, Gagnon and Knetter (1996), Bacchetta and van Wincoop (2005). Monetary stability has been identified among the macroeconomic indicators that are important for the degree of pass-through—Taylor (2000), Devereux, Engel and Storgaard (2004). As one or more of these factors vary across time for different exporters, the pricing policies of exports can change, which in turn would affect the degree of exchange rate pass-through.

The aim of this paper is to empirically investigate the economic factors that affect the stability of the pricing policies of exporters. This includes the stability in the exchange rate pass-through coefficient as well as the stability in the response to variables that affect the firm's markup. We do so in a panel dataset of U.S. automobile imports. The challenge in disentangling different factors behind the degree of exchange rate pass-through is that the pricing policies of exporters are unobservable and they may change along with economic factors. One needs to build inferences not only about the optimal pricing rules that exporters follow, but also about the underlying economic fundamentals that can affect the choice of the pricing rule itself[2]. For that

[2]For example, Devereux et al. (2004) show that when faced with the choice of PCP versus LCP, a profit-maximizer exporter optimally chooses PCP if the variance of the exchange rate exceeds by two times the covariance between the exchange rate and the marginal cost. Otherwise the exporter chooses LCP. Thus in this example the optimal pricing policy of one single firm may change as the volatility of the exchange rate changes. Of course, in a general equilibrium model the firm's choice has a feedback effect in the exchange rate; however, we consider this partial equilibrium rationale appropriate for our empirical work since the feedback effects of automobile exporters in the US economy may be considered negligible.

reason we consider that the appropriate econometric framework is the hidden regime switching methodology popularized by Hamilton (1990, 1994) and its later extension by Diebold, Lee and Weinbach (1994) to build inferences about the underlying fundamentals along with the pricing decisions.

We start by theoretically formulating the optimal export pricing decision of a firm under exchange rate uncertainty. One important implication that comes out of our formulation is that, keeping everything else constant, the degree of exchange rate pass-through affects other variables in the pricing policy. Allowing for strategic complementarities, the degree of exchange rate pass-through can affect the marginal cost pass-through in addition it can affect the sensitivity to changes in the competitors prices. Hence, instead of focusing only on the potential changes of the pass-through parameter, we investigate the stability of the export pricing policies of the foreign automobile manufacturers.

The empirical model assumes that in every period exporters set prices by following either a "high pass-through" or a "low pass-through" pricing policy. The transition from one policy to the other is governed by a Markov process whose transition probabilities depend on economic fundamentals; for the choice of the economic fundamentals we rely on the theoretical literature on determinants of the optimal choice of the exchange rate pass-through. The actual state of the firm is unobservable: we only observe the actual price, but do not observe the pricing regime that it comes from. Nevertheless, we can estimate the probability of being in one regime versus the other along with the pricing equations by closely following[3] Diebold, Lee and Weinbach's (1994) methodology. The estimated probabilities show which factors are significant in determining the degree of pass-through. Furthermore, analyzing the trends in those factors, we investigate the role of each of the factors in the decline of the exchange rate pass-through.

Our dataset consists of 35 automobile models from 7 exporting countries for the 1980-2004 period. For each automobile we observe the manufacturer's suggested retail price, the number of units imported into the US, physical characteristics of the car and the location of the assembling plant of the units sold in the US. The manufacturer's suggested retail price is at the port of entry, thus the exchange rate pass-through coefficients we estimate are the at-the-dock rates[4]; the manufacture's suggested retail prices are net of any retail or transportation cost that may be affected by domestic components and, different from dealer's prices, the suggested retail price does not include variations due to discriminatory practices—Goldberg (1996).

Our estimations suggest that the "low pass-through" regime is charac-

[3]However we differ in some aspects, for example we adapt their time-series methodology to our panel dataset. This and other differences are detailed below.

[4]The percentage of exchange rate fluctuations that the exporters choose to transmit is interpreted as the pass-through "at the dock". The exchange rate pass-through to the final consumption goods depend also on local costs. See, for example, Burnstein, Neves and Rebelo (2003) and Corsetti and Dedola (2004).

terized by: a low exchange rate pass-through; a low response to misalignments in the firm's relative price; a low volatility of technology and preference shocks; and a higher duration than the high pass-through regime. These findings are robust to including different variables in the transition probabilities.

We identify three significant factors behind the switching of pricing policies: the US inflation relative to that of the exporter country, the volatility of the exchange rate and the market concentration (measured by the Herfindahl index of the industry). Using the conditional probabilities estimated we build inferences about the fraction of firms in the low pass-through regime for each year in our sample; thus we build an inference on the average degree of the exchange rate pass-through. We find that, everything else constant, the cross-country inflation differential explains abut 20% of the year-to-year variations in the exchange rate pass-through coefficient; the volatility of the exchange rate explains 36% and the market concentration about 38%. In a five-year horizon the percentage due to market concentration falls to 28% whereas the percentage due to exchange rate volatility increases to 48% and the the percentage due to inflation remains the same.

The paper is organized as follows: next section develops the theoretical export pricing equation we use in our estimations. Section 3 presents the empirical methodology we use. Section 4 describes the sources of our data and talks about the variables that we construct. Results are presented and interpreted in Section 5. Exchange rate pass-through dynamics and its decomposition are discussed in Section 6. Finally, conclusions are presented in Section 7.

2 Pricing of Exports

The aim of this section is to develop an optimal pricing equation for our empirical framework and to highlight the notion that the changes in the degree of exchange rate pass-through can also imply changes in other parameters of the pricing policy, thus motivating our choice of the regime switching framework.

Assume that there is a continuum of foreign and domestic firms selling to the US market in a monopolistically competitive fashion. Focus on the pricing problem of a single foreign firm. The typical foreign firm presets its product's price one period before its product is sold to the US consumer; next, in the period that the product is sold, the producer *partially adjusts* its preset price with the observed exchange rate.

Formally, let $\mathbb{L}_t$ be the set of firms in the US market and let $\ell \in \mathbb{L}_t$, be the index of a typical foreign firm. [5] At time $t-1$ the foreign firm z optimally chooses the price for the product that will be sold at time t, $p^*_{\ell t}$, denominated in the producer's own currency; then in period t the price is converted to US dollars using the following transformation:

$$p_{\ell t} = \left(e_t\right)^{\delta} p^*_{\ell t}, \tag{1}$$

[5] Note that, in the spirit of Feenstra (1994), we allow for changes in the mass (i.e. the number) of varieties in the market.

where $p_{\ell t}$ is the price in US dollars that the consumer faces in the US market, e_t is the nominal exchange rate, and the parameter $\delta \in [0, 1]$ measures the degree of exchange rate pass-through in the export prices. Note that $\delta = 0$ implies that the firm does not incorporate in its price any of the information in the exchange rate observed at t; that is there is zero pass-through. However as it will become clear later, when $\delta = 0$ the foreign firm base its price for the US market p_t only on its exchange rate expectations $E_{t-1}e_t$. On the contrary, when $\delta = 1$ the

is setting the export price in US dollars, hence is using local currency pricing (LCP); and $\delta = 1$ implies that the firm is using producer currency pricing (PCP). Thus, our pricing specification contains as special cases the two pricing schemes often used in the literature: LCP and PCP.

Assume that the demand for the good ℓ produced by the firm i is a function of its relative price $p_{\ell t}/P_{\mathbb{L}t}$, where $P_{\mathbb{L}t}$ is the price index of the industry, as well as a function of a vector of variables $\underline{Y}_{\ell t}$ such as consumer's income or consumer's preference shocks—thus not all elements in the vector $\underline{Y}_{\ell t}$ are line or firm specific. Let

$$Q\left(\frac{p_{\ell t}}{P_{\mathbb{L}t}}; \underline{Y}_{\ell t}\right) \tag{2}$$

be the demand function, and let $\eta\left(\frac{p_{\ell t}}{P_{\mathbb{L}t}}; \underline{Y}_{\ell t}\right) \equiv -\frac{\partial Q(\cdot)}{\partial p_{\ell t}} \frac{p_{\ell t}}{Q(\cdot)} > 0$ be the price elasticity of demand. The production technology exhibits constant returns to scale.

In absence of technology shocks, the real marginal cost is $\frac{\psi^*_{\ell t}}{P^*_t}$, where $\psi^*_{\ell t}$ is the nominal marginal cost denominated in foreign currency and P^*_t is the price index of the foreign consumption basket; however we allow for exogenous technology shocks $Z^*_{\ell t}$ that may disturb production costs; thus the effective real marginal cost is $\frac{\psi^*_{\ell t}}{P^*_t}\frac{1}{Z^*_{\ell t}}$. The producer chooses $p^*_{\ell t}$ to maximize expected real profits subject to the transformation (1) and the demand function (2). Thus the producer maximizes:

$$\mathbb{E}_{t-1}\frac{\Upsilon_t}{P^*_t}\left\{\frac{p_{\ell t}}{e_t}Q\left(\frac{p_{\ell t}}{P_{\mathbb{L}t}};\underline{Y}_{\ell t}\right)-\frac{\psi^*_{\ell t}}{Z^*_{\ell t}}Q\left(\frac{p_{\ell t}}{P_{\mathbb{L}t}};\underline{Y}_{\ell t}\right)\right\},$$

where Υ_t is the relevant stochastic discount factor between $t-1$ and t.

