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The Harrod-Balassa-Samuelson effect and endogenous extensive margins☆

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Abstract

In the last few decades, the world economy has witnessed the expansion of trade especially in the number of exchanged varieties, the so-called "extensive margins". In a theoretical model where extensive margins in both traded and non-traded sectors are endogenously determined, it is shown that the HBS effect is amplified. Following an HBS productivity shock, when countries expand their extensive margins rather than scale of production, wages appreciate further. Therefore, the expansion in extensive margins leads to a stronger appreciation in the price of non-traded goods. A panel regression across OECD countries indicates consistency with the theoretical model.

Keywords: *The Harrod-Balassa-Samuelson effect, firm entry, real exchange rate, extensive margin*
JEL classification: F12, F41, F43

1. Introduction

The Harrod-Balassa-Samuelson (HBS) effect (Balassa (1964), Harrod (1933) and Samuelson (1964)) is known to result in an increase in a country's real

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exchange rate. The mechanism through which the real exchange rate appreciates can be described as follows. Whenever the traded sector experiences higher productivity gains than the non-traded sector, under the assumption of perfect labor market integration a countrywide wage increase results in the appreciation of price levels, in the non-traded more so than in the traded sector. This leads to an overall CPI inflation relative to other countries.

Traditionally the HBS effect is based on the implicit assumption that firms adjust only their production output of existing goods, i.e. intensive margins. It is generally assumed that no adjustment is made in the variety of new products or via entry of new firms, the so-called extensive margins.

Figure 1 shows the average growth of 4-digit Standard International Trade Classification (SITC) of exported and imported goods in the U.S. bilateral trade with 15 OECD countries.[1] From 1980 to 2000 the average 4-digit SITC exports into the U.S. and imports from the U.S. increased by 38.1% and 13.4%, respectively. When a country's consumption basket contains higher number of varieties, a real depreciation of its welfare-based price index is implied. Broda and Weinstein (2004, 2006) discuss the direct consequence of extensive margins on welfare, stemming from the increased number of imported varieties in the U.S. over the last 30 years.

[Figure1]

This theoretical paper addresses the following questions. How will the classical HBS effect be affected by such a long run expansionary trend in extensive margins? What is the consequence of an expansion in extensive margins on a country's relative wages, terms of trade and relative domestic prices between traded and non-traded goods? How would the international transmission mechanism be influenced by such an expansion of extensive margins?

The model setup is very classical on the one hand: two countries, two sectors and one factor of production. On the other hand, the model is of a general equilibrium type based on monopolistic competition with endogenously determined traded and non-traded extensive margins.

The recent literature on the HBS effect emphasizes the role played by heterogenous firms, in which firms differ according to their productivities,

[1] Countries include Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan,, Netherlands, Norway, Portugal, Spain and United Kingdom. 4-digit SITC covers 9980 product categories.

exporting requires fixed costs and therefore only the more productive firms can successfully export (Melitz (2003)). Based on this approach, Ghironi and Melitz (2005) and Bergin et al. (2006) discuss how the traditional HBS effect can be adopted to such a setup with heterogenous firm productivities.

In our model firms within the traded respectively non-traded sectors are homogenous in terms of their productivities. Even then, a change in extensive margins might arise endogenously and asymmetrically in both sectors. This sector specific adjustment is the result of the interaction of classical substitution and income effects between the traded and non-traded goods.

Our key results are as follows: an HBS type productivity shock leads to an expansion in extensive margins in the traded sector. This is driven by each firm's choice of location under costly trade. As a result, the country's wage level increases due to not only the positive productivity shock, but also given consumers' preference for variety. A broader range of exported varieties in turn acts as a positive demand shock that amplifies a country-wide wage appreciation. As a consequence, prices in the non-traded sector increase beyond the levels anticipated under the traditional HBS mechanism.

Such a strong wage appreciation due to an expansion in extensive margins raises the possibility of an improvement in the terms of trade (Krugman (1989), Corsetti et al. (2007)).[2] This in itself might be viewed by other countries as a negative spillover effect who may face more expensive imported goods. However as long as consumers display a preference for variety, their utility from consuming a broader rage of imported varieties at higher prices could still increase.

This is in sharp contrast to the traditional model where the gains of a productivity shock are transmitted to other countries only through a depreciation in the terms of trade.[3] The results of our numerical simulation are consistent with Broda and Weinstein (2004, 2006) , which emphasize the importance of taking into account the welfare implications of expanded extensive margins.

[2] Several empirical studies support the view that the terms of trade appreciate due to extensive margins (Debaere and Lee. (2004), Hummels and Klenow (2005), Galstyan and Lane (2008)).

[3] Acemoglu and Ventura (2002) argue such income redistributive role of terms of trade. But the empirical evidence often goes against this traditional view. For instance, Corsetti et al. (2006) and Kollmann (2008) with VAR estimates report the heterogeneity in terms of trade variations among industrialized countries.

We also conducted an empirical investigation of the theoretical model using a panel data set. Our model predicts that in addition to their indirect impact through the amplified wage appreciation, higher extensive margins should result in the depreciation of the welfare-based price index. Méjean (2008) tests how extensive margins may directly impact the HBS hypothesis in a panel cointegration framework. She finds that the direct composition effect of changing extensive margins plays a minor role in the determination of real exchange rate fluctuations. Our regression analysis finds similar results.

The structure of the paper is as follows. In section 2 the model and its equilibrium conditions are presented. Section 3 discusses the comparative statics as well as the corresponding welfare implications. Section 4 analyzes both analytically and numerically how the endogenously determined extensive margins amplify the HBS effect. In section 5, the relevance of the model is investigated using a panel data regression across OECD countries. Section 6 concludes.

2. The model

The world economy consists of two countries, Home and Foreign, each comprising traded and non-traded sectors. Foreign variables are denoted with asterisks. There are n_T (n_T^*) and n_N (n_N^*) Home (Foreign) traded and non-traded firms which are endogenously determined, each representing one product variety. Each country is populated by one unit mass of households which supply labor in an elastic way. Production of traded and non-traded goods only require labor as input. Trade is balanced.

2.1. Households

The utility of a representative household in Home increases with consumption C and decreases with labor supply l:

$$U = \ln C - l. \tag{1}$$

Consumption is composed of traded (C_T) and non-traded goods (C_N):

$$C = \left[\delta^{\frac{1}{\rho}} C_T^{1-\frac{1}{\rho}} + (1-\delta)^{\frac{1}{\rho}} C_N^{1-\frac{1}{\rho}} \right]^{\frac{1}{1-\frac{1}{\rho}}}, \tag{2}$$

where δ $(1-\delta)$ is preference weight for traded (non-traded) goods. The parameter ρ denotes the elasticity of substitution between traded and non-traded goods. C_T and C_N are also composed of n_T and n_N varieties as follows:

$$C_T = \left[\int_0^{n_T} c\left(h_T\right)^{1-\frac{1}{\sigma}} dh_T + \int_0^{n_T^*} c\left(f_T\right)^{1-\frac{1}{\sigma}} df_T \right]^{\frac{1}{1-\frac{1}{\sigma}}}, \quad C_N = \left[\int_0^{n_N} c\left(h_N\right)^{1-\frac{1}{\sigma}} dh_N \right]^{\frac{1}{1-\frac{1}{\sigma}}}, \tag{3}$$

where $c(h_T)$, $c(f_T)$ and $c(h_N)$ denote the demand for Home traded, Foreign traded and Home non-traded varieties which are indexed by $h_T \in [0, n_T]$, $f_T \in [0, n_T^*]$ and $h_N \in [0, n_N]$ respectively. The parameter σ is the elasticity of substitution among the varieties. The love for variety is therefore specified following Dixit-Stiglitz (Dixit and Stiglitz (1977)). It follows that the marginal utility in consuming one additional variety is represented by $1/(\sigma - 1)$. We follow convention such that $\sigma > 1$, $\rho > 0$ and $0 < \delta < 1$.

