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A comment on "The effect of a common currency on the volatility of the extensive margin of trade"

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Abstract

In this paper I comment on Auray, Eyquem, and Pontineau (2012). I show that their introduction of sticky-prices into Ghironi & Melitz (2005) framework is incorrect and generates a bias in simulation results. Additionally, I find that, by introducing sticky-prices into Ghironi & Melitz (2005) framework in a correct way, the model is able to account for the empirical findings of Auray, Eyquem, and Pontineau (2012). Finally, I also find that if central banks target a data-consistent CPI inflation, results improve quantitatively.

JEL classification: E32; E52; F41.
Keywords: Pricing-to-market; Local currency pricing; Extensive Margin; Monetary Union; Monetary Policy.

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1 Introduction

The paper by Auray, Eyquem, and Pontineau (2012) (henceforth AEP) is important and very interesting. They analyze both empirically and theoretically the effects of the European Monetary Union on the volatility of the extensive margin of trade in member countries. In the empirical part of their analyses, the authors conclude that the volatility of the extensive margin of trade has decreased (increased) in Germany and Italy (in the remaining countries) on average about 38% (59%). To account for these facts, AEP extend the two-country framework of Ghironi & Melitz (2005) (henceforth G&M). First, to allow for non-trivial monetary policy effects, AEP introduce sticky-prices by assuming price adjustment costs (Rotemberg (1982)).[1] Then, AEP consider two types of exchange rate regimes, a fixed exchange rate regime and monetary union. Under the fixed exchange rate regime there are two countries, a leader and a follower. The leader's central bank targets inflation in the domestic producer prices index (PPI) and domestic output gap. The follower's central bank pegs its exchange rate to the leader. Under the monetary union, the union's central bank attaches the same weight to each country PPI inflation and output gap. The reported simulation results of their calibrated model are qualitatively in line with their empirical findings. Monetary unification gives rise to a decrease (increase) in the volatility of the extensive margin of trade in the leader (follower) country.

The main motivation for writing this comment is to correct one apparent flaw in the introduction of sticky-prices into the framework of G&M. AEP disregard an implicit but crucial assumption in G&M that is *pricing-to-market cum local currency pricing* (PTM-LCP).[2] Since firms pay iceberg-melting costs when selling abroad, marginal costs to supply home and foreign markets are different. As a result, if exporting firms were unable to set different prices in

[1] AEP also allow for labor supply, fixed in G&M, to be endogenous.

[2] The PTM assumption allows firms to engage in third-degree price discrimination. That is, with segmented markets, firms can adjust their prices to the specific local demand conditions. The LCP assumption allows firms to set their prices in the currency of the buying country. See, for a review, Obstfeld and Rogoff (2000).

different markets (PTM-LCP assumption), the optimal price chosen by these firms would depend on the relative size of each market. In this case, the price set by exporters and non-exporters would be different. Because being an exporter or not depends on the firm specific productivity level, the average productivity levels defined in Melitz (2003) are not valid. Therefore, the assumption of PTM-LCP is a crucial building block of G&M framework.

With the assumptions of flexible prices and PTM-LCP, G&M derive a rather neat relationship between domestic and export prices: export prices are simply equal to domestic prices corrected for exchange rates and transactions costs. Nevertheless, this relationship, assumed by AEP, does not hold once Rotemberg (1982) adjustment costs are introduced to the model.

Furthermore, the log-linearization of the model is also incorrect. In the correct log-linear form of their model, the volatility of the extensive margin of trade falls with monetary unification falls everywhere.

Because AEP do not state any assumption regarding the flexibility of export prices, I study the implications of both flexible and sticky export prices. I find that, when all prices are sticky, the model is qualitatively able to predict the empirical findings by AEP: the leader's (follower's) volatility of the extensive margin of trade falls (increases) with monetary unification. On the contrary, when only domestic prices are sticky, the volatility of the extensive margin of trade falls everywhere with monetary unification.