To obtain a log-linear approximation of the model let $\hat{x}_t \equiv \frac{dx_t}{\bar{x}}$ denote the deviations of the variable x_t from its steady-state $\bar{x}$. Thus, a log-linear approximation of the first-order condition, around the steady-state, yields[6]

$$\hat{p}_{\ell t} = \delta\left\{\hat{e}_t - \mathbb{E}_{t-1}\hat{e}_t\right\} + \mathbb{E}_{t-1}\left\{\hat{\psi}^*_{\ell t} + \hat{e}_t - \hat{Z}^*_{\ell t}\right\} + \mathbb{E}_{t-1}\left\{\hat{\Phi}_{\ell t}\right\}, \tag{3}$$

where

$$\hat{\Phi}_{\ell t} \equiv -\frac{1}{\bar{\eta}-1}\hat{\eta}_{\ell t},$$

and $\bar{\eta} \equiv \eta(\cdot)|_{ss} > 1$ is the price elasticity evaluated at steady-state values.

[6]The first-order condition implies $\mathbb{E}_{t-1}\left\{\frac{\Upsilon_t}{P^*_t}(e_t)^{\delta-1}Q(\cdot)\left[\eta(\cdot)-1\right]\right\} = \mathbb{E}_{t-1}\left\{\frac{\Upsilon_t}{P^*_t}\frac{\psi^*_{\ell t}}{Z^*_{\ell t}}\eta(\cdot)Q(\cdot)\Big/p^*_{\ell t}\right\}$; moreover, in absence of uncertainty we obtain the well known condition $p_{\ell t} = \frac{\eta(\cdot)}{\eta(\cdot)-1}\psi^*_{\ell t}e_t$.

Thus, the exporter's optimal price denominated in dollars can be decomposed in three components. The first term in (3) captures the exchange rate surprise that the producer passes to its price, i.e. δ captures the degree of exchange rate pass-through. The second term, is the expected marginal cost in terms of dollars. The third term, $\hat{\Phi}_{\ell t}$, captures the demand-side effects that may affect the gap between the firm's price and its marginal cost in dollar terms; thus, we refer to $\hat{\Phi}_{\ell t}$ as the firm's markup. In turn, the markup is a decreasing function of the price elasticity.

Different functional forms for the utility function will imply different determinants for the mark-up term. Three notable utility specifications often used in the related literature are the Dixit-Stiglitz aggregator, the Dotsey-King aggregator and the translog utility index. The utility index proposed in Dixit and Stiglitz (1977) delivers a CES demand with constant markup; thus $\hat{\Phi}_{\ell t} = 0 \ \forall t$.[7] The latter two utility specifications deliver time varying markups. Both under the Dotsey and King (2005) aggregator (which builds on Kimball (1995)), and the translog utility index proposed in Feenstra (1994), the price elasticity of demand is a function of the firm's price and the price of competitors. Hence, the optimal price in those settings respond to the

[7]Note that this feature does not depend on our assumption of one-period-ahead preset prices, for example, assuming Calvo pricing and a CES demand we can show that the optimal price, up to a first-order approximation, only depends on the current and expected marginal costs. Actually, the Dixit-Stiglitz aggregator is widely adopted in macroeconomic models of the business cycle precisely for its tractability.

marginal cost, the exchange rate and the price of competitors summarized by the price index of the industry.[8]

Note that in our general specification, the markup is a function of the firm's relative price $\frac{p_{\ell t}}{P_{\mathbb{L}t}}$ and other determinants of demand summarized in the vector $\underline{Y}_{\ell t}$; thus the optimal price also accounts for the expected impact in the firm's markup due to changes in the firm's relative price. We make this explicit by using a log-linear approximation of the markup together with equation (3) to obtain a first-order approximation of the optimal price: [9]

$$\hat{p}_{\ell t} = \delta \hat{s}_t + \frac{1}{1+\kappa(\delta)} \mathbb{E}_{t-1}\{\hat{\psi}_{\ell t} - \hat{Z}^*_{\ell t}\} + \frac{\kappa(\delta)}{1+\kappa(\delta)} \mathbb{E}_{t-1}\{\hat{P}_{\mathbb{L}t}\} + \frac{\chi(\delta)}{1+\kappa(\delta)} \mathbb{E}_{t-1}\{\hat{\underline{Y}}_{\ell t}\} \quad (4)$$

where

$$\hat{s}_t = \hat{e}_t - \mathbb{E}_{t-1}\hat{e}_t$$

is the exchange rate surprise, and

$$\hat{\psi}_{\ell t} \equiv \hat{\psi}^*_{\ell t} + \hat{e}_t,$$

[8] Devereux, Engel and Storgaard (2004) use a Dixit-Stiglitz aggregator in a model of the endogenous choice of exchange rate pass-through. Gust, Leduc and Vigfusson (2006) use a Dotsey-King aggregator in a model that shows that trade integration produces a decline in the exchange rate pass-through. Using a translog utility index Feenstra (1996) shows that there is a non-linear relation between pass-through and the market share—market share of source country.

[9] Note that $\hat{\Phi}_{\ell t} = -\kappa\{\hat{p}^*_{\ell t} + \delta \hat{e}_t - \hat{P}_{\mathbb{L}t}\} + \hat{\underline{Y}}'_{\ell t}\chi$, where $\chi \equiv -\frac{\partial \eta(\cdot)}{\partial \underline{Y}_{\ell t}}\Big|_{ss} \frac{\bar{X}}{\bar{\eta}(\bar{\eta}-1)}$ and $\frac{\partial \eta(\cdot)}{\partial \underline{Y}_{\ell t}}$ is a column vector of derivatives of the price-elasticity with respect to the vector $\underline{Y}_{\ell t}$.

is the exchange-rate-adjusted nominal marginal cost. $\kappa(\delta) \equiv \frac{\bar{\eta}_1}{\bar{\eta}(\bar{\eta}-1)} \frac{\bar{e}^{\delta} \bar{p}^*(z)}{\bar{P}^L}$ makes explicit that the coefficient is a function of the exchange rate pass-through where $\bar{\eta}_1 \equiv \frac{\partial \eta(\cdot)}{\partial(p_t(z)/P_t^L)}\big|_{ss}$, $\chi(\delta) \equiv -\frac{\partial \eta(\cdot)}{\partial \underline{Y}_{\ell t}}\big|_{ss} \frac{\bar{X}}{\bar{\eta}(\bar{\eta}-1)}$ is a column vector of parameter values[10], and the upper bar indicates that the functions are evaluated at steady-state values.

In order to have a positive marginal cost pass-through coefficient we must constrain $\kappa(\delta) > -1$. Moreover, for prices to be strategic complements in the sense that the optimal price increases when the average price of competitors increases[11], as in Bergin and Feenstra (1999), we further require $\kappa(\delta) > 0$. In turn, $\kappa(\delta) > 0$ requires $\bar{\eta}_1 > 0$, that is, as in Dotsey and King (2005) or Gust, Leduc and Vigfusson (2006), in steady-state, the price elasticity must be increasing in the firm's relative price.

Equation (4) makes transparent that the instability of the exchange rate pass-through parameter can bring instability to other parameters of the price equation.[12] The optimal pricing implies that the degree of the exchange rate pass-through also can affect the marginal cost pass-through and the sensitivity of the firm's mark-up to the average price of the competitors. Thus, this theoretical framework points towards an empirical setting general enough to

[10]Recall that $\hat{\underline{Y}}_{\ell t}$ is a column vector of variables.
[11]See Bratsiotis (2007) and references therein.
[12]Note that in the special case of a CES demand $\kappa(\delta) = \chi(\delta) = 0$, thus in that special case the instability of the exchange rate pass-through can be studied in isolation, as in Devereux et al. (2004).

jointly analyze the stability of the exchange rate pass-through coefficient together with the stability of other parameters, given the decision rules for the choice of degree of pass-through. The regime switching model presented in the following section provides a useful framework for analyzing the stability of all the components of pricing decisions as well as the underlying decision factors.

3 A Regime Switching Model of Price Setting and its Estimation

3.1 Empirical Framework

We use the optimal pricing policy (4) as our benchmark to build an empirical framework. We assume that in each period t the foreign firm ℓ is subject to a random shock $\xi_{\ell t} \in \{0, 1\}$ that follows a two-state first-order Markov process. The random shock $\xi_{\ell t}$ triggers one of the two different sets of parameter values in the optimal pricing policy (4): $\{\delta_{\xi_{\ell t}}, \kappa(\delta_{\xi_{\ell t}}), \chi(\delta_{\xi_{\ell t}})\}$, and hence determines the pricing regime. We refer to the two pricing policies resulting from those sets of parameters as the "high pass-through" pricing regime and the "low pass-through" pricing regime. The actual state of the firm ℓ is unobservable to the econometrician, she only observes the actual price but does not observe the pricing regime it comes from. It is worth mentioning that our assumption of a first-order Markov process for $\xi_{\ell t}$, implies history dependence in the adoption of a particular pricing policy. Thus, estimates of the transition probability matrix of the Markov process provide estimates of the degree of persistence or stickiness of the high (low) pass-through pricing regime.