We now discuss the consumer optimization problem. We examine a static economy with no household level investment decision. The total amount of investments which are equally shared among domestic households coincides with the total amount of firm dividends which are also equally distributed. All firm profits are paid out as dividends. This implies that the total amount of investments equals total firm profits in Home.

The budget constraint for the Home representative household becomes:

$$\int_0^{n_T} p\left(h_T\right) c\left(h_T\right) dh_T + \int_0^{n_T^*} p\left(f_T\right) c\left(f_T\right) df + \int_0^{n_N} p\left(h_N\right) c\left(h_N\right) dh_N \leq l. \tag{4}$$

where nominal wages are set as numéraire ($w = 1$). By maximizing the utility under the above constraint, labor supply and the optimal consumption can be found as

$$l = 1, \qquad C = P^{-1}, \tag{5}$$

where the consumer price index is defined as

$$P = \left[\delta P_T^{1-\rho} + (1-\delta) P_N^{1-\rho}\right]^{\frac{1}{1-\rho}}, \tag{6}$$

and

$$P_T = \left[\int_0^{n_T} p\left(h_T\right)^{1-\sigma} dh_T + \int_0^{n_T^*} p\left(f_T\right)^{1-\sigma} df_T \right]^{\frac{1}{1-\sigma}}, \quad P_N = \left[\int_0^{n_N} p\left(h_N\right)^{1-\sigma} dh_N \right]^{\frac{1}{1-\sigma}}. \tag{7}$$

In the above expressions $p(h_T)$, $p(f_T)$ and $p(h_N)$ denote the prices of individual varieties. It is worth noting that, as a result of maximization, consumption depends on only real wages (P^{-1}). This is because the substitution and income effects cancel out on labor supply.[4]

The optimal consumption for traded and non-traded goods are given by:

$$C_T = \delta \left(\frac{P_T}{P} \right)^{-\rho} C, \qquad C_N = (1-\delta) \left(\frac{P_N}{P} \right)^{-\rho} C. \tag{8}$$

Symmetrically, the optimal consumption for individual traded and non-traded varieties are found,

$$c\left(h_T\right) = \left(\frac{p\left(h_T\right)}{P_T} \right)^{-\sigma} C_T, \; c\left(f_T\right) = \left(\frac{p\left(f_T\right)}{P_T} \right)^{-\sigma} C_T, \; c\left(h_N\right) = \left(\frac{p\left(h_N\right)}{P_N} \right)^{-\sigma} C_N. \tag{9}$$

Similar expressions hold in Foreign.

2.2. Firms

Firms in the traded and non-traded sectors in Home each have a sector specific technology which is linear in the employed labor,

$$y\left(h_T\right) = \alpha_T l(h_T), \qquad y\left(h_N\right) = \alpha_N l(h_N), \tag{10}$$

where $y(h_T)$ $(y\left(h_N\right))$ represents the production scale of individual traded (non-traded) firms. α_T (α_N) denotes a productivity shock in production and $l(h_T)$ $(l(h_N))$ denotes the labor demand for the production in the traded (non-traded) sector.

Traded firms sell their products abroad as well as domestically. We assume exports with iceberg trade cost, where a fraction of τ disappears during

[4] It is easily shown that the result holds with an inelastic labor supply function as well. This is also the case for a more general non-separable utility between consumption and leisure as analyzed in Stockman and Tesar (1995).

transport. The resource constraint for each traded and non-traded firm becomes:

$$y(h_T) \geq c(h_T) + (1+\tau)c^*(h_T), \qquad y(h_N) \geq c(h_N), \tag{11}$$

and their operational real profits (in terms of Home labor unit) are given by:

$$\pi(h_T) = p(h_T)c(h_T) + \varepsilon p^*(h_T)c^*(h_T) - l(h_T), \qquad \pi(h_N) = p(h_N)c(h_N) - l(h_N), \tag{12}$$

where $p^*(h_T)$ denotes the price of individual Home traded varieties in Foreign, expressed in terms of Foreign labor unit. It follows that ε denotes the relative wage between Home and Foreign. For example, a lower ε represents a real wage appreciation in Home.

Prices are determined by the firms' monopolistic profit maximizing behavior,

$$p(h_T) = \frac{\sigma}{\sigma-1}\frac{1}{\alpha_T} \equiv p_T, \qquad p(h_N) = \frac{\sigma}{\sigma-1}\frac{1}{\alpha_N} \equiv p_N, \tag{13}$$

where p_T and p_N denote the prices which are symmetric among firms. Note also that with trade cost the price of Home exported goods can be expressed as $p^*(h_T) = \varepsilon^{-1}p(h_T)(1+\tau)$.

We therefore obtain the price indices,

$$P_T = p_T \Omega^{\frac{1}{1-\sigma}}, \qquad P_N = p_N n_N^{\frac{1}{1-\sigma}}, \tag{14}$$

where $\Omega \equiv n_T + n_T^* \phi(\varepsilon p_T^*/p_T)^{1-\sigma}$ $(\Omega^* \equiv n_T^* + n_T \phi(\varepsilon p_T^*/p_T)^{\sigma-1})$ captures the degree of competition among traded varieties in Home (Foreign) market. The parameter ϕ represents the "freeness" of trade which is defined as $\phi \equiv (1+\tau)^{1-\sigma}$ $(0 \leq \phi \leq 1)$; thus $\phi = 1$ means complete trade liberalization. Observe that an expansion in extensive margins translates into a deflation into these price indices.

Finally, using the above expressions, profits can be rewritten as:[5]

$$\pi_T = \frac{\delta p_T^{1-\rho}}{\sigma}\left[\frac{1}{\Omega^{\frac{\rho-\sigma}{1-\sigma}}P^{1-\rho}} + \phi\frac{\varepsilon^{\sigma}\left(p_T^*/p_T\right)^{\sigma-\rho}}{\Omega^{*\frac{\rho-\sigma}{1-\sigma}}P^{*1-\rho}}\right], \quad \pi_N = \frac{(1-\delta)\,p_N^{1-\rho}}{\sigma}\frac{1}{n_N^{\frac{\rho-\sigma}{1-\sigma}}P^{1-\rho}}. \tag{16}$$

π_T and π_N denote the equilibrium profits for the Home representative traded and non-traded firm. Observe that profits of exporting firms are decomposed into their domestic and export components. Similar expressions hold in Foreign.

2.3. Entry and balanced trade

Firm creation in the traded (non-traded) sector requires $1/\nu_T$ $(1/\nu_N)$ units of labor. ν_T (ν_N) denotes a productivity shock in the cost of firm creation in the traded (non-traded) sector. At equilibrium operational profits in each sector in each country must be equal to the cost of entry:

$$\pi_T = \frac{1}{\nu_T}, \qquad \pi_N = \frac{1}{\nu_N}, \qquad \pi_T^* = \frac{1}{\nu_T^*}, \qquad \pi_N^* = \frac{1}{\nu_N^*}. \tag{17}$$

Furthermore more given the balanced trade assumption, aggregate profits from export sales should be the same across both countries:[6]

$$\frac{\delta\phi}{\sigma}\left[\frac{n_T p_T^{1-\rho}\varepsilon^{\sigma}\left(p_T^*/p_T\right)^{\sigma-\rho}}{\Omega^{*\frac{\rho-\sigma}{1-\sigma}}P^{*1-\rho}} - \frac{n_T^* p_T^{*1-\rho}\varepsilon^{1-\sigma}\left(p_T^*/p_T\right)^{\rho-\sigma}}{\Omega^{\frac{\rho-\sigma}{1-\sigma}}P^{1-\rho}}\right] = 0. \tag{19}$$

[5] Those of Foreign counterparts are given by,

$$\pi_T^* = \frac{\delta p_T^{*1-\rho}}{\sigma}\left[\frac{1}{\Omega^{*\frac{\rho-\sigma}{1-\sigma}}P^{*1-\rho}} + \phi\frac{\varepsilon^{-\sigma}\left(p_T^*/p_T\right)^{\rho-\sigma}}{\Omega^{\frac{\rho-\sigma}{1-\sigma}}P^{1-\rho}}\right], \quad \pi_N^* = \frac{(1-\delta)\,p_N^{*1-\rho}}{\sigma}\frac{1}{n_N^{*\frac{\rho-\sigma}{1-\sigma}}P^{*1-\rho}}. \tag{15}$$

[6] This is basically the same condition as the fact that real export sales equalizes across countries under balanced trade such that

$$n_T^* p(f_T)c(f_T) = n_T\varepsilon p^*(h_T)c^*(h_T). \tag{18}$$

In summary, the model contains five equilibrium conditions (four free entry conditions and the balanced trade condition) and five endogenously determined variables: $n_{T,}$ n_{N}, n_T^*, n_N^* and ε.