Finally, if central banks target PPI inflation, as assumed by AEP, they disregard the effects of imported inflation. Therefore, I also study how the results change when central banks target data-consistent consumer price index (CPI) inflation rather than PPI inflation. I find that targeting CPI inflation improves the results quantitatively.

The rest of the paper is organized as follows. In section 2, I derive the optimal prices under the assumptions of flexible and sticky prices. These derivations render it possible to see and correct the flaw in AEP's export price equation. In section 3, I present how monetary policy is conducted under the assumption of data-consistent CPI inflation targeting. In section 4, I compare results. Section 5 concludes.

2 Firm's optimal decision under different pricing assumptions

An exporting home firm producing variety ω chooses real domestic price relative to home price index, $\rho_{d,t}(\omega)$, and real export price relative to foreign price index, $\rho_{x,t}(\omega)$, to maximize the following real profits

$$\begin{aligned} d_t(\omega) = {} & \rho_{d,t}(\omega)^{1-\theta} y_t^d - \frac{\eta_1}{2}\left(\frac{p_{d,t}(\omega)}{p_{d,t-1}(\omega)} - 1\right)^2 \rho_{d,t}(\omega)^{1-\theta} y_t^d \\ & + q_t \rho_{x,t}(\omega)^{1-\theta} y_t^{*d} - \frac{\eta_2}{2}\left(\frac{p_{x,t}(\omega)}{p_{x,t-1}(\omega)} - 1\right)^2 q_t \rho_{x,t}(\omega)^{1-\theta} y_t^{*d} \\ & - \frac{\bar{w}_t}{a_t z(\omega)} \rho_{d,t}(\omega)^{-\theta} y_t^d - (1+\tau)\frac{\bar{w}_t}{a_t z(\omega)} \rho_{x,t}(\omega)^{-\theta} y_t^{*d} - \frac{\bar{w}_t f_x}{a_t} \end{aligned} \tag{1}$$

where y_t^d (y_t^{*d}) denotes aggregate home (foreign) demand.[3,4] Parameters η_1 and η_2 govern the effects of Rotemberg (1982) adjustment costs in the setting of domestic and export prices.[5] In order to supply foreign markets, besides production costs, firms face melting-iceberg costs and must also pay a fixed cost, $\frac{\bar{w}_t f_x}{a_t}$.[6]

[3] In the previous equation, I have already considered the demand and production functions used by AEP.

[4] In this section, I only present the home firm's optimal decisions. Symmetric decisions hold in the foreign country.

[5] I use AEP's notation to denote the remaining variables and parameters. In cases I use different notations, I will call the attention of the reader.

[6] Out of the production for exporting, $y_{x,t}$, only $\frac{y_{x,t}}{1+\tau}$ is actually sold.

The optimal prices resulting from the maximization of profits in Eq. 1 differ depending on $\eta_i = 0$ or $\eta_i > 0$ for $i = 1, 2$. Obviously, when $\eta_1 = \eta_2 = 0$, prices are flexible. In that case, the optimal prices of an exporting firm are the ones presented in G&M, that is

$$\rho_{d,t}(\omega) = \frac{\theta}{\theta - 1}\frac{w_t}{a_t z(\omega)}, \qquad \rho_{x,t}(\omega) = q_t^{-1}(1+\tau)\frac{\theta}{\theta - 1}\frac{w_t}{a_t z(\omega)}$$

and one gets a neat relationship between real domestic and export prices: $\rho_{x,t}(\omega) = q_t^{-1}(1+\tau)\rho_{d,t}(\omega)$, which is also AEP's Eq. 1. In the remaining three cases, AEP's Eq. 1 holds only in steady-state.