Accordingly, based on (4), we model observed changes in the optimal price denominated in dollars of the variety ℓ, $\Delta\hat{p}_{\ell t} \equiv \hat{p}_{\ell t} - \hat{p}_{\ell t-1}$, as:

$$\Delta\hat{p}_{\ell t} = \beta^{s}_{\xi_t}\Delta\hat{s}_t + \beta^{\psi}_{\xi_t}\Delta\hat{\psi}_{\ell t} + \beta^{P_{\mathbb{L}}}_{\xi_t}\Delta\hat{P}_{\mathbb{L}t} + \Delta\hat{Y}'_{\ell t}\beta^{y}_{\xi_t} + \varepsilon_{\xi_{\ell t}} \tag{5}$$

where $\Delta\hat{s}_t$ is a proxy for the change in the exchange rate surprise; $\Delta\hat{\psi}_{\ell t}$ is a proxy for the expected change in the exchange-rate-adjusted nominal marginal cost; $\Delta\hat{P}_{\mathbb{L}t}$ is a proxy for the expected change in the average price of the competitors; and $\Delta\hat{Y}_{\ell t}$ is a column vector of proxies for expected changes in other variables that may affect the firm's markup.[13] Section 4 describes in detail how we construct the variables utilized in our estimations.

The error term $\varepsilon_{\xi_{\ell t}}$ follows a standard normal distribution, $\varepsilon_t \sim i.i.d.\mathfrak{F}(0, \sigma^2_{\xi_{\ell t}})$. Note that the error term $\varepsilon_{\xi_{\ell t}}$ contains unobservable technology shocks, $\hat{Z}^*_{\ell t}$ in equation (4), as well as unobservable demand shocks or preference shocks for which we cannot control for in the vector $\Delta\hat{Y}_{\ell t}$. Hence, we can only identify the variance $\sigma^2_{\xi_{\ell t}}$ as the variance of an aggregate of both, technology and preference shocks.

Following Diebold, Lee and Weinbach (1994), we assume that the transition probability matrix that governs the two-state Markov process $\xi_{\ell t} \in \{0, 1\}$

[13] For example we include fixed effects, oil price shocks and disposable income in the US in $\Delta\hat{Y}_{\ell t}$.

contains the following elements:

$$\begin{aligned}
g_{\ell t}^{00} &\equiv \Pr(\xi_{\ell t}=0|\xi_{\ell t-1}=0)=\mathfrak{B}(\underline{z}_{\ell t-1}'\phi_0),\\
g_{\ell t}^{11} &\equiv \Pr(\xi_{\ell t}=1|\xi_{\ell t-1}=1)=\mathfrak{B}(\underline{z}_{\ell t-1}'\phi_1),\\
g_{\ell t}^{01} &\equiv \Pr(\xi_{\ell t}=0|\xi_{\ell t-1}=1)=1-g_{\ell t}^{11},\\
g_{\ell t}^{10} &\equiv \Pr(\xi_{\ell t}=1|\xi_{\ell t-1}=0)=1-g_{\ell t}^{00}
\end{aligned} \tag{6}$$

where $\mathfrak{B}(x)=\frac{\exp(x)}{1+\exp(x)}$ is the logistic function, $\underline{z}_{\ell t}$ is a vector of economic variables that determine the transition probabilities, and ϕs are vectors of parameters to estimate. We choose the determinants of the transition probabilities, $z_{\ell t}$, based on the theories on optimal choice of the exchange rate pass-through and optimal choice of the currency denomination of exports. When $\underline{z}_{\ell t}=1\ \forall t$, the model boils down to the model of Hamilton (1991) with constant transition probabilities.

3.2 The Log-likelihood Function and Its Estimation

We jointly estimate the parameters in equations (5) and (6) by following closely the EM algorithm proposed by Diebold, Lee and Weinbach (1994). Let $\beta_0=\left[\beta_0^{e}\ \beta_0^{\psi}\ \beta_0^{P_{\mathbb{L}}}\ \beta_0^{y'}\ \right]'$, $\beta_1=\left[\beta_1^{e}\ \beta_1^{\psi}\ \beta_1^{P_{\mathbb{L}}}\ \beta_1^{y'}\ \right]'$, and $\theta=\left[\beta_0'\ \sigma_0\ \phi_0'\ \beta_1'\ \sigma_1\ \phi_1'\ \right]'$. Let $\mathbb{I}_{\ell t}^{0}$ be the indicator function equal to one if $\xi_{\ell t}=0$ and zero otherwise (independent of $\xi_{\ell t-1}$); also let $\mathbb{I}_{\ell t}^{00}$ be the indicator function equal to one if

$\xi_{\ell t-1} = 0$ and $\xi_{\ell t} = 0$ and zero otherwise. Similarly let $\mathbb{I}^{11}_{\ell t}$ be equal to one if $\xi_{\ell t-1} = 1$ and $\xi_{\ell t} = 1$ and zero otherwise. As a result, we also have $\mathbb{I}^{10}_{\ell t} = 1 - \mathbb{I}^{00}_{\ell t}$ and $\mathbb{I}^{01}_{\ell t} = 1 - \mathbb{I}^{11}_{\ell t}$.

To simplify the notation below, let $y_{\ell t} \equiv \Delta\hat{p}_{\ell t}$ be the dependent variable in the price equation; let $X_{\ell t} = \left[\Delta\hat{s}_t \; \Delta\hat{\psi}_{\ell t} \; \Delta\hat{P}_{\mathbb{L}t} \; \Delta\hat{Y}'_{\ell t}\right]'$ be the vector of explanatory variables at t in the pricing equation. Further, denote $\underline{m}_\tau$ to be a $\tau \times 1$ vector of observations of the corresponding variable m for $t = 1, \dots \tau$. Thus $\underline{y}_{\ell T}$ is the vector with T observations of our dependent variable, $\underline{X}_{\ell T}$ is the matrix of explanatory variables in the pricing equation (5), and $\underline{Z}_{\ell T}$ is the matrix of variables in the probability equations (6). Hence, the matrices $\underline{y}_{\ell T}$, $\underline{X}_{\ell T}$ and $\underline{Z}_{\ell T}$ represent our data after the appropriate transformations (see Section 4).

The contribution of the unit ℓ to the complete-data likelihood function is:[14]

$$\begin{aligned} L_\ell\left(\underline{y}_{\ell T}, \underline{\xi}_{\ell T}, |\underline{X}_{\ell T}, \underline{X}_{\ell T}, \underline{Z}_{\ell T}; \theta\right) &= \prod_{t=1}^{T} \mathfrak{F}\big(y_{\ell t}, \xi_{\ell t} | \underline{y}_{\ell t-1}, \underline{\xi}_{\ell t-1}, \underline{X}_{\ell T}, \underline{z}_{\ell T}; \theta\big) \\ &= \prod_{t=1}^{T} \mathfrak{F}\big(y_{\ell t} | \xi_{\ell t}, \underline{X}_{\ell T}; \beta_0, \beta_1, \sigma_0, \sigma_1\big) \Pr(\xi_t | \xi_{t-1}, z_{t-1}; \phi_0, \phi_1) \end{aligned}$$

[14]It is complete-data likelihood function in the sense that ξ_ℓ is observable, so as the data in all possible states. Of course, the econometrician only observes the prices $\hat{p}_{\ell t}$, and she has to make an inference about the state $\xi_{\ell t}$.

where

$$\mathfrak{F}\left(y_{\ell t}|\xi_{\ell t}=i,\underline{X}_{\ell T};\beta_i,\sigma_i\right)=\frac{1}{\sqrt{2\pi\sigma_i^2}}\exp\left(\frac{-\left(y_{\ell t}-X'_{\ell t}\beta_i\right)^2}{2\sigma_i^2}\right)$$

for $i = 0, 1$.

We can conveniently write the contribution of the unit ℓ to the complete-data log-likelihood function in terms of the indicator function as:

$$\begin{aligned}\log L_\ell\left(\underline{y}_{\ell T},\underline{\xi}_{\ell T},|\underline{X}_{\ell T},\underline{Z}_{\ell T};\theta\right)=\sum_{t=1}^{T}\Big\{&\mathbb{I}^0\log\mathfrak{F}\left(y_{\ell t}|\xi_{\ell t}=0,\underline{X}_T;\beta_0\right)\\&+[1-\mathbb{I}^0]\log\mathfrak{F}\left(y_{\ell t}|\xi_{\ell t}=1,\underline{X}_T;\beta_1\right)+\mathbb{I}^{00}\log g_{\ell t}^{00}+\mathbb{I}^{10}\log(1-g_{\ell t}^{00})\\&+\mathbb{I}^{11}\log g_{\ell t}^{11}+\mathbb{I}^{01}\log(1-g_{\ell t}^{11})\Big\}\end{aligned}$$

Assuming that the Markov processes ξ_ℓ are independent across units ℓ, we can write the complete-data log-likelihood function for the of $\mathbb{L}^*$ automobile lines as:

$$\log L\left(\underline{y}_T,\underline{\xi}_T,|\underline{X}_T,\underline{Z}_T;\theta\right)=\sum_{\ell=1}^{\mathbb{L}*}\log L_\ell\left(\underline{y}_{\ell T},\underline{\xi}_{\ell T},|\underline{X}_{\ell T},\underline{Z}_{\ell T};\theta\right).$$

Since the states that the data comes from are unobservable, it is not feasible to construct the complete-data log-likelihood function. For models with unobservable data or variables, the EM algorithm is often employed in order to maximize the incomplete-data log-likelihood function. The EM algorithm is a two-step iterative procedure to maximize the expected complete-data log-likelihood function conditional upon the observed data. It is initiated by assigning initial probabilities for being in each state. In the first step (the *expectation* step), conditional on the initial guess, inferences on $\xi_{\ell t}$ are obtained using all the information in the sample. These inferences are called the smoothed probabilities. Then, in the second step (*maximization),* the expected complete-data log likelihood is maximized with respect to the parameters of the model. The procedure is iterated until θ converges. See Diebold, Lee and Weinbach (1994) for a detailed description of the EM procedure and the Appendix for our implementation. Once the estimates of θ are obtained, we can make inferences about the regime that was more likely to have been in effect in setting the price of a specific automobile line for a given year.