Note that with the above free entry conditions (17), the production scale in each traded and non-traded firm is given by:[7]

$$y_T = (\sigma - 1)\frac{\alpha_T}{\nu_T}, \qquad y_N = (\sigma - 1)\frac{\alpha_N}{\nu_N}. \tag{20}$$

We now discuss the parametric restrictions necessary to prevent full agglomeration of firms. Using the balanced trade condition (19), profits in each sector are rewritten as:

$$\pi_T = \frac{P_T C_T}{\sigma n_T}, \qquad \pi_N = \frac{P_N C_N}{\sigma n_N}. \tag{21}$$

These expressions highlight how extensive margins are connected to profits. Each denominator represents a direct competition effect, each sector's profits decrease proportionally with an expanding extensive margins (n_T and n_N). On the other hand profits increase proportionally with nominal consumption spending in that sector ($P_T C_T$ and $P_N C_N$). The latter is also the function of extensive margins.

For instance, inspecting the demand function of traded goods (8), a 1% rise in n_T increases $P_T C_T$ by approximately $\frac{(\rho-1)(1-\delta)}{\sigma-1}$ %.[8] This rise in profits with higher nominal spending (the numerator) is balanced by the direct competition effect (the denominator). We obtain a finite number of firms in each country and full agglomeration of firms can be avoided when the latter condition is smaller than one. Combined with the conventional $\sigma > 1$ and $0 < \delta < 1$ the above condition is satisfied when

[7] Using optimal pricing conditions (13) we can rewrite operational profits in each sector as

$$\pi_T = \frac{1}{\sigma} p_T y_{h_T}, \qquad \pi_N = \frac{1}{\sigma} p_N y_{h_N}.$$

Combined with (17) we get (20).

[8] "Approximately", because as we shall see, a rise in the number of varieties result in an appreciation of relative wages which makes it harder to enter into that market compared to abroad. Corsetti et al. (2007) also neglect such an effect which passes through in general equilibrium when they discuss the restriction on parameters.

$$\rho \leq \sigma.$$

Product substitution is therefore stronger among varieties than between traded and non-traded goods. This is intuitive and assumed from here on.

3. Comparative statics

We introduce positive productivity shocks in each of the traded and non-traded sectors, which reduce marginal cost in production or entry cost ($d\alpha_T > 0$ or $d\nu_T > 0$ and $d\alpha_N > 0$ or $d\nu_N > 0$). Following each type of shock, the comparative statics results are provided. At the symmetric steady state, we set $\overline{\alpha}_T = \overline{\alpha}_N = \overline{\nu}_T = \overline{\nu}_N = \overline{\alpha}_T^* = \overline{\alpha}_N^* = \overline{\nu}_T^* = \overline{\nu}_N^* = 1$ without loss of generality. It is straightforward that at the symmetric steady state $\overline{n}_T = \overline{n}_T^*$ and $\overline{n}_N = \overline{n}_N^*$. Because trade is balanced $\overline{\varepsilon} = 1$. The steady state ratio between the number of traded and non-traded extensive margins is denoted by $\lambda \equiv \overline{n}_T/\overline{n}_N$ (see appendix A). As a consequence the steady state share of nominal spending on the traded and non-traded goods are expressed by $\lambda/(\lambda+1)$ and $1/(\lambda+1)$ respectively.[9] Table 1 and Table 2 show the results of comparative statics.

3.1. Endogenous determination of traded and non-traded extensive margins

Extensive margins in both sectors are determined endogenously. They depend crucially on the elasticity of the substitution between traded and non-traded goods, ρ. It is well known that ρ determines the strength of substitution effect following variations in relative prices of traded and non-traded goods (P_N/P_T). Even with identical productivities among firms within each sector, changes in the non-traded extensive margins arise endogenously. This stands in contrast to the supply side explanation based on heterogenous marginal costs in production across firms (Melitz (2003), Ghironi and Melitz (2005), Bergin et al. (2006)).

More specifically, in line with the Slutsky equation, variations in extensive margins in Home as a result of any shock dx can be expressed as (see appendix B for details):

$$\frac{1}{\overline{n}_T}\frac{dn_T}{dx} = (\rho - 1)\left(\frac{1}{\lambda+1}\right)\left[\frac{1}{\overline{P}_N}\frac{dP_N}{dx} - \frac{1}{\overline{P}_T}\frac{dP_T}{dx}\right] + \frac{1}{\overline{\nu}_T}\frac{d\nu_T}{dx}, \tag{22}$$

[9] These equal δ and $1-\delta$ under Cobb-Douglas case ($\rho = 1$).

Shock on Home traded sector

$$\frac{1}{\overline{n}_T}\frac{dn_T}{d\alpha_T} = (\rho-1)\left(\frac{1}{1+\lambda}\right)(\sigma-1)\left[\frac{1}{\sigma-\rho} - \frac{\phi}{\Delta}(1+\Upsilon)\right],$$

$$\frac{1}{\overline{n}_N}\frac{dn_N}{d\alpha_T} = -(\rho-1)\left(\frac{\lambda}{1+\lambda}\right)(\sigma-1)\left[\frac{1}{\sigma-\rho} - \frac{\phi}{\Delta}(1+\Upsilon)\right],$$

$$\frac{1}{\overline{n}_T}\frac{dn_T^*}{d\alpha_T} = (\rho-1)\left(\frac{1}{1+\lambda}\right)(\sigma-1)\frac{\phi}{\Delta}(1+\Upsilon),$$

$$\frac{1}{\overline{n}_N}\frac{dn_N^*}{d\alpha_T} = -(\rho-1)\left(\frac{\lambda}{1+\lambda}\right)(\sigma-1)\frac{\phi}{\Delta}(1+\Upsilon),$$

$$\frac{1}{\overline{\varepsilon}}\frac{d\varepsilon}{d\alpha_T} = -(\sigma-1)\left\{(\sigma-\rho)(1-\phi) + (1+\phi)\left[(\sigma-1) - (\rho-1)\left(\frac{\lambda}{1+\lambda}\right)\right]\right\}\Delta^{-1} < 0,$$

Shock on Home non-traded sector

$$\frac{1}{\overline{n}_T}\frac{dn_T}{d\alpha_N} = -(\rho-1)\left(\frac{1}{1+\lambda}\right)(\sigma-1)\left(\frac{1}{\sigma-\rho} - \frac{\phi}{\Delta}\Upsilon\right),$$

$$\frac{1}{\overline{n}_N}\frac{dn_N}{d\alpha_N} = (\rho-1)\left(\frac{\lambda}{1+\lambda}\right)(\sigma-1)\left(\frac{1}{\sigma-\rho} - \frac{\phi}{\Delta}\Upsilon\right),$$

$$\frac{1}{\overline{n}_T}\frac{dn_T^*}{d\alpha_N} = -(\rho-1)\left(\frac{1}{1+\lambda}\right)(\sigma-1)\frac{\phi}{\Delta}\Upsilon,$$

$$\frac{1}{\overline{n}_N}\frac{dn_N^*}{d\alpha_N} = (\rho-1)\left(\frac{\lambda}{1+\lambda}\right)(\sigma-1)\frac{\phi}{\Delta}\Upsilon,$$

$$\frac{1}{\overline{\varepsilon}}\frac{d\varepsilon}{d\alpha_N} = (\sigma-1)(\rho-1)(1-\phi)\left(\frac{1}{1+\lambda}\right)\Delta^{-1},$$

where $\lambda = \left(\frac{\delta}{1-\delta}\right)^{\frac{\sigma-1}{\sigma-\rho}}(1+\phi)^{\frac{\rho-1}{\sigma-\rho}}$

$$\Delta \equiv (\sigma-\rho)(1-\phi)$$
$$+2\left\{(\sigma-\rho)(\sigma-1) + \phi\left[(\sigma-\rho)\left(\frac{\lambda}{1+\lambda}\right) + \rho(\sigma-1)\left(\frac{1}{1+\lambda}\right)\right]\right\} > 0,$$

and $\Upsilon \equiv (\rho-1)\left(\frac{1}{1+\lambda}\right)\left(\frac{\sigma}{\sigma-\rho}\right)$.