AEP explicitly assume adjustment costs, paid in terms of domestic goods, in the domestic price decision. Nevertheless, no such assumption is made regarding the export prices. As a result, and as an intellectual exercise, I have decided to include the case $\eta_1 > 0, \eta_2 = 0$ in my analysis. Then, the optimal real domestic price is

$$\rho_{d,t}(\omega) = \mu_{d,t}\frac{\bar{w}_t}{a_t z(\omega)}, \tag{2}$$

where

$$\mu_{d,t} = \frac{\theta}{(\theta-1)\left(1 - \frac{\eta}{2}\pi_{d,t}^2\right) + \eta\left(\pi_{d,t}(1+\pi_{d,t}) - \beta(1-\delta)E_t\left[\frac{\pi_{d,t+1}(1+\pi_{d,t+1})^2 y_{t+1} u_{c,t+1}}{(1+\pi_{t+1}) y_t u_{c,t}}\right]\right)}. \tag{3}$$

Since, $\eta_2 = 0$ the optimal real export price is still $\rho_{x,t}(\omega) = q_t^{-1}(1+\tau)\frac{\theta}{\theta-1}\frac{w_t}{a_t z(\omega)}$.[7] These pricing decisions have implications on real export profits, cut-off export firm, average real export price, and labor market clearing conditions, which are summarized in Appendix A.

Now, I consider the case of $\eta_1 > 0, \eta_2 > 0$.[8] In this case, exporters must pay adjustment costs, paid in terms of domestic goods, to adjust its domestic and export prices. As a result, both domestic and export prices are sticky. The

[7] Note that $\mu_{d,t}$ in my notation is the same as μ_t in AEP's notation.

[8] The case $\eta_1 = 0, \eta_2 > 0$ is not considered because of its lack of interest for this comment.

optimal real domestic price decision is still the one in Eq. 2. But, the optimal real export price is given by

$$\rho_{x,t}(\omega) = q_t^{-1}(1+\tau)\mu_{x,t}\frac{w_t}{a_t z(\omega)}, \tag{4}$$

where, defining $\pi_{x,t} \equiv \left(\frac{p_{x,t}(\omega)}{p_{x,t-1}(\omega)} - 1\right)$,

$$\mu_{x,t} = \frac{\theta}{(\theta-1)\left(1-\frac{\eta}{2}\pi_{x,t}^2\right) + \eta\left(\pi_{x,t}(1+\pi_{x,t}) - \beta(1-\delta)E_t\left[\frac{q_{t+1}\pi_{x,t+1}(1+\pi_{x,t+1})^2 y_{t+1}^* u_{c,t+1}}{q_t(1+\pi_{t+1}^*)y_t^* u_{c,t}}\right]\right)}. \tag{5}$$

Comparing Eqs. 3 and 5, one can easily see that $\mu_{x,t}$ is, in general, different from $\mu_{d,t}$. Hence, AEP's Eq. 1 is not consistent with the maximizing behavior. As before, Eq. 4 has implications on real export profits, cut-off export firm, average real export price, and labor market clearing conditions, which are summarized in Appendix B.

3 Monetary Policy and exchange rate regimes

AEP consider two types of exchange rate regimes, a fixed exchange rate regime and monetary union. Under the fixed exchange rate regime there are two countries, a leader (home country) and a follower (foreign country). The leader's central bank targets domestic inflation and domestic output gap using a Taylor (1995) type rule. The follower pegs its exchange-rate to the leader. Under the monetary union, both countries share the same currency and the union's central bank uses a Taylor (1995) type rule to target union wide inflation and output gap.

AEP assume central banks target PPI inflation rate, $\pi_{d,t}$, because the model-consistent CPI does not correspond to the data-consistent CPI. Nevertheless, if the central bank targets PPI inflation rate (as defined by AEP), it does not consider the role of imported inflation. Furthermore, it is possible to obtain a data-consistent CPI from the model. Therefore, in what follows I consider the case under which central banks target CPI inflation.