We compute the variance-covariance matrix following the supplemented EM algorithm (SEM) of Mang and Rubin (1991). The main idea behind SEM is to find the increased variability due to missing information (in our case unobservable regimes), and add it to the complete data variance-covariance matrix, which we find analytically based on the information matrix. The details on computing the variance-covariance matrix, and the SEM algorithm canalso be found in the Appendix.

4 Data Description and Sources

Our data on automobile imports into the US comes from *Ward's Automotive Yearbook*. We have collected information on automobile imports for the 1980-2004 period. Although *Ward's Automotive Yearbook* has information on more imported automobiles, we restrict our attention to 35 lines. Our choice of automobile models depends on the availability of price and quantity data for the baseline models. Because we would like to analyze the changes in prices of individual goods and link them to macroeconomic trends, we look at the models that have information for at least ten consecutive years. Furthermore, we restrict our choice of models based on the availability of information on the input-sourcing for each model. Gron and Swenson (2000) have shown that accounting for factor-market decisions of firms are important in measuring pass-through. In order to control for marginal costs incurred in different locations, we choose the lines for which we know the input sources and content of production. As a result, we end up with 35 baseline models from seven exporting countries: France, Germany, Italy, Japan, Korea, Sweden and the United Kingdom.

As our dependent variable, we use the manufacturer's suggested retail price (in U.S. dollars) at the port of entry.[15] Since we are interested in the

[15]Since we are looking at prices at the port of entry, the pass through coefficient estimates only reflect the pass through at the dock, and not the pass-through to the final consumer prices.

pricing decisions of exporting firms, we would like to get prices that are net of any additions that the dealers might charge. Therefore, we do not use the transaction prices. The manufacturer's suggested retail prices do not include destination charges[16], state or local taxes or optional equipment. However, they include ocean freight and U.S. import duty. *Ward's Automotive Yearbook* provides information also on the physical attributes, segment and sales of each model. The physical attributes include engine specifications (size,horse power, cylinders, etc.) and dimensions (height, weight, length). We use the information on the physical characteristics of the car to adjust the prices for quality differences, and use the quality-adjusted prices in our estimations.[17] We also use the information on physical attributes in addition to prices to categorize the automobiles in different market segments. The automobiles in our sample fall into one of the three segments: small, middle and luxury. This categorical variable helps us calculate the share of sales of each line in its own segment. Moreover, we build a Herfindahl index using the total quantity sold in each segment to measure the market concentration. Finally, we use the data on sales to construct the total market share of exporting countries. As suggested by Feenstra, Gagnon and Knetter (1996) and Bacchetta

[16] After 1990, Wards Automotive Yearbook reports prices including the destination charges. For those years, we collected the information on destination charges from the *Market Data Book*, and subtracted them from the reported prices.

[17] To obtain the quality-adjusted prices we regress our original prices against the ratio of horse-power to car weight and eliminate the systematic component.

and van Wincoop (2005), the market share is defined as quantity of exports by a country to the U.S. as a ratio of total new automobile sales in the US.

All the other variables used as regressors in the pricing and the probability equations are constructed from monthly series so that the information set corresponds to the information set available to the exporter at the time of the price announcement. The model year runs from October to September of the following year. Hence, we construct the exchange rate variable as an average of monthly nominal market rates, official rates if market rates are not available (source: International Financial Statistics), over the model year of the automobiles. The exchange rate surprise variable is constructed by taking away the average of the exchange rate over the past 24 months. This average over the last two model years acts as a proxy for the expected exchange rate.[18] As a proxy for marginal cost, we use the monthly manufacturing wage rates of the exporting countries (reported by Bureau of Labor Statistics), convert them to dollar terms using the monthly exchange rates, and construct the averages over the model year. Similar to exchange rate surprises, marginal cost surprises are constructed by taking away the average over the previous 24 months.

We collected monthly information on the US CPI of new cars as a proxy for the price index of competitors (source: Bureau of Labor Statistics), and

[18]We also construct the excpected exchange rate as an average over the past 12 and 36 months. The results do not change from the ones presented in the next section.

constructed the model year average. Inflation variable is the average of annualized inflation rates calculated from consumer price indices. Finally, our proxy for the exchange rate volatility is the average of monthly squared changes in the log of the exchange rate during the previous 24 months. The data consumer price indices and exchange rates come from the International Financial Statistics.

5 Empirical Results

In this section we present the estimates of the pricing policies of new automobiles from England, France, Germany, Italy, Japan, Korea and Sweden. Our sample is a panel data of prices of 35 narrowly defined car models that covers the period 1980-2004. Our strategy in the sequence of models is first to keep the transition probabilities constant as in Hamilton (1991), and discuss the dimensions in which the low pass-through regime differs from the high-pass-through one. Next, we consider the fundamental variables that various theories have identified as important determinants for the choice of currency denomination of exports and the degree of exchange rate pass-through. Hence, we allow for time-varying transition probabilities as in Diebold et al. (1994) and discuss the significance of various economic indicators in the light of our estimation results.

5.1 Constant Transition Probabilities

As highlighted in equation (5), we allow the optimal export price of the firm to respond to changes in the exchange rate surprises, expected changes in marginal cost, proxied by changes in the wage index of exporter's country, and to expected changes in prices of competitors, proxied by changes in the US CPI of new cars. We also control for the automobile line specific fixed effects and US disposable income.[19] We constrain the fixed effects and disposable income to be equal across regimes, and focus on the parameter instability in the exchange rate pass-through, marginal cost and the industry price index. The transition probabilities (6), as in Hamilton (1991), are constant.[20]

The parameter estimates, standard errors and some statistics for the model with constant transition probabilities are reported in the first column of Table 1. Table 1 shows that our estimation identifies two distinct regimes that are characterized by three results. First, we obtain two different and highly significant exchange rate pass-through coefficients. While the exchange rate pass-through is 16.13% in the "high-pass-through" (HPT) regime, it is 4.87% in the "low-pass-through" (LPT) one. Second, the LPT regime is also characterized by lower sensitivity to changes in the industry

[19]In an alternative specification, we have also controlled for oil price shocks. The results look very similar, and are available upon request.

[20]If we include segment dummies that correspond to luxury, medium and small cars, instead of a single constant, our conclusions below do not change.

price index; one coefficient being almost twice as big as the other (0.5027 vs. 0.9149). Third, in the LPT regime the joint volatility of technology and preference shocks measured by the variance of the shocks is low ($\hat{\sigma}_0^2 = 0.0002$) whereas in the HPT regime it is much higher ($\hat{\sigma}_1^2 = 0.0127$).[21] Finally, the predicted duration of the LPT regime is 2.73 years, while in the HPT regime it is 2.5 years.[22] The estimation results show that the changes in the wage rate are not very different across the two regimes, and it is not significant in the HPT regime. While tests about the existence of two regimes versus one regime are not fully developed in the literature at this time (see discussion in Hamilton 2005), the three significantly different coefficients we identify exposes the instability of the whole export pricing regime, and not only the pass-through coefficient. Furthermore, the likelihood ratio test for the equality of the pass-through coefficients across the two regimes rejects the equality constraint.

One important implication emerges from our first specification. In states of the economy where exporters are faced with a mix of preference and technology shocks with low volatility, they smooth further prices by passing a lower percentage of changes in both, exchange rates and marginal costs;

[21]As a reference, business cycle models for the US estimate the variance of technology shocks in the US around 0.00008 and preference shocks around 0.00091. Our estimates of σs jointly account for both, technology shocks in the exporter's country and preference shocks in the US.

[22]The expected duration is calculated using $\frac{1}{1-\bar{g}_{ii}}$ where $\bar{g}_{ii}$ is the average predicted probability for regime i. See Hamilton (1994) for further details.

therefore there is a non-linear relation between the volatility of exporters' prices and the volatility of exogenous shocks that they face. Moreover, this implication carries over more general specifications presented below.

Although this specification with constant transition probabilities is illustrative, there are theoretical arguments to believe that the transition probabilities across the pricing regimes are not constant over time but vary with macroeconomic and/or microeconomic conditions. We start to explore some of those theoretical arguments in the next subsection.

5.2 Economic Factors as Drivers of Transition Probabilities

The theoretical literature on export pricing suggests a diverse set of variables for the determination of the optimal degree of exchange rate pass-through. While a strand of the literature focuses on firm specific and industry specific factors affecting the firms' decisions, other studies focus on country specific factors or macroeconomic conditions. Each of the factors can affect the likelihood of the price being in one of the two regimes. By allowing the transition probabilities to be functions of one or more of these factors, we investigate their significance in the export pricing and pass-through decisions. Furthermore, we analyze the role of each of these factors in leading to a decline in the average pass-through.