Table 1: Shocks on marginal cost

Shock on Home traded sector
$\frac{1}{\overline{n}_T}\frac{dn_T}{d\nu_T} = (\rho-1)\left(\frac{1}{1+\lambda}\right)\left[\frac{1}{\sigma-\rho} - \frac{\phi}{\Delta}(1+\Upsilon)\right] + 1 > 0,$
$\frac{1}{\overline{n}_N}\frac{dn_N}{d\nu_T} = -(\rho-1)\left(\frac{\lambda}{1+\lambda}\right)\left[\frac{1}{\sigma-\rho} - \frac{\phi}{\Delta}(1+\Upsilon)\right],$
$\frac{1}{\overline{n}_T}\frac{dn^*_T}{d\nu_T} = (\rho-1)\left(\frac{1}{1+\lambda}\right)\left[\frac{\phi}{\Delta}(1+\Upsilon)\right],$
$\frac{1}{\overline{n}_N}\frac{dn^*_N}{d\nu_T} = -(\rho-1)\left(\frac{\lambda}{1+\lambda}\right)\left[\frac{\phi}{\Delta}(1+\Upsilon)\right],$
$\frac{1}{\overline{\varepsilon}}\frac{d\varepsilon}{d\nu_T} = -\left\{(\sigma-\rho)(1-\phi) + (1+\phi)\left[(\sigma-1) - (\rho-1)\left(\frac{\lambda}{1+\lambda}\right)\right]\right\}\Delta^{-1} < 0,$
Shock on Home non-traded sector
$\frac{1}{\overline{n}_T}\frac{dn_T}{d\nu_N} = -(\rho-1)\left(\frac{1}{1+\lambda}\right)\left(\frac{1}{\sigma-\rho} - \frac{\phi}{\Delta}\Upsilon\right),$
$\frac{1}{\overline{n}_N}\frac{dn_N}{d\nu_N} = (\rho-1)\left(\frac{\lambda}{1+\lambda}\right)\left(\frac{1}{\sigma-\rho} - \frac{\phi}{\Delta}\Upsilon\right) + 1 > 0,$
$\frac{1}{\overline{n}_T}\frac{dn^*_T}{d\nu_N} = -(\rho-1)\left(\frac{1}{1+\lambda}\right)\left(\frac{\phi}{\Delta}\Upsilon\right),$
$\frac{1}{\overline{n}_N}\frac{dn^*_N}{d\nu_N} = (\rho-1)\left(\frac{\lambda}{1+\lambda}\right)\left(\frac{\phi}{\Delta}\Upsilon\right),$
$\frac{1}{\overline{\varepsilon}}\frac{d\varepsilon}{d\nu_N} = (\rho-1)(1-\phi)\left(\frac{1}{1+\lambda}\right)\Delta^{-1}.$

Table 2: Shocks on entry cost

$$\frac{1}{\overline{n}_T}\frac{dn_N}{dx} = -(\rho-1)\left(\frac{\lambda}{\lambda+1}\right)\left[\frac{1}{\overline{P}_N}\frac{dP_N}{dx} - \frac{1}{\overline{P}_T}\frac{dP_T}{dx}\right] + \frac{1}{\overline{\nu}_N}\frac{d\nu_N}{dx}. \tag{23}$$

Extensive margins in Home traded (n_T) and non-traded sector (n_N) depend on the income and substitution effects captured in the square brackets in (22) and (23). In addition they depend directly on entry cost shocks.

3.1.1. Shocks on marginal cost

We can find the corresponding expressions in Table 1. For instance, given a positive shock on marginal cost such as $d\alpha_T > 0$, an appreciation of non-traded goods prices (a rise in P_N/P_T) takes place as a result of the conventional HBS effect. This is captured by the expression $(\sigma-1)\left[\frac{1}{\sigma-\rho} - \frac{\phi}{\Delta}(1+\Upsilon)\right] > 0$ in Table 1.[10] Provided this change in relative prices, when traded and non-traded goods are substitutes ($\rho > 1$) higher (lower) demand, higher (lower) expenditures, hence higher (lower) profits in the traded (non-traded) sector are achieved. This is due to the fact that a relatively strong substitution and weak income effects increase (decrease) extensive margins in the traded (non-traded) sector. When traded and non-traded goods are complements ($0 < \rho < 1$) lower (higher) profits in the traded (non-traded) sector come about as a result of relatively weak substitution and strong income effects which decrease (increase) extensive margins in the traded (non-traded) sector.

Furthermore extensive margins in Foreign crucially depend on the elasticity between traded and non-traded goods. With the same marginal cost

[10] To be precise, not only the variations in nominal prices, but also those in extensive margins can directly have impact on theoretical price indices. This is because in general equilibrium, the relative prices between traded and non-traded goods are endogenous with respect to extensive margins as well:

$$\frac{1}{\overline{P}_N}\frac{dP_N}{dx} - \frac{1}{\overline{P}_T}\frac{dP_T}{dx} = \left[\frac{1}{\overline{p}_N}\frac{dp_N}{dx} - \frac{1}{\overline{p}_T}\frac{dp_T}{dx}\right] - \frac{\phi}{1+\phi}\frac{dTOT}{dx}$$
$$-\frac{1}{\sigma-1}\left[\frac{1}{1+\phi}\frac{1}{\overline{n}_T}\frac{dn_T}{dx} + \frac{\phi}{1+\phi}\frac{1}{\overline{n}_T}\frac{dn_T^*}{dx} + \frac{1}{\overline{n}_N}\frac{dn_N}{dx}\right].$$

The results in Table 1 and Table 2 reflect such a general equilibrium impact.

shock in Home, a deflation of imported goods prices takes place as a consequence of productivity gains in Home. Hence, traded goods become cheaper than non-traded goods in Foreign (a rise in P_N^*/P_T^*).[11] When traded and non-traded goods are substitutes (complements), Foreign traded extensive margins (n_T^*) rise (decrease) and Foreign non-traded extensive margins (n_N^*) decrease (rise) because (in spite) of lower prices of traded goods. Naturally, changes in Foreign extensive margins are smaller compared to those in Home.

We now turn to a positive marginal cost shock hitting the non-traded sector in Home, $d\alpha_N > 0$. First of all the prices of non-traded goods depreciates (a decrease of P_N/P_T, captured by $-(\sigma-1)\left(\frac{1}{\sigma-\rho}-\frac{\phi}{\Delta}\Upsilon\right) < 0$ in Table 1). Symmetrically, when traded and non-traded goods are substitutes (complements), such a shock increases (decreases) extensive margins in the non-traded sector (n_N) while decreasing (increasing) extensive margins in the traded sector (n_T). In analogy to shocks affecting the traded sector, shocks in the non-traded Home sector impact both traded and non-traded extensive margins in Foreign, although very small in magnitude.

3.1.2. Shocks on entry cost

The income and substitution effects discussed above are also observed in the case of entry cost shocks, $d\nu_T > 0$ and $d\nu_N > 0$. In addition to similar effects arising from marginal cost shocks, entry cost shocks can directly expand extensive margins the sector experiencing the shock as it is shown in Table 2. This direct impact is also captured in the last terms of equations (22) and (23).

Note in particular, when the income and substitution effects cancel each other ($\rho = 1$), only such entry cost shocks influence the extensive margins.[12]

[11] This is mainly due to a higher number of imported varieties from Home. See the discussion in section 3.3.