Following G&M, I use the average nominal price for all varieties sold in the home (foreign) country, $\tilde{p}_t$ ($\tilde{p}_t^*$), as a data-consistent CPI in the home (foreign) country. The total number of varieties available for consumers in the home country as $nn_t \equiv n_t + n_{x,t}^*$. Under CES product differentiation, price indeces can be split into two components, one reflecting the average prices and one reflecting the number of varieties: $p_t = nn_t^{\frac{1}{1-\theta}} \tilde{p}_t$. Hence, I propose that in the case of fixed exchange rate, the leader country sets its monetary policy to respond to its domestic targets, $\tilde{\pi}_t \equiv \frac{\tilde{p}_t}{\tilde{p}_{t-1}} - 1$ and $y_{gdp,t}^r$, as follows

$$\hat{r}_t = \rho_r \hat{r}_{t-1} + (1 - \rho_r)(\phi_\pi \hat{\tilde{\pi}}_t + \phi_y \hat{y}_{gdp,t}^r), \tag{6}$$

and the follower country pegs its exchange rate as

$$\hat{r}_t^* = \hat{r}_t - \phi_e(\hat{e}_t - \hat{e}_{t-1}), \tag{7}$$

where $\phi_e > 0$, $\phi_\pi > 1$, $\rho_r \geq 0$, and where hats denote log deviations.[9]

In the case of a monetary union, both countries are assumed to have the same weight in terms of the response of monetary policy and, by definition, the nominal exchange rate is constant. Therefore, I propose that, the central bank sets the nominal interest according to

$$\hat{r}_t = \hat{r}_t^* = \hat{r}_t^u = \rho_r \hat{r}_{t-1}^u + (1 - \rho_r)(\phi_\pi \hat{\tilde{\pi}}_t^u + \phi_y \hat{y}_{gdp,t}^{u,r}), \tag{8}$$

where

$$\hat{\tilde{\pi}}_t^u = (1/2)\hat{\tilde{\pi}}_t + (1/2)\hat{\tilde{\pi}}_t^* \tag{9}$$

and $\hat{y}_{gdp,t}^{r,u}$ is as defined by AEP. Replacing $\tilde{\pi}_t$ by $\pi_{d,t}$ in Eqs. 6 and 9, one

[9] I follow AEP and use $\phi_y = 0.25$, $\phi_\pi = \phi_e = 1.5$, and $\rho_r = 0$.

obtains the monetary policy rules defined by AEP.

4 Results

In this section, I show how the volatility of the extensive margin of trade changes with monetary unification under four scenarios. In the first scenario, prices are sticky and central banks target PPI inflation. The second scenario corresponds to AEP's model with correct log-linear form.[10] In the third scenario, only domestic prices are sticky and central banks target PPI inflation. In the forth scenario, all prices are sticky and central banks target a data-consistent CPI inflation.

In Table 1, I summarize the simulation results for all four scenarios and, for comparison reasons, I also add the simulation results reported by AEP.[11] The simulation results, for the first four scenarios, are based on the HP filtered population moments filtered with smoothing parameter $\lambda = 6$.[12,13] In the first scenario (presented in the columns below "Sticky-prices"), central banks target PPI inflation rate and both prices are sticky ($\eta_1 > 0, \eta_2 > 0$).[14] Under these assumptions, the model is able to qualitatively predict AEP empirical results for a wide range of different calibrations. Using the baseline calibration, the leader's (follower's) volatility of the extensive margin of trade falls by 10.29% (1.63%). This result, however, is clearly dependent on the response of monetary policy to output, that is, on the parameter ϕ_y. In case $\phi_y = 0.5$, in both countries, the volatility in the number of exporters falls with monetary unification.

[10] For a summary of the corrections, check Appendix C.

[11] For ease of comparison between the four scenarios and the simulation results reported by AEP, I follow AEP's calibration, use the same steady-state, and use AEP's remaining assumptions.