To clarify the interpretation of our estimates of the conditional probabilities (6), and to shed some light on the relevance of the economic factors for the pass-through, we consider the following. Assume that there is a continuum of mass one of firms exporting to the US; out of that mass of firms, the fraction Λ_t is subject to the "low pass-through" state in t (i.e. $\xi_t = 0$) and a mass $(1 - \Lambda_t)$ is subject to the high pass-through. Recall that g_t^{00} is the transition probability of a firm acting under the low pass-through state in t given that it was in the same state in $t-1$; and $(1-g_t^{11}) = g_t^{01}$ is the transition probability of a firm switching from the high pass-through regime in $t-1$ to the low pass-trough regime in t. Thus, in this setting, the evolution of the mass of firms in the low pass-trough regime is given by

$$\Lambda_t = \Lambda_{t-1} g_t^{00} + (1 - \Lambda_{t-1})(1 - g_t^{11}), \tag{7}$$

where $g_t^{ii} = \frac{\exp(\underline{z}'_{\ell t-1}\hat{\phi}_i)}{1+\exp(\underline{z}'_{\ell t-1}\hat{\phi}_i)}$. Given the initial condition Λ_{-1} the dynamics of the fraction of firms in the low pass-through regime is driven by the transition probabilities g_t^{00} and g_t^{11}, which in turn, we assume are driven by economic factors.[23]

The major factors that we focus on in our estimations of the pricing equations (5) with time-varying transition probabilities (6), g_t^{00} and g_t^{11}, are ex-

[23]To be precise, we use $g_t^{ii} = 1/\mathbb{L}^* \sum_{\ell=1}^{\mathbb{L}^*} g_{\ell t}^{ii}$ for $i = 0, 1$; and as initial condition we use the steady-state expression for Λ evaluated with the probabilities estimated for $t = 1$, that is $\Lambda_{-1} = \frac{(1-g_1^{11})}{2-g_1^{00}-g_1^{11}}$. However the initial condition only affects substantially the first couple of years and after that the path of Λ_t is virtually independent of the initial conditions.

change rate volatility, industry concentration, exporting country's market share and monetary stability. Each of these factors have been theoretically shown to be important in the pass-through decisions of the exporting firms. In the following subsections, we briefly review the theoretical arguments, and present the results for each of those factors. In all the specifications discussed below, the coefficients in the pricing equations maintain magnitudes and significance similar to the ones found in the estimation with constant probabilities. Therefore, in the following discussions, we focus our attention on the estimates of the probabilities, and their interpretation.

5.2.1 Industry Specific Factors

The role of product substitutability in the problem of price setting and pass-through have been studied extensively. Some of the seminal papers are Giovannini (1988), Donnenfeld and Zilcha (1991) and Friberg (1998). The main finding common to these papers is that under exchange rate uncertainty, the curvature of the demand and cost functions are important for the choice of currency. Given the common assumptions of constant or decreasing returns to scale for the production technology, high degrees of elasticity of substitution will make the profit function concave. Therefore, if an export good is not very differentiated, the firm can find it more profitable to absorb the exchange rate fluctuations, and not to pass-through much of it. Moreover, the higher the exchange rate uncertainty, the greater the incentive will be to do so.

As an empirical proxy for product substitutability, we consider the Herfindahl index for the US automobile market, which captures the degree of concentration in the market.[24] We examine the effects of market concentration by including the change in Herfindahl index in the probability function.[25] The second column of estimates in Table 1 shows that the market concentration is a statistically significant determinant of both transition probabilities $g_{\ell t}^{00}$ and $g_{\ell t}^{11}$.

To investigate the implication of the transition probabilities for the propensity to be in the low pass-through regime and the average exchange rate pass-through, we construct the estimated fraction of firms in the LPT regime throughout the sample using equation (7). Panel B of Figure 1 shows the evolution of the fraction of firms, Λ as well as the change in the Herfindahl index. Panel A of Figure 1 shows that the Herfindahl index for the automobile industry shows a clear downward trend until 1990, and a non-monotonic upward trend since then. Still, in the second half of our sample, the industry is more

[24]As a second measure we can also use the share of sales of each automobile line in its own segment (small, medium or luxury car). We prefer to focus on the results with the Herfindahl index since towards the end of our sample some automobiles are both imported and produced in the US. Having information only on the imported quantities, our measure of the segment share will be underestimated. The results from this specification show that segment share is significant at 10% in the LPT regime.

[25]Including the level of the Herfindahl index in the probability function created problems in the convergence of the SEM algorithm. Therefore, we examine the results for the difference of the variable.

concentrated than the first half. Panel B of Figure 1 shows that the fraction of firms in the LPT regime is on average higher after 1990, and the evolution of the fraction follows the changes in the Herfindahl closely. This is in line with the theories that suggest that higher market concentration (implying higher substitutability) should lead the firms to pass-through less of the exchange rate fluctuations. Therefore, we can infer that the higher market concentration in the post-1990 sample, is associated with lower pass-through on average in the same period.

5.2.2 Country Specific Factors

Secondly, we consider the total market share of an exporting country as a factor in the determination of the pricing policies. The importance of this factor in the presence of strategic interactions, has been studied by Feenstra, Gagnon and Knetter (1996), Bodnar, Dumas and Marston (2002) and Bacchetta and van Wincoop (2005). These studies highlight the fact that high market share implies that the firms from a particular exporting country do not face much competition from firms that have not experienced similar cost shocks. Therefore, given a certain level of demand in the destination country, the firms can pass-through more of the fluctuations of the exchange rate.

The third column of Table 1 shows that the country share variable is a significant determinant of both of the conditional probabilities, $g_{\ell t}^{00}$ and $g_{\ell t}^{11}$.

Secondly, the variation in the market shares and the estimates of the conditional probabilities imply that a firm in the LPT regime will stay in that regime on average for 3.06 years; where as, the duration in the HPT regime is only 1.81 years. The plots of unconditional probabilities for each country, constructed using equation (7), are shown in Figure 2. For most of the countries, there is a systematic positive relationship between the market share and the fraction of firms being in the LPT regime. The exception is Japan before 1995, where an increase in Japan's market share is associated with a decrease in the fraction of Japanese firms in the LPT regime. These results resemble the empirical findings in Feenstra, Gagnon and Knetter (1996), who show that pass-through increases with country market share only when market share is already large, and decreases with market share when it is small. Since all countries, except for Japan, have small shares of the US automobile market, the propensity to choose a low degree of pass-through decreases for the firms in those countries. The implications for the average pass-through can be drawn by looking at the total fraction of firms in the LPT regime. Panel (H) in Figure 2 shows a downward trend in the estimated mass of firms in the LPT regime up until 2000. These results may be driven by the Japanese country share dynamics, given their dominant share in the market.

5.2.3 Macroeconomic Factors

The last set of factors that we consider relate to monetary and macroeconomic stability in the importing and exporting countries. Taylor (2000) notes that stable inflation rates affect the degree to which the firms pass-through the fluctuations in the exchange rate to their prices by reducing their pricing power. Similarly, Devereux, Engel and Storgaard (2004) show, in a general equilibrium framework, that the firms optimally set prices in the currency of the country that has more stable money growth. Hence, if the importing country has relatively low and stable inflation rates, more exporting firms will set their prices in the importing country's currency, and as a result, the importing country will experience a lower pass-through.[26] To empirically evaluate the importance of monetary stability, we include inflation rates of both countries as explanatory variables in the probability functions as well as a measure of the volatility of the exchange rate.

The column "inflation" in Table 1 shows the results for the specification with transition probabilities as functions of the US inflation rate and the inflation rate in the exporter country. While the variable US inflation (coefficients ϕ_{02} and ϕ_{12}) is significant in both transition probabilities, the inflation

[26]In a set up similar to Devereux et al. (2005), Goldberg and Tille (2005) contrast the role of that macroeconomic conditions to industry specific features for the firms' optimal choice of currency. They show that macroeconomic variability matters for the firms' decisions if their products are highly differentiated. In industries with high elasticities of demand, the firms tend to herd together in the choice of currency rather than basing their decisions on macroeconomic conditions.

rate of the exporting country is not significant. Figure 3 shows that the reduction in the US inflation rates imply an increase the fraction of firms in the low pass-through regime. This is consistent with the idea that increased monetary stability in the US has lead the exporters to pass-through less of the exchange rate fluctuations, contributing to the decline in the pass-through. Similar to the previous specification, the expected duration of the LPT and HPT regimes are 3.14 and 2.33 years, respectively.

The last column in Table 1 shows our estimates for the model with the volatility of the exchange rate. The volatility of the exchange rate is highly significant in the high pass-through regime. As shown in Figure 4, there is a negative relationship between the volatility of the exchange rate and the fraction of firms in the low pass-through regime. During periods of high volatility, firms tend to pass-through more of the fluctuations. The reduction in the volatilities towards the end of our sample imply a higher fraction of firms adopting low pass-through (see Panel H in Figure 4). Hence, greater macroeconomic stability in the form of lower exchange rate volatilities has lead the average pass-through to decline.