[12] The consequents of a Cobb-Douglas preference is similar to those of a pure income shock. In the latter case, a 1% increase in market size due to a sudden increase in Home population results in a symmetric 1% rise in nominal spending for both traded and non-traded sectors. Free entry conditions require that these higher profits be driven to zero by the entry of new firms. Without any productivity shock, relative prices between traded and non-traded goods remain unchanged. So we observe that a pure income effect for both goods increases both sectors' extensive margins identically. At the same time, the balanced trade condition would require an appreciation of the terms of trade (wage appreciation due to higher extensive margins in Home traded sector).

3.2. Relative wages and the terms of trade

Table 1 and Table 2 also show the general equilibrium response of relative wages, ε, which are the key in considering the HBS effect. It is shown that for both types of shocks which hit the traded sector, $d\alpha_T > 0$ and $d\nu_T > 0$, Home wages appreciate.

In order to see the impact of a change in extensive margins on relative wages, it would be interesting to contrast our model with a standard "fixed" variety economy where the adjustment takes place only in terms of production scale, i.e. intensive margins. Appendix C provides the description of such a fixed variety economy. We define the HBS productivity process as $dz_T \equiv d\alpha_T = d\nu_T > 0$ which improve technology both in production and entry simultaneously in the traded sector. The comparison between fixed and flexible variety economy is made under such a shock. As we will see the contrast appears sharply by comparing the terms of trade (TOT) which include by definition the variations in relative wages. We define $TOT \equiv \varepsilon p_T^*/p_T$ such that positive variations in the terms of trade represents a depreciation for Home.

3.2.1. Fixed variety economy

In a fixed variety economy it is shown that the terms of trade depreciate after an HBS shock:

$$\frac{1}{\overline{\overline{TOT}}} \frac{dTOT}{dz_T} = \frac{1}{\overline{\varepsilon}} \frac{d\varepsilon}{dz_T} + 1 > 0. \tag{24}$$

In such a standard model without entry, a country which is hit by a positive productivity shock provides its goods at lower prices in spite of a wage appreciation.

3.2.2. Flexible variety economy

Under the flexible variety economy, however, it is shown that the terms of trade *appreciate* following an HBS type shock:[13]

$$\frac{1}{\overline{z}_T}\frac{dTOT}{dz_T} = \frac{1}{\overline{z}_T}\frac{d\varepsilon}{dz_T} + 1 < 0. \tag{25}$$

Why do the terms of trade appreciate with increasing extensive margins? As we have seen in Table 1 and Table 2, extensive margins increase in Home traded sector primarily due to a positive entry cost shock ($d\nu_T > 0$) and secondly as a result of a substitution effect. Concurrently, when consumers display love for variety, world demand shifts toward goods produced in Home, which results in a strong appreciation in relative wages. This increases the marginal cost of production which in turn results in an appreciation of the terms of trade. In short, the consequence induced by an increase in extensive margins is similar to a positive demand shock. A sort of "home market effect" (Krugman (1980)) is at work where the gains from a productivity shock results in a wage appreciation and higher extensive margins.

We briefly mention the case of an anti-HBS shock $dz_N \equiv d\alpha_N = d\nu_N > 0$. Under such a shock, the variations in the terms of trade coincide with those of relative wages without any productivity change in the traded sector:

$$\frac{1}{\overline{z}_N}\frac{dTOT}{dz_N} = \frac{1}{\overline{z}_N}\frac{d\varepsilon}{dz_N}. \tag{26}$$

As it is seen in Table 1 and Table 2, relative wages appreciate only when the Home traded sector provides higher extensive margins compared to those in the Foreign traded sector. This is the case under $0 < \rho < 1$ where the income and substitution effects work in favor of the traded extensive margins. Symmetrically, under $\rho > 1$ wages, hence the terms of trade depreciate.

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[13] Using the expression of relative wages in Table 1 and Table 2, the terms of trade appreciate if and only if the following condition is satisfied:

$$(\sigma - \rho) + \sigma(\rho - 1)\left(\frac{1}{\lambda + 1}\right) > 0$$

This is a linearly increasing function in σ that we define as $f(\sigma)$. When $0 < \rho < 1$, $f(1) = \left(\frac{\lambda}{\lambda+1}\right)(1-\rho) > 0$, so $f(\sigma) > 0$ for $\sigma > 1$. And it is straightforward that the above condition holds when $\rho \geq 1$ because $\sigma \geq \rho$.

3.3. Welfare

Extensive margins have a direct impact on welfare. In this subsection, we investigate the welfare implications of our model with a numerical simulation for both flexible and fixed variety economies. For calibration purposes, the elasticity of substitution among varieties ($\sigma = 3.8$) and the trade cost ($\tau = 0.3$) are chosen from Ghironi and Melitz (2005). The weight on the traded sector ($\delta = 0.25$) is taken from Obstfeld and Rogoff (2004).

Reinhart and Ostry (1992) estimate the elasticity of substitution between traded and non-traded goods (ρ) as 1.22-1.28 for all regions and 0.66-1.44 for each individual region. In contrast Stockman and Tesar (1995) give an estimate of 0.44 and argue that it tends to be low for industrialized countries. Mendoza (1995) on the other hand observes 0.74 for industrialized countries. We simulate the model with a range of $0 < \rho \leq 2$. This range arrows us to observe the interaction between the income and substitution effects previously discussed.

Figure 2 shows the changes in extensive margins and welfare induced by an HBS type shock as a function of the elasticity of traded and non-traded goods for both flexible (solid lines) and fixed (dashed lines) variety economies. In our model, welfare depends only on CPI as follows: $C = P^{-1}$ ($C^* = P^{*-1}$). As shown in the third column panels in Figure 2, the HBS type shock improves welfare (a lower CPI) in Home for the entire range of ρ. The transmission of this productivity shock to Foreign is also positive. This is due to the direct welfare impact from higher imported extensive margins which is only partially countered by the imported price appreciation (the terms of trade appreciation due to extensive margins analyzed in section 3.2.2).

Welfare improves in both flexible and fixed variety economies in both countries. For the fixed variety economy, a positive transmission is driven by the terms of trade depreciation as it is in section 3.2.1.

In contrast to the "welfare-based" CPI, the "empirical-based" or "observed" CPI fails to capture the variations in extensive margins. We define $\widetilde{P}$ to represent the empirical-based CPI. The usage of such a price index is based on the observation that conventional price indices ignore direct welfare gains from variety *even in the long* (see Feenstra (1994) and Broda and Weinstein (2004, 2006)). In defining the exact welfare-based price index based on C.E.S function, they decompose it into the part which reflect average nominal prices and extensive margins. Following Ghironi and Melitz (2005), we define the empirical-based CPI as,

$$\widetilde{P} \equiv P \left(n_T + n_T^* + n_N\right)^{\frac{1}{\sigma-1}} \tag{27}$$

With such a definition, $\widetilde{P}$ only imperfectly captures the variations in extensive margins. The corresponding empirical-based consumption, $\widetilde{C}$ is measured based on such a CPI as $\widetilde{C} = PC/\widetilde{P}$. Similar expressions hold for Foreign. Because the difference does not matter without extensive margins, empirical and welfare-based consumptions are identical in a fixed variety economy.

The last column panels in Figure 2 show such empirical-based consumptions for both countries. What is striking is that an HBS type shock now negatively affects welfare in Foreign. This is because welfare gains from increased imported extensive margins are not taken into account. Moreover, the inflation in imported goods results in a negative welfare transmission. The result is reminiscent of the empirical findings of Broda and Weinstein (2004, 2006). They argue for an inflation bias in the U.S. imported price index and significant (unobserved) welfare gains from higher imported extensive margins.

[Figure 2]

4. The Harrod-Balassa-Samuelson effect with extensive margins

What is the implication of extensive margins for the HBS effect? As it is well known, the HBS effect refers to the real exchange rate appreciation following asymmetric productivity shocks between traded and non-traded sectors. Because empirical-based price indices only partially reflect variations in extensive margins, it is natural to define a real exchange rate (RER) based on the price indices mentioned in the previous section:

$$\widetilde{RER} \equiv \frac{\varepsilon \widetilde{P}^*}{\widetilde{P}}. \tag{28}$$

This is to be contrasted with the welfare-based real exchange rate $RER \equiv \varepsilon P^*/P$ that is defined with the theoretical price indices.