[12] This approach is slightly different from the one used by AEP. In their case, they HP-filter the artificial data using $\lambda = 6.25$. However, since I am analysing relative changes in the volatility of the extensive margin of trade between two different exchange rate regimes, this different assumption does not imply significant changes in the results presented.

[13] I do not show the impulse response functions (IRF) since it does not present significant changes in comparison with AEP's IRF.

[14] In case $\eta_2 > 0$, then $\eta_1 = \eta_2 = 4.7785$.

–Insert Table 1 around here–

The results regarding the correct log-linear form of AEP's model are presented in the columns below "ll correction". My objective is to compare two different ways to introduce sticky prices, the correct one and the flawed one. Clearly, the model with flawed introduction of sticky prices is unable to qualitatively predict AEP's empirical results unless the central banks has a weak response to output ($\phi_y = 0$ and $\phi_y = 0.125$). As a result, the reported results by AEP are biased also because of their inconsistent log-linearizations.

In the third case (presented in the columns below "Flexible $\rho_{x,t}(\omega)$"), central banks target PPI inflation rate and, domestic prices are sticky, and export prices are flexible ($\eta_1 > 0, \eta_2 = 0$). Under these assumptions, unless central banks has a weak response to output ($\phi_y = 0$ and $\phi_y = 0.125$), the model is unable to qualitatively predict AEP's empirical results. Using the baseline calibration, the leader's (follower's) volatility of the extensive margin of trade falls by 4.76% (0.76%).

Comparing the first and third scenarios simulation results, one concludes that the export pricing decision plays a crucial role on the effects of monetary unification on the volatility of the extensive margin of trade for the follower. I argue that, under the baseline calibration, when different pricing assumptions are considered, the relative importance of internal stabilization in each country on the volatility of the number of foreign exporters change. On one hand, when export prices are sticky, foreign exporters' prices become more dependent on home market conditions because of their mark-up (see Eq. 5). This, in turn, increases the dependency of foreign export profits and foreign export cut-off to home conditions. As a result, a stronger stabilization of home conditions leads to a lower volatility of the extensive margin of trade in the foreign country.

When the foreign country pegs its nominal exchange rate to the leader, the latter has a higher stabilization power given its focus on domestic variables. When countries integrate in a monetary union, home and foreign conditions have the same weight for monetary policy. This implies that home domestic conditions are not as strongly stabilized as in the fixed exchange rate case resulting in a higher volatility of the foreign extensive margin of trade. This happens dispites foreign country domestic conditions are more important for policymakers. On the other hand, when export prices are flexible, the relative dependence of foreign extensive margin of trade to home conditions falls since their mark-up is constant. As a result, when countries integrate a monetary union, and foreign conditions become relevant for monetary policy, foreign volatility of the extensive margin of trade falls.

In the forth case (presented in the columns below "$\tilde{\pi}_t$ targetting"), central banks target data-consistent CPI and both prices are sticky ($\eta_1 > 0, \eta_2 > 0$). Under these assumptions, the model is able to qualitatively predict AEP's empirical results for a wide range of different calibrations. In addition, because central banks take into consideration the role of imported inflation, the magnitudes of the change in the volatility of the extensive margin of trade are closer to the empirical ones reported by AEP. Using the baseline calibration, the leader's volatility of the extensive margin of trade falls by 21.88% and increases for followers by 5.75%. Nevertheless, on the contrary of AEP's empirical results, the change, in absolute value, in the volatility of the extensive margin of trade for the leader is higher than for the follower.

5 Conclusion

In this paper, I have commented on AEP's contributions. I have shown that their inconsistencies in the model derivations and log-linearizations led to biased theoretical results. In addition, I have also analyzed the role of sticky export prices on the effect of monetary unification on the volatility of the extensive margin of trade. I also considered two different inflation targets for central banks, PPI inflation and data-consistent CPI.