6 Implications for the Exchange Rate Pass-Through Dynamics

To study the implications of our estimates for the evolution of the average exchange rate pass-through in the automobile industry, we aggregate the individual prices in a price index. Consider the price index of imported cars

$$\hat{P}_t = \sum_{\ell} \omega_\ell \hat{p}_{\ell t}$$

where ω_ℓ is the weight associated to the car model ℓ and $\hat{p}_{\ell t}$ follows the pricing policy 5. Let $\mathbb{I}^0_{\ell t}$ be an indicator function equal to one if the firm ℓ is in the low pass-through regime in period t and zero otherwise. From the price index and the pricing policy (5) it follows that the exchange rate pass-through coefficient is

$$\eta_t \equiv \frac{\partial \hat{P}_t}{\partial \text{Exch. Rate}_t} = \sum_{\ell} \omega_\ell \left[\mathbb{I}^0_{\ell t} \beta^s_0 + \left(1 - \mathbb{I}^0_{\ell t}\right) \beta^s_1 \right].$$

Using Λ_t derived in equation (7) to replace the indicator function we obtain

$$\mathbb{E}_t \eta_t = \sum_{\ell} \omega_\ell \left[\Lambda_t \beta^s_0 + \left(1 - \Lambda_t\right) \beta^s_1 \right].$$

Table 2 presents a general specification that includes market concentration, exporting country's market share, inflation differential and the exchange rate volatility as the determinants of the transition probabilities. We estimate the exchange rate pass-through based on this general specification. Figure 5 shows the evolution of the exchange rate pass-through based on the estimates from our general specification in Table 2. It shows a non-monotonic downward trend with the highest pass-through coefficient of 13.4% in 1987 and the lowest pass-through coefficient of 6.4% in 2001.

To understand the contribution of each factor to the decline in the pass-trhough, we decompose the smoothed probabilites obtained from the general specification presented in Table 2, the results of the decomposition are presented in Table 3. As the results in Table 3 show country market share has the minimal (sometimes negative) contribution to the decline in the pass-through. Changes in the market concentration, inflation differential and exchange rate volatility all have sizable effects. The cross-country inflation differential explains abut 20% of the year-to-year variations in the exchange rate pass-through coefficient; the volatility of the exchange rate explains 36% and the market concentration about 38%. In a five-year horizon the percentage due to market concentration falls to 28% whereas the percentage due to exchange rate volatility increases to 48% and the the percentage due to inflation remains the same.

7 Conclusions

We investigate the changes in the pricing policies and the exchange rate pass-through decisions of automobile firms exporting to the US. To that end we set up and estimate a regime switching model of export pricing, where the changes in the pricing regimes are governed by a Markov process. The transition probabilities of the Markov process depend on both macroeconomic and microeconomic factors. We estimate our model using data on 35 automobile imports from 7 countries. As our estimations show, a change in the pricing policies does not only imply a decline in the average pass-through in the automobile industry, but it also implies a lower sensitivity to misalignments in the firm's relative price, and higher duration of pricing policies. Furthermore, the low pass-through pricing policy we identify is associated with periods of low volatility of demand and technology shocks.

From our estimation results, we conclude that both microeconomic and macroeconomic factors are important in the pricing policy determination. While market concentration is positively associated with the propensity to be in a low pass-through regime, the inflation rate in the US and the exchange rate volatility are negatively correlated. Our results highlight the fact that in the recent decades, there has been some structural changes in the pricing policies of exporters based on a number of factors. Therefore, it is constructive to study the pass-through phenomenon at a disaggregated level to understand the reasons behind its decline. For the automobile industry, the bigger fraction of the decline can be attributed to enhanced macroeconomic stability in the US, and the increased propensity of the exporting firms to respond to the enhanced stability.

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Table 1

Parameter	constant	market concentration	country share	inflation	volatility of exch.rate
β_0^e	0.0487**	0.0410**	0.0675**	0.0738**	0.0428**
	(0.0170)	(0.00001)	(0.0214)	(0.0189)	(0.0146)
β_0^ψ	0.0701**	0.0741**	0.0652**	0.0708**	0.0688**
	(0.0170)	(0.0163)	(0.0200)	(0.0188)	(0.0161)
$\beta_0^{P_L}$	0.5027**	0.5172**	0.5507**	0.5599**	0.4641**
	(0.0548)	(0.0381)	(0.0639)	(0.0582)	(0.0561)
β_1^e	0.1613**	0.1625**	0.1721*	0.1512**	0.1609**
	(0.0782)	(0.0731)	(0.0921)	(0.0455)	(0.0754)
β_1^ψ	0.0415	0.0426	0.0449	0.0497	0.0433
	(0.1044)	(0.1015)	(0.1235)	(0.1008)	(0.1053)
$\beta_1^{P_L}$	0.9149**	0.9098**	0.9512**	0.9600**	0.9017**
	(0.3266)	(0.3104)	(0.3827)	(0.2799)	(0.3077)
β_1^Y	-0.2843**	-0.2446**	-0.3058**	-0.2052	-0.2879**
	(0.1233)	(0.0074)	(0.1300)	(0.1273)	(0.1269)
ϕ_{01}	0.5468**	0.1955	1.2013**	0.3050	0.1608
	(0.2300)	(0.1763)	(0.3176)	(0.3387)	(0.3366)
ϕ_{02}		-2.6878**	-0.0185**	0.8127*	0.0211
		(1.0425)	(0.0079)	(0.4281)	(0.0178)
ϕ_{03}				0.2571	
				(0.6918)	
ϕ_{11}	0.4068*	0.0517	1.0476**	-0.3849	-0.4860
	(0.2182)	(0.1796)	(0.3232)	(0.3906)	(0.3604)
ϕ_{12}		-3.9405**	-0.0573**	1.0655**	0.0601**
		(0.7197)	(0.0098)	(0.0000)	(0.0205)
ϕ_{13}				0.5782	
				(0.4362)	
σ_0^2	0.0002**	0.0002**	0.0004**	0.0004**	0.0002**
	(0.0001)	(0.0000)	(0.0001)	(0.0000)	(0.0000)
σ_1^2	0.0127**	0.0125**	0.0146**	0.0141**	0.0123**
	(0.0015)	(0.0014)	(0.0018)	(0.0018)	(0.0012)
Duration LPT	2.73	2.24	3.06	3.14	2.65
Duration HPT	2.5	2.07	1.81	2.33	2.56
Avg. $\frac{\partial p^{00}}{\partial Z}$		-0.6284	-0.0039	0.1741	0.0049
Avg. $\frac{\partial p^{11}}{\partial Z}$		-0.8957	-0.0106	0.2519	0.0137
Likelihood	539.4300	545.4033	550.9184	536.9687	547.7699
Obs.	583	583	583	583	583
RMSE	0.0787	0.0787	0.0783	0.0786	0.0788
AIC	-4.8909	-4.8829	-4.8928	-4.8783	-4.8817

Table 2

Pricing Equation Parameters	β_0^e	β_0^ψ	$\beta_0^{P_L}$	β_1^e	β_1^ψ	$\beta_1^{P_L}$	β_1^Y
	0.0461**	0.0622**	0.5818**	0.1598**	0.0525	0.9108**	-0.2152
	(0.0136)	(0.0161)	(0.0584)	(0.0747)	(0.1031)	(0.3180)	(0.0000)
	σ_0^2	σ_1^2					
	0.0002**	0.0125**					
	(0.0000)	(0.0013)					
Transition Equation Parameters	constant		market concentration		country share		
	ϕ_{01}	ϕ_{11}	ϕ_{02}	ϕ_{12}	ϕ_{03}	ϕ_{13}	
	0.4707&	-0.1269	-1.4246*	-2.4510**	-0.0339**	-0.0409**	
	(0.3796)	(0.3808)	(0.7949)	(0.8436)	(0.0119)	(0.0104)	
	inflation differential		volatility of the exch. rate				
	ϕ_{04}	ϕ_{14}	ϕ_{05}	ϕ_{06}			
	2.4265**	1.7967*	2.4061	5.6383**			
	(1.1450)	(0.9999)	(2.2027)	(2.2583)			
	Duration LPT	Duration HPT					
	2.4749	2.0753					
	Likelihood	Obs.	RMSE	AIC			
	565.7261	583	0.0787	-4.8587			

Notes:

- The specification includes fixed effects that are constrained to be the same across the two regimes.
- Inflation differential is defined as the difference between the Us inflation rate and the exporting country's inflation rate.

Table 3: Decomposition of the Decline in the Exchange Rate Pass-through

	country share	market concentration	inflation differential	volatility of exchange rate
k=1	2.4968	38.8041	22.3118	36.3873
k=2	-0.8371	34.0912	34.9767	31.7691
k=3	0.9009	20.2732	23.0193	55.8066
k=4	-0.2276	22.3565	19.1138	58.7573
k=5	1.4206	28.5989	21.1794	48.8011

Notes:

- Each row corresponds to the decomposition of the exchange rate pass-through at a different horizon, where k is the number of years.