Now we explore the above empirical-based real exchange rate variation following an HBS type shock, $dz_T > 0$. We decompose the variation into three parts following Canzoneri et al. (1999):

$$\frac{1}{\overline{z}_T}\frac{d\widetilde{RER}}{dz_T} = \frac{1-\phi}{1+\phi}\frac{1}{\overline{z}_T}\frac{dTOT}{dz_T}$$
$$- \frac{1}{\lambda+1}\left[\left(\frac{1}{\overline{P}_N}\frac{d\widetilde{P}_N}{dz_T} - \frac{1}{\overline{P}_T}\frac{d\widetilde{P}_T}{dz_T}\right) - \left(\frac{1}{\overline{P}_N}\frac{d\widetilde{P}^*_N}{dz_T} - \frac{1}{\overline{P}_T}\frac{d\widetilde{P}^*_T}{dz_T}\right)\right]$$
$$+ \frac{1}{\sigma-1}\frac{1}{2\lambda+1}\frac{\lambda}{\lambda+1}\left(\frac{1}{\overline{n}_N}\frac{dn_N}{dz_T} - \frac{1}{\overline{n}_N}\frac{dn^*_N}{dz_T}\right), \quad (29)$$

where $\widetilde{P}_T$ and $\widetilde{P}_N$ denote average prices of traded and non-traded goods respectively.

The first term is the impact of terms of trade fluctuations under costly trade ($\phi \neq 1$) and under imperfect substitution among varieties ($\sigma \neq \infty$). The second term captures, the traditional text book HBS effect that is due to international difference in relative prices of non-traded goods.[14] The last term measures the direct welfare impact from changes in extensive margins. For instance, a higher number of non-traded varieties in Home results in a real depreciation.[15]

The specific nature of the HBS effect with extensive margins is twofold. On the one hand, extensive margins provide a further source of variation in the real exchange rate (the third term). On the other hand, as discussed in the previous section, they magnify the wage appreciation. This is reflected by the terms of trade fluctuations (the first term) and international difference in relative prices (the second term). Therefore the original mechanism in the text book HBS effect, namely the real appreciation due to countrywide wage

[14] It would be interesting to see how easily to go back to such a text book effect in the current model. Within the setting of this paper the terms of trade fluctuation arises because varieties are imperfect substitutes. Without product differentiation ($\sigma = \infty$), such a movement of terms of trade disappears. In addition, because of Dixit-Stiglitz preference, the marginal utility which stems from one additional variety $1/(\sigma-1)$ goes to 0. Therefore, only the second term becomes the source of real exchange rate fluctuations as it is described in the traditional HBS effect.

[15] As it is discussed, this term would correspond to an imperfect effort of statistical agencies who change the reference basket in the medium and long run. Because in this model there are no asymmetric fluctuations about the available set of traded varieties between two countries, no term which captures this type of relative availability enters into the HBS decomposition contrary to Ghironi and Melitz (2005).

appreciation (the second term), becomes amplified with extensive margins in flexible variety economy.

A numerical simulation demonstrates our findings. Figure 3 provides a calibrated decompositions of the HBS effect for both flexible and fixed variety economies. The same parameters as in Figure 2 are utilized. Compared to the fixed variety economy where terms of trade depreciate (dashed line), in the flexible variety economy (solid line) the terms of trade appreciate. The second term, the appreciation of prices of non-traded goods, is also amplified in the flexible variety economy. The contribution of the second term is larger than the first term as it is consistent to the prediction of the original HBS theory. In contrast, the impact from the third term remains small. In case of complementary between traded and non-traded goods as observed in industrialized countries ($\rho < 1$), the third term adds only a slight real depreciation.

In the next section, we investigate this empirically.

[Figure3]

5. Empirical testing

We regress these three terms in the previous section with a panel data for 15 OECD countries.[16] All variables of each country are constructed against those of the U.S., considering the U.S. as "Foreign". The first term, the terms of trade, is measured by relative unit labor costs in the traded sector (ULC). The second term, the price of non-traded in terms of traded goods, is constructed using the productivity difference between the sectors (α_T/α_N). What is difficult to measure is the relative number of non-traded extensive margins. We approximate it by the variation of 4-digit SITC in bilateral trade with the U.S. ($SITC$). For instance, a decrease in the number of exported relative to the number of imported goods categories could be interpreted as a rise in non-trade varieties in that country against the U.S.. The equation used for the regression is specified as follows:

$$\ln \frac{\varepsilon_t^i P^{US}}{P_t^i} = \beta_i + \beta_1 \ln \frac{\varepsilon_t^i ULC_t^{US}}{ULC_t^i} + \beta_2 \ln \frac{\alpha_{T,t}^i/\alpha_{N,t}^i}{\alpha_{T,t}^{US}/\alpha_{N,t}^{US}} + \beta_3 \ln \frac{SITC_{it}^{US}}{SITC_{USt}^i} + \mu_{it}, \quad (30)$$

[16] Countries are the same as in Figure 1. See footnote 1.

where $i \in \{1, ..., 15\}$, $t \in \{1980, ..., 2000\}$ and μ_{it} denotes error terms which are supposed to be i.i.d..

The regression encounters the classical problem of endogeneity between regressors and error terms which potentially may arise because of measurement errors and the simultaneous determination of variables at equilibrium. Hausman test shows endogeneity between error terms and the terms of trade (ULC), and the proxy of non-traded extensive margins ($SITC$). To get unbiased estimators, these variables are instrumented by their first period lag. To check the robustness, as alternative measure for the third term, we use the (negative) variation in total R&D expenditure ($R\&D$) and GDP per head ($GDPh$). Although both variables are recommended by Debaere and Lee. (2004) as a good approximation for the nation's variety and quality improvement, the Levin, Lin and Chu test (Levin et al. (2002)) reveals that theses two variables are non-stationary. We therefore makes use their first differences.[17] Both variables are also instrumented by their first period lag. Details about the data are provided in appendix D.

Table 2 documents the results of the regression. In all three specifications, the regressors are significant at 1 or 5% level. Although significant, relatively small coefficients on the second term would point to a slow and sticky adjustment of the traditional HBS channel, possibly induced by an imperfect labor market integration between the sectors. Relatively large coefficients on relative unit labor costs would indicate the importance of terms of trade in real exchange rate fluctuations rather than the original HBS mechanism. This result is reminiscent of Engel (1999) and Betts and Kehoe (2006). The elasticity of the relative number of exported and imported SITC is small (.069), matching the prediction of the theoretical model. Our result also corresponds to the empirical findings of Méjean (2008). She measures the direct composition effect of extensive margins using "supplier access" (Redding and Venables (2004)) in testing the direct welfare-based HBS effect.

[17]A panel cointegration test can be used to check whether the stochastic trends are shared and the equilibrium relationship holds for these two alternative variables. In case of cointegration, the regression with original R&D expenditure and GDP per head show that their elasticity becomes smaller (.210 and 1.15 respectively, both significative at 1% level), but other coefficients do not change dramatically. The details of this regression as well as Levin, Lin and Chu test are available upon request.

$\ln \varepsilon_t^i P_t^{US}/P_t^i$			
$\ln \varepsilon_t^i ULC_t^{US}/ULC_t^i$	.493***	.55***	.527***
	(.037)	(.040)	(.049)
$\ln(\alpha_{T,t}^i/\alpha_{N,t}^i)/\left(\alpha_{T,t}^{US}/\alpha_{N,t}^{US}\right)$	-.077***	-.071***	-.068***
	(.012)	(.013)	(.015)
$\ln SITC_{it}^{US}/SITC_{USt}^i$	.069**		
	(.033)		
$\ln R\&D_t^{US}/R\&D_t^i$		1.29***	
		(.409)	
$\ln GDPh_t^{US}/GDPh_t^i$			3.71**
			(1.45)
Nb observations	300	285	285
Country fixed effect	Yes	Yes	Yes
R^2	.529	.539	.467

Table 2: The HBS decomposition

R&D and GDP per head are their first differences. Regressors are instrumented by their first period lag except international productivity difference between traded and non-traded sector.