I found that sticky export prices are crucial for the model to be qualitatively able to mimic AEP's empirical results. This result, however, is dependent on the weight central banks attach to output stabilization. In addition, I found that if central banks target data-consistent CPI, the model's results are quantitatively closer to AEP's empirical results.

AEP makes an important contribution to our understanding of the volatility of the extensive margin of trade. In addition, AEP is also pioneer in the introduction of sticky-prices into G&M framework. I hope my comment complements and improves their contributions leading to a deeper understanding of the volatility of the extensive margin of trade.

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Table 1: Changes in the volatility of the extensive margin of trade, in %.

	Sticky-prices		ll correction		Flexible $\rho_{x,t}(\omega)$		$\tilde{\pi}_t$ targetting		AEP report	
	H	F	H	F	H	F	H	F	H	F
Baseline	-10.29	1.63	-8.77	-2.38	-4.76	-0.76	-21.88	5.75	-5.56	0.53
$\varphi = 0.25$	-10.31	1.54	-8.77	-2.54	-4.73	-0.84	-19.81	4.31	-5.58	0.46
$\varphi = 0.30$	-10.32	1.47	-8.77	-2.67	-4.70	-0.90	-17.79	2.98	-5.59	0.41
$\gamma = 1$	-9.16	3.91	-7.80	0.88	-4.59	1.20	-19.47	9.80	-6.23	2.87
$\gamma = 5$	-11.88	-0.07	-10.52	-5.13	-5.42	-2.31	-24.53	2.79	-5.83	-1.39
$\psi = 0.5$	-11.46	0.33	-9.71	-5.14	-4.91	-2.05	-23.52	3.19	-6.56	-0.55
$\psi = 5$	-8.11	2.13	-6.78	-0.31	-3.93	0.19	-18.51	6.64	-4.07	0.80
$\eta = 1$	-2.80	2.28	-2.32	1.68	-1.40	1.12	-7.83	7.29	-1.44	1.05
$\eta = 10$	-16.51	-5.26	-15.54	-10.84	-8.86	-6.09	-30.15	-5.84	-9.37	-1.95
$\rho(a_t; a_t^*) = 0.25$	-9.28	1.44	-7.57	-2.03	-4.23	-0.67	-20.10	5.04	-5.34	0.51
$\rho(a_t; a_t^*) = 0.50$	-7.77	1.17	-5.96	-1.57	-3.45	-0.54	-17.28	4.05	-4.95	0.47
$\phi_y = 0$	-0.60	0.53	-1.10	0.99	-0.76	0.71	-13.39	12.18	-0.20	0.19
$\phi_y = 0.125$	-5.02	3.12	-4.13	1.55	-2.29	1.02	-17.70	11.22	-2.62	1.33
$\phi_y = 0.5$	-19.86	-7.78	-18.08	-14.06	-10.51	-7.11	-28.69	-8.35	-11.78	-4.39

Appendix A

Under the case $\eta_1 > 0, \eta_2 = 0$, the real export profits are

$$d_{x,t}(\omega) = q_t \frac{1}{\theta}(\rho_{x,t}(\omega))^{1-\theta} c_t^* - f_x \frac{\bar{w}_t}{a_t}.$$

where I use $y_t^{*d} = c_t^*$ since foreign consumers only demand home made goods for consumption purposes. The export cut-off firm is

$$z_{x,t} = (1+\tau)\frac{\theta}{\theta-1}\left(\theta \frac{f_x}{c_t^*}\right)^{\frac{1}{\theta-1}} \left(\frac{\bar{w}_t}{q_t a_t}\right)^{\frac{\theta}{\theta-1}}$$

The average real export price is

$$\tilde{\rho}_{x,t} \equiv \rho_{x,t}(\tilde{z}_{x,t}) = \frac{\theta}{\theta-1}\frac{\bar{w}_t}{\nabla z_{x,t} a_t}$$

The labor market clearing conditions are

$$l_t = n_t \frac{\tilde{d}_{d,t}}{\left(\mu_{d,t} - \frac{\eta}{2}\pi_{d,t}^2 \mu_{d,t} - 1\right)} \frac{1}{\bar{w}_t} + \frac{\theta-1}{\bar{w}_t} n_{x,t}\tilde{d}_{x,t} + \frac{\theta}{a_t} n_{x,t} f_x + \frac{1}{a_t} n_{e,t} f_e,$$

Note that all these equations are the same as in Ghironi & Melitz (2005).