Figure 1: Market Concentration & % of Firms in Low Pass-trough Regime

A) Herfindahl Index

B) Fraction of Firms in Low Pass-through & Change in Herfindahl Index

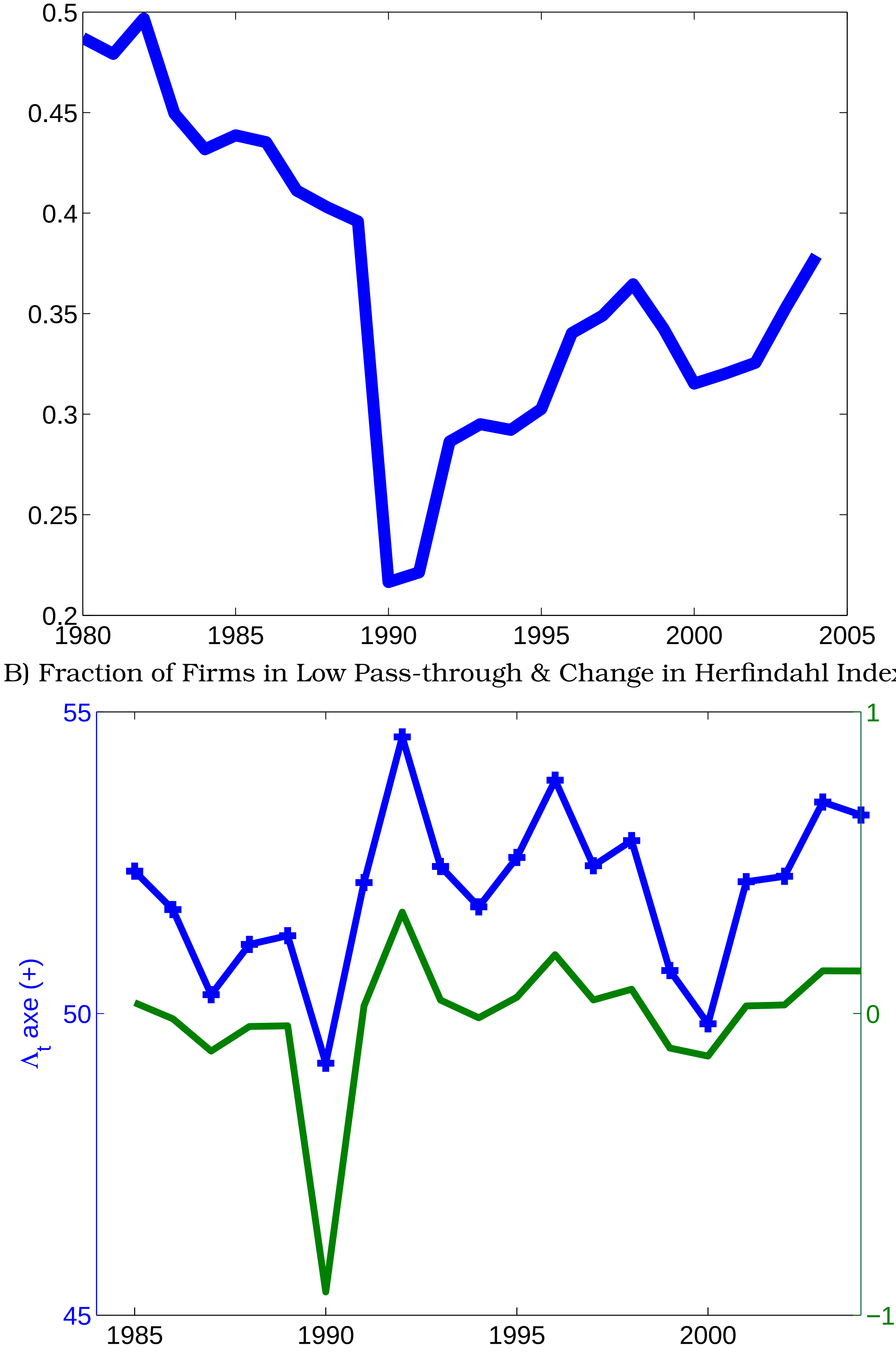


Figure 2: Exporter's Country Share & % of Firms in Low Pass-trough Regime

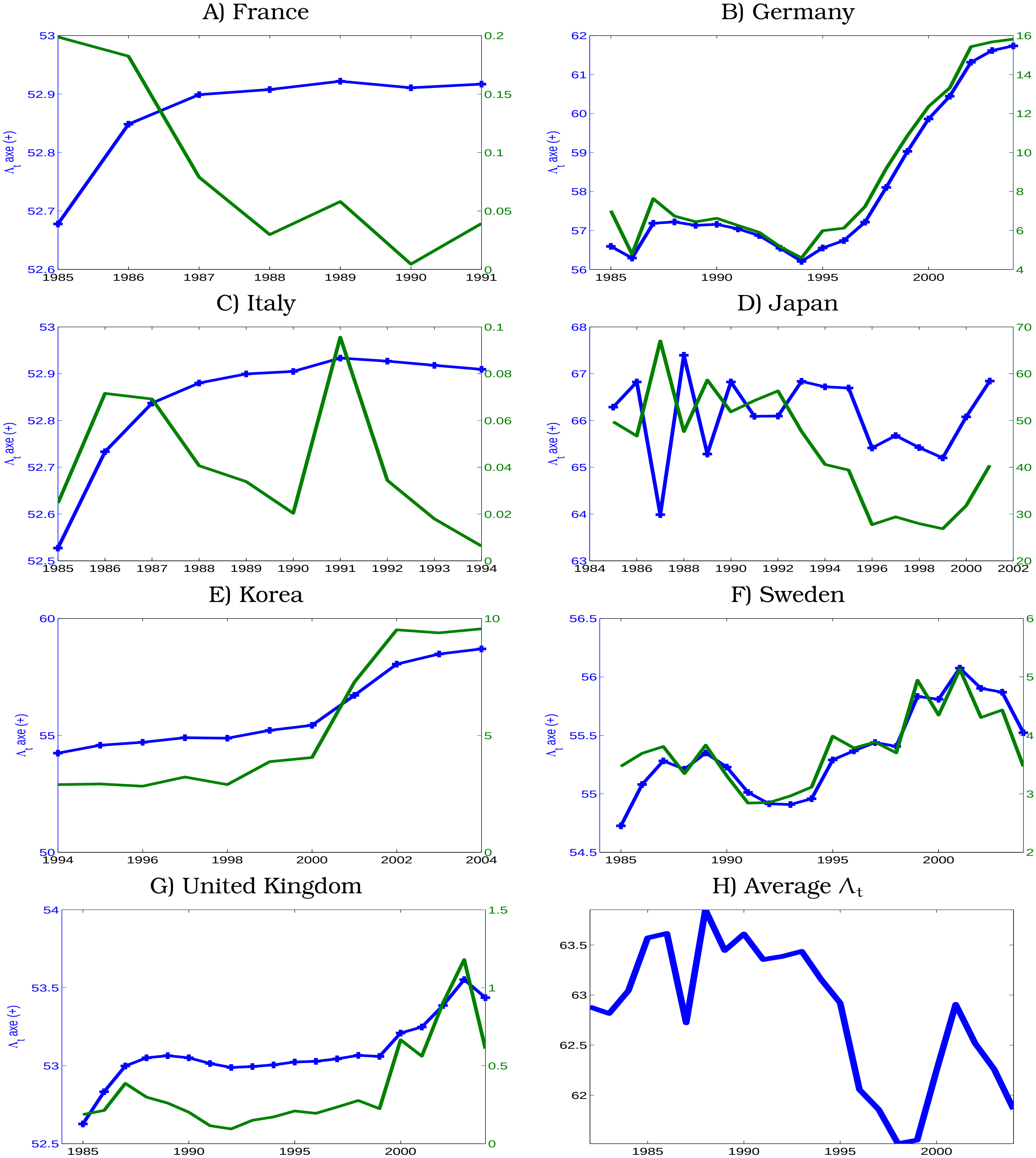