Std. in parentheses. ***,** denote significance level at 1% and 5%.

6. Conclusion

In this paper, the HBS effect has been revisited taking into account the recent empirical trends in international trade, including the expansion in extensive margins. The paper shows that the more a country exports in terms of extensive rather than intensive margins, the stronger a real exchange rate appreciation the country will experience. We witness an amplified HBS effect working "indirectly" through the expansion in extensive margins. The model also predicts that there would be a small "direct" impact from a change in extensive margins on the HBS effect. It would be interesting in for future research to explore these findings in dynamic context and revisit the "persistence" and "volatility" puzzle in a real exchange rate fluctuations (Rogoff (1996)).

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Appendix A. Symmetric steady state

The steady state ratio between traded and non-traded extensive margins λ can be found as follows. Using the demand functions (8) and $PC = 1$, profits in each sector at steady state can be rewritten as:

$$\overline{\pi}_T = \frac{1}{\sigma \overline{n}_T} \delta \left(\frac{\overline{P}_T}{\overline{P}} \right)^{1-\rho}, \qquad \overline{\pi}_N = \frac{1}{\sigma \overline{n}_N} (1-\delta) \left(\frac{\overline{P}_N}{\overline{P}} \right)^{1-\rho}.$$

From the definition of price indices P_T and P_N, the relative price between traded and non-traded goods at steady state is given by:

$$\frac{\overline{P}_T}{\overline{P}_N} = \left(\frac{\overline{n}_N}{\overline{n}_T} \frac{1}{1+\phi} \right)^{\frac{1}{\sigma-1}}.$$

Finally taking the ratio of profits for the sectors and combining with the above relation, λ is given by:

$$\lambda \equiv \frac{\overline{n}_T}{\overline{n}_N} = \left(\frac{\delta}{1-\delta} \right)^{\frac{\sigma-1}{\sigma-\rho}} (1+\phi)^{\frac{\rho-1}{\sigma-\rho}}. \tag{A.1}$$

Observe that under the parametric restrictions discussed in the paper, a larger preference weight on traded goods (an increase in δ) expands the steady state traded extensive margins.

Appendix B. Substitution and income effects on extensive margins

Using equations (17) and (21), for any types of shock dx the total differential of relative profits between the traded and non-traded sector in Home is expressed by:

$$\frac{1}{\overline{n}_T} \frac{dn_T}{dx} = \left(\frac{1}{1+\lambda} \right) \left[\left(\frac{1}{\overline{P}_T} \frac{dP_T}{dx} - \frac{1}{\overline{P}_N} \frac{dP_N}{dx} \right) + \left(\frac{1}{\overline{C}_T} \frac{dC_T}{dx} - \frac{1}{\overline{C}_N} \frac{dC_N}{dx} \right) \right] + \frac{1}{\overline{\upsilon}_T} \frac{d\upsilon_T}{dx} \tag{B.1}$$

$$\frac{1}{\overline{n}_N} \frac{dn_N}{dx} = -\left(\frac{\lambda}{1+\lambda} \right) \left[\left(\frac{1}{\overline{P}_T} \frac{dP_T}{dx} - \frac{1}{\overline{P}_N} \frac{dP_N}{dx} \right) + \left(\frac{1}{\overline{C}_T} \frac{dC_T}{dx} - \frac{1}{\overline{C}_N} \frac{dC_N}{dx} \right) \right] + \frac{1}{\overline{\upsilon}_N} \frac{d\upsilon_N}{dx} \tag{B.2}$$

The above expressions indicate that variations in extensive margins proportionally depend on nominal expenditure and entry cost shocks.

More specifically, we find that it is instructive to separate the substitution and income effects using the Slutsky equation. The substitution effects are found by deriving the following Hicksian demand functions for each of the traded and non-traded baskets:

$$C_T = \frac{\delta}{\left[\delta + (1-\delta)\left(\frac{P_T}{P_N}\right)^{\rho-1}\right]^{\frac{1}{1-\frac{1}{\rho}}}} C, \tag{B.3}$$

$$C_N = \frac{(1-\delta)}{\left[\delta\left(\frac{P_T}{P_N}\right)^{1-\rho} + (1-\delta)\right]^{\frac{1}{1-\frac{1}{\rho}}}} C, \tag{B.4}$$

where C denotes the original consumption bundle. Total impact of the shock can be decomposed as,

$$\frac{1}{\overline{\overline{C}}_T}\frac{dC_T}{dx} = \left\{ \begin{array}{c} \underbrace{-\rho\left(\frac{1}{\lambda+1}\right)\left(\frac{1}{\overline{\overline{P}}_T}\frac{dP_T}{dx} - \frac{1}{\overline{\overline{P}}_N}\frac{dP_N}{dx}\right)}_{Substitution\ Effect} \\ \underbrace{-\frac{1}{\overline{\overline{P}}_T}\frac{dP_T}{dx} + \left(\frac{1}{\lambda+1}\right)\left(\frac{1}{\overline{\overline{P}}_T}\frac{dP_T}{dx} - \frac{1}{\overline{\overline{P}}_N}\frac{dP_N}{dx}\right)}_{Income\ Effect} \end{array} \right\}, \tag{B.5}$$

$$\frac{1}{\overline{\overline{C}}_N}\frac{dC_N}{dx} = \left\{ \begin{array}{c} \underbrace{-\rho\left(\frac{\lambda}{\lambda+1}\right)\left(\frac{1}{\overline{\overline{P}}_N}\frac{dP_N}{dx} - \frac{1}{\overline{\overline{P}}_T}\frac{dP_T}{dx}\right)}_{Substitution\ Effect} \\ \underbrace{-\frac{1}{\overline{\overline{P}}_N}\frac{dP_N}{dx} + \left(\frac{\lambda}{\lambda+1}\right)\left(\frac{1}{\overline{\overline{P}}_N}\frac{dP_N}{dx} - \frac{1}{\overline{\overline{P}}_T}\frac{dP_T}{dx}\right)}_{Income\ Effect} \end{array} \right\}. \tag{B.6}$$

Substituting these relationships in (B.1) and (B.2), we get (22) and (23) in the paper. Similar expressions hold in Foreign.

Appendix C. Fixed variety economy

In a fixed variety economy, extensive margins in each sector remain at their symmetric steady state values ($n_T = n_T^* = \overline{n}_T$ and $n_N = n_N^* = \overline{n}_N$) regardless of the type of shocks hitting the economy. Therefore only the relative wage ε is endogenous. In this case the variation in relative wages are found only from the balanced trade condition. Table A-1 provides the results.

Shock on Home traded sector
$\frac{1}{\overline{\varepsilon}}\frac{d\varepsilon}{dz_T} = -\frac{2(\sigma-\rho)+(\rho-1)\left[2-(1-\phi)\left(\frac{1}{\lambda+1}\right)\right]}{\Theta} < 0,$
Shock on Home non-traded sector
$\frac{1}{\overline{\varepsilon}}\frac{d\varepsilon}{dz_N} = -\frac{(\rho-1)\left(\frac{1}{\lambda+1}\right)}{\Theta},$
where $\Theta \equiv 2\sigma - 1 + \phi + 2(\rho-1)\phi\left(\frac{1}{\lambda+1}\right) > 0.$

Table A-1: Fixed variety economy

Appendix D. Data

Real exchange rates are computed using CPI and nominal exchange rates (price of national currency per U.S. dollar) from OECD Main Economic Indicator. Unit labor costs and labor productivities for each traded and non-traded sector are constructed from OECD STAN database for Industrial Analysis. The definition of traded and non-traded sector and their computation methods follow Méjean (2008). Annual fluctuations of 4-digit SITC (rev2) are taken from NBER-UN world trade data. Total R&D expenditures (Gross Domestic Expenditure on R&D, GERD) and GDP per head come from OECD data source.

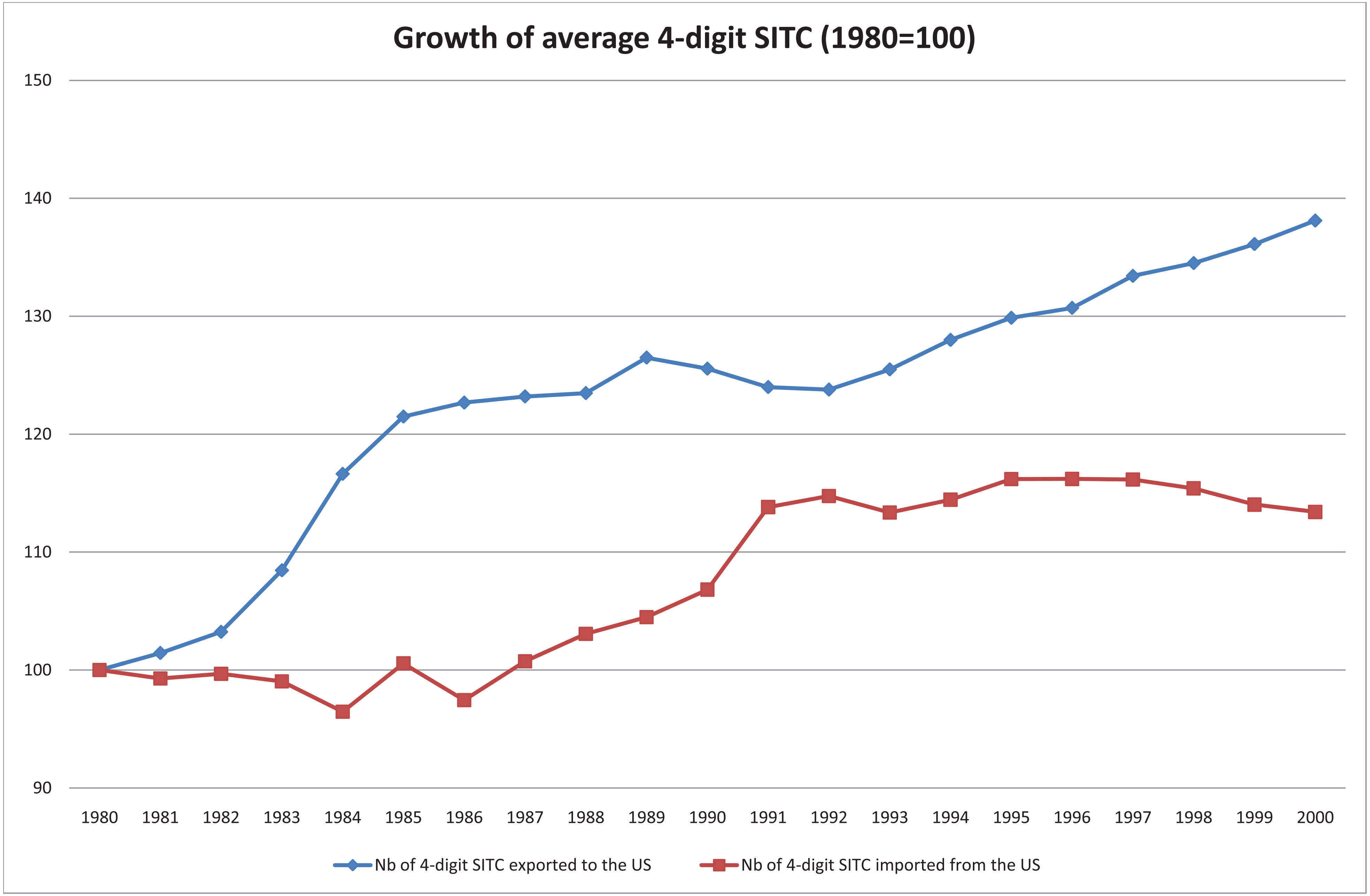
Growth of average 4-digit SITC (1980=100)
150
140
130
120
110
100
90
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
Nb of 4-digit SITC exported to the US
Nb of 4-digit SITC imported from the US

Figure 1

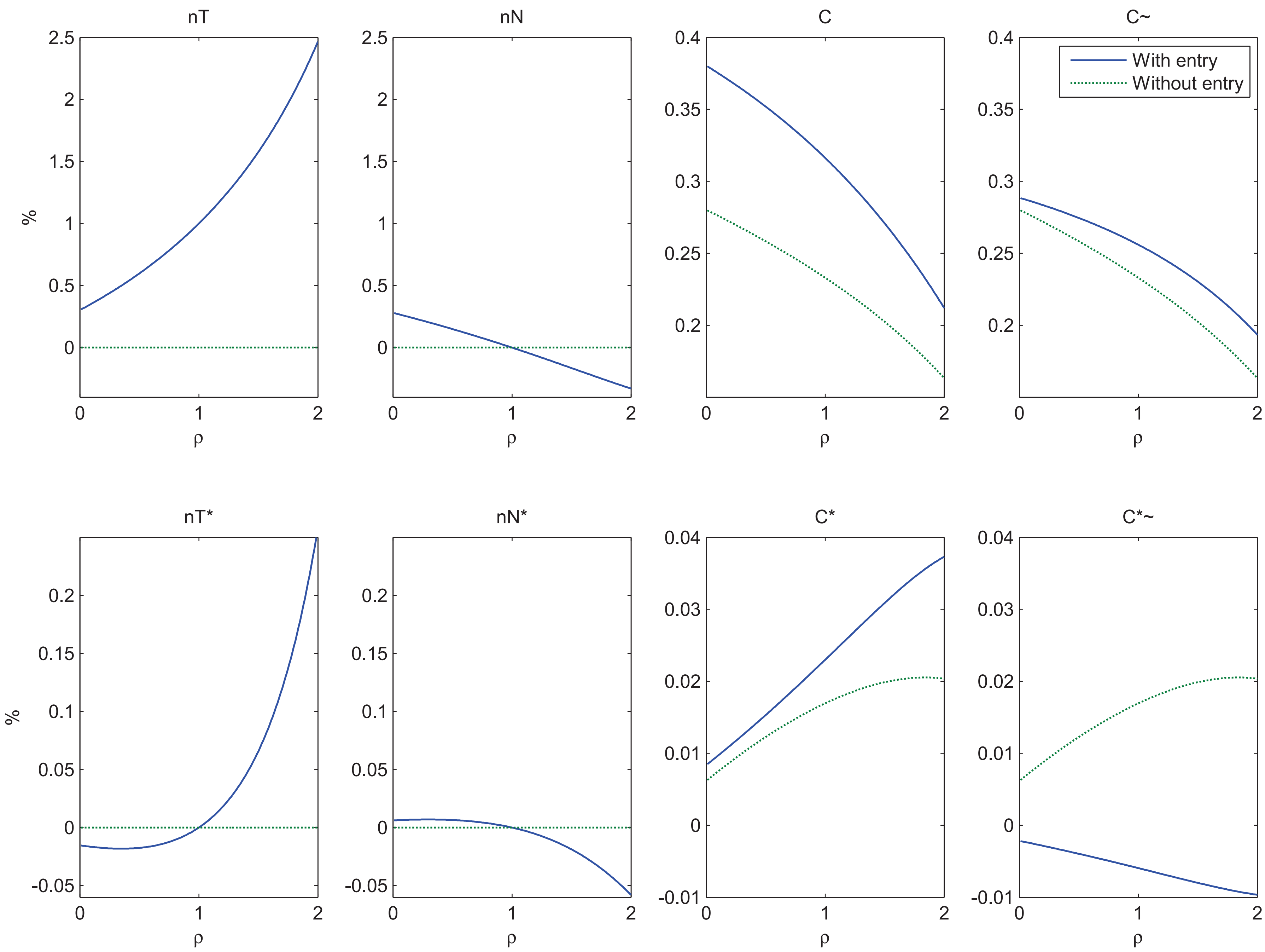

Figure 2: Extensive margin and welfare with different traded non-traded elasticity