Appendix B

Under the case $\eta_1 > 0, \eta_2 > 0$, the real export profits are

$$d_{x,t}(\omega) = \left(1 - \frac{\eta}{2}\pi_{x,t}^2 - \mu_{x,t}^{-1}\right) q_t (\rho_{x,t}(\omega))^{1-\theta} c_t^* - \frac{\bar{w}_t f_x}{a_t},$$

where I use $y_t^{*d} = c_t^*$ since foreign consumers only demand home made goods for consumption purposes. The export cut-off firm is

$$z_{x,t} = \left(1 - \frac{\eta}{2}\pi_{x,t}^2 - \mu_{x,t}^{-1}\right)^{\frac{1}{1-\theta}} (1+\tau)\mu_{x,t} \left(\frac{f_x}{c_t^*}\right)^{\frac{1}{\theta-1}} \left(\frac{\bar{w}_t}{q_t a_t}\right)^{\frac{\theta}{\theta-1}},$$

The average real export price is

$$\tilde{\rho}_{x,t} = q_t^{-1}(1+\tau)\mu_{x,t}\frac{\bar{w}_t}{a_t \nabla z_{x,t}},$$

The labor market clearing conditions are

$$\begin{aligned} l_t = n_t &\frac{\tilde{d}_{d,t}}{\left(\mu_{d,t} - \frac{\eta}{2}\pi_{d,t}^2\mu_{d,t} - 1\right)}\frac{1}{\bar{w}_t} + n_{x,t}\frac{\tilde{d}_{x,t}}{\left(\mu_{x,t} - \frac{\eta}{2}\pi_{x,t}^2\mu_{x,t} - 1\right)}\frac{1}{\bar{w}_t} \\ &+ n_{x,t}\frac{f_x}{a_t}\left(\frac{1}{\left(\mu_{x,t} - \frac{\eta}{2}\pi_{x,t}^2\mu_{x,t} - 1\right)} + 1\right) + n_{e,t}\frac{f_e}{a_t} \end{aligned}$$

Appendix C

Log-linearizing of the evolution on the total number of varieties yields

$$\begin{aligned} \hat{n}_t - (1-\delta)\hat{n}_{t-1} - \delta\hat{n}_{e,t-1} = 0 \\ \hat{n}_t^* - (1-\delta)\hat{n}_{t-1}^* - \delta\hat{n}_{e,t-1}^* = 0 \end{aligned}$$

Log-linearizing of total average profits yields

$$\begin{aligned} \frac{\tilde{\rho}_d^{1-\theta}c}{\theta}\hat{\tilde{d}}_{d,t} + \varphi(k_1-1)f_x\frac{\bar{w}}{a}(\hat{n}_{x,t} - \hat{n}_t + \hat{\tilde{d}}_{x,t}) - f_e\Phi\bar{w}\hat{\tilde{d}}_t = 0 \\ \frac{\tilde{\rho}_d^{1-\theta}c}{\theta}\hat{\tilde{d}}_{d,t}^* + \varphi(k_1-1)f_x\frac{\bar{w}}{a}(\hat{n}_{x,t}^* - \hat{n}_t^* + \hat{\tilde{d}}_{x,t}^*) - f_e\Phi\bar{w}\hat{\tilde{d}}_t^* = 0 \end{aligned}$$

Note that in the last two equations even though f_e and a are assumed to be 1, $\bar{w} \neq 1$.

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