Figure 3: US inflation & % of Firms in Low Pass-trough Regime

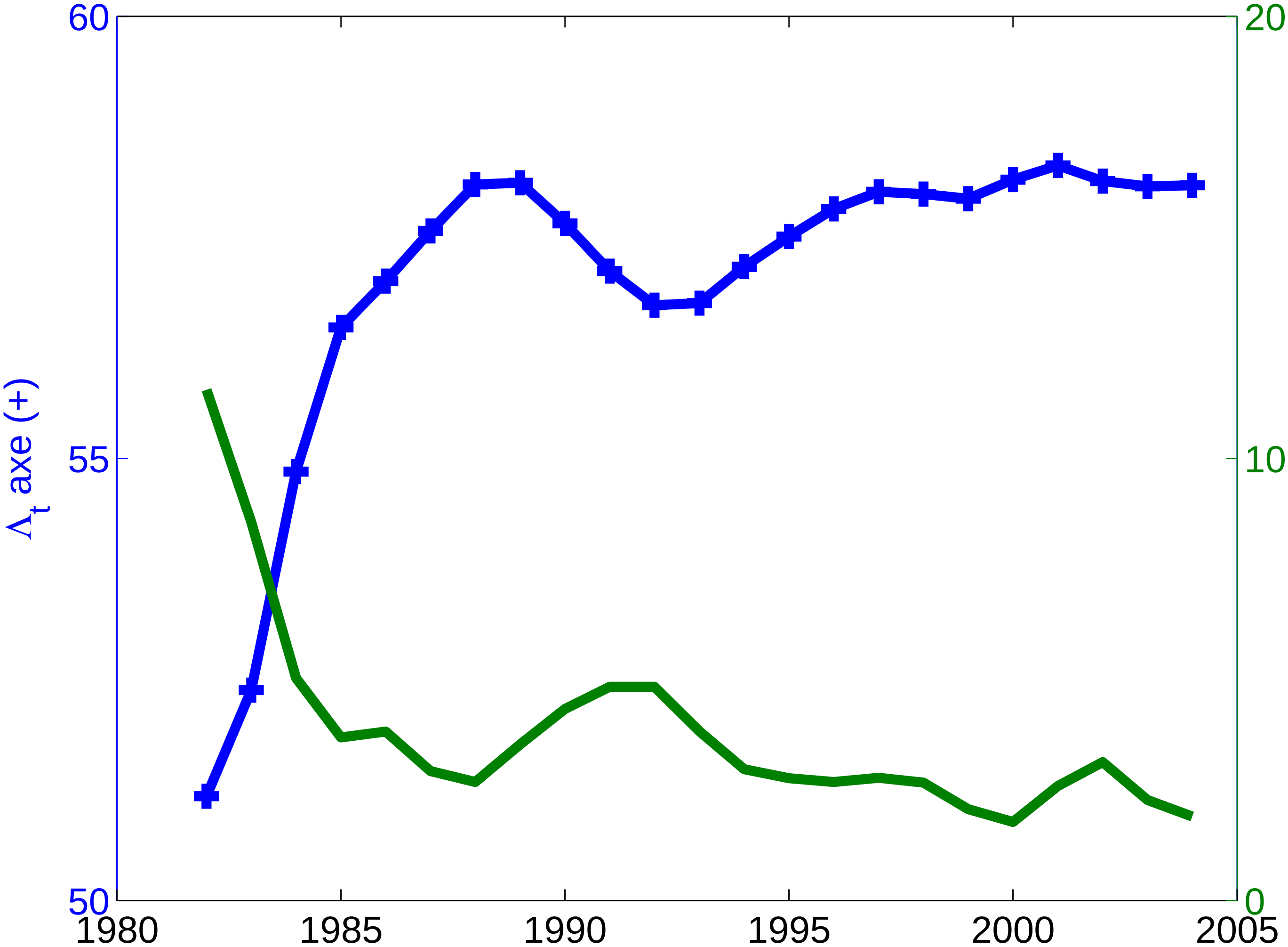


Figure 4: Exchange Rate Volatility & % of Firms in Low Pass-trough Regime

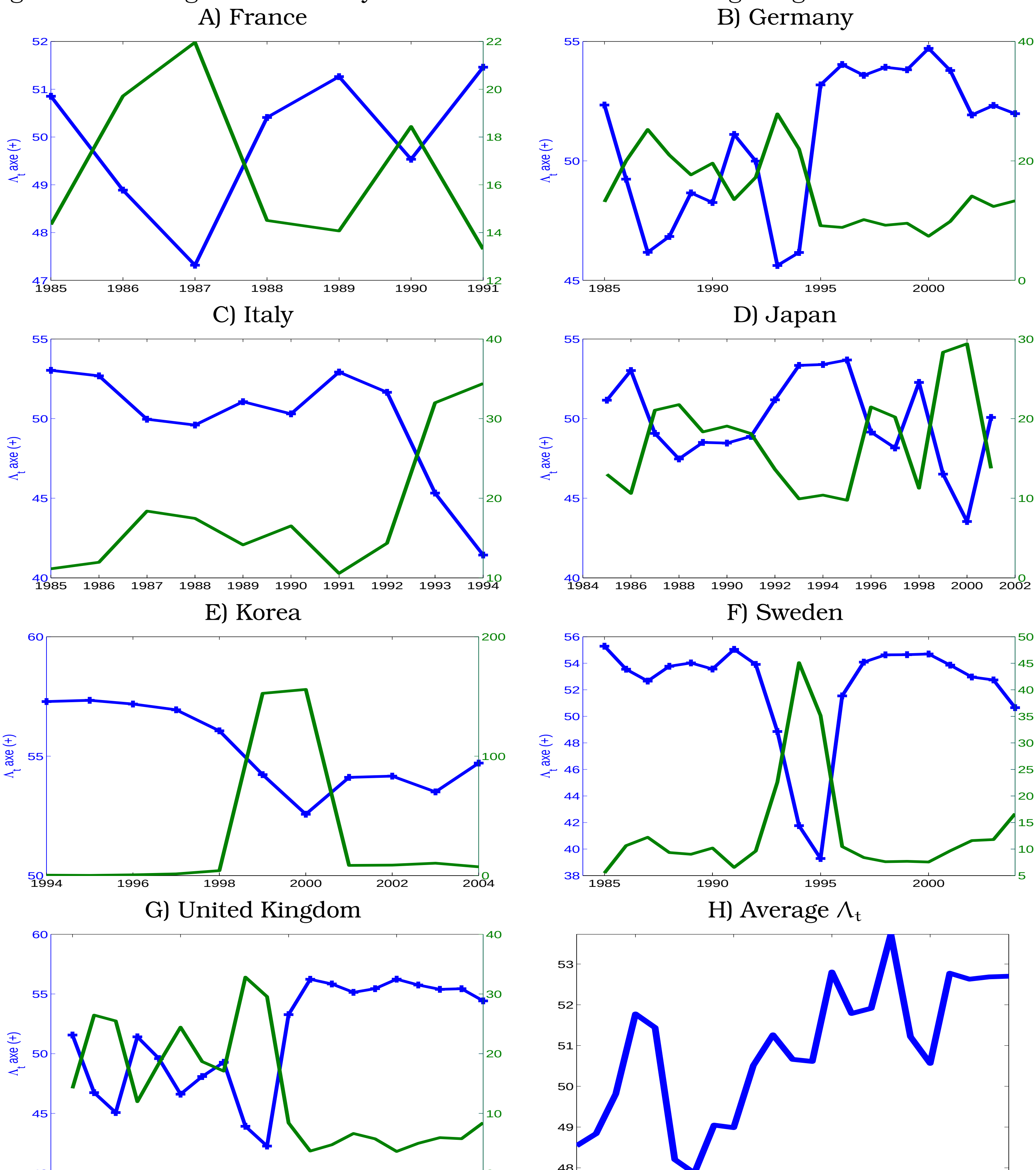
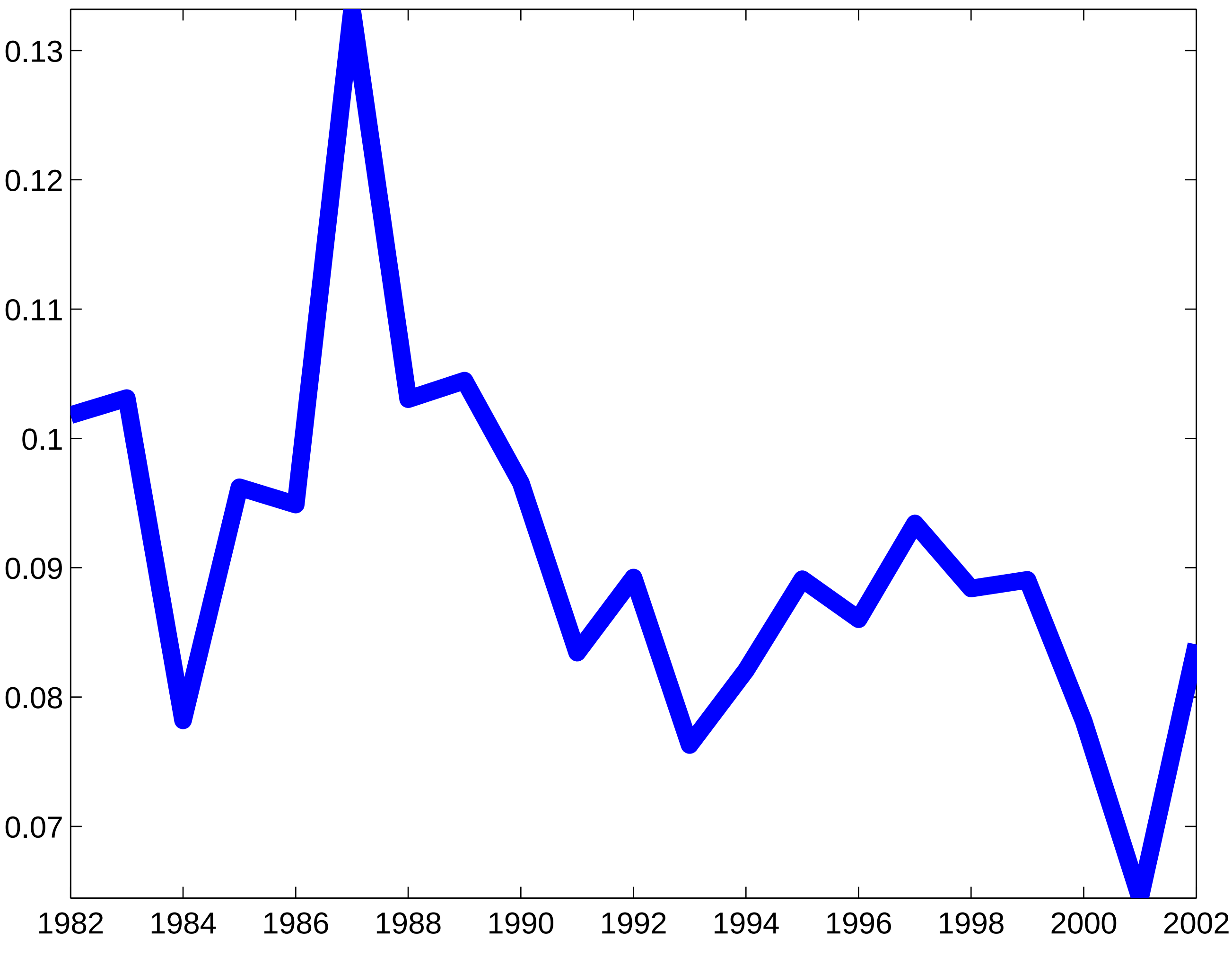


Figure 5: Estimated Exchange Rate Pass-Through Coefficient



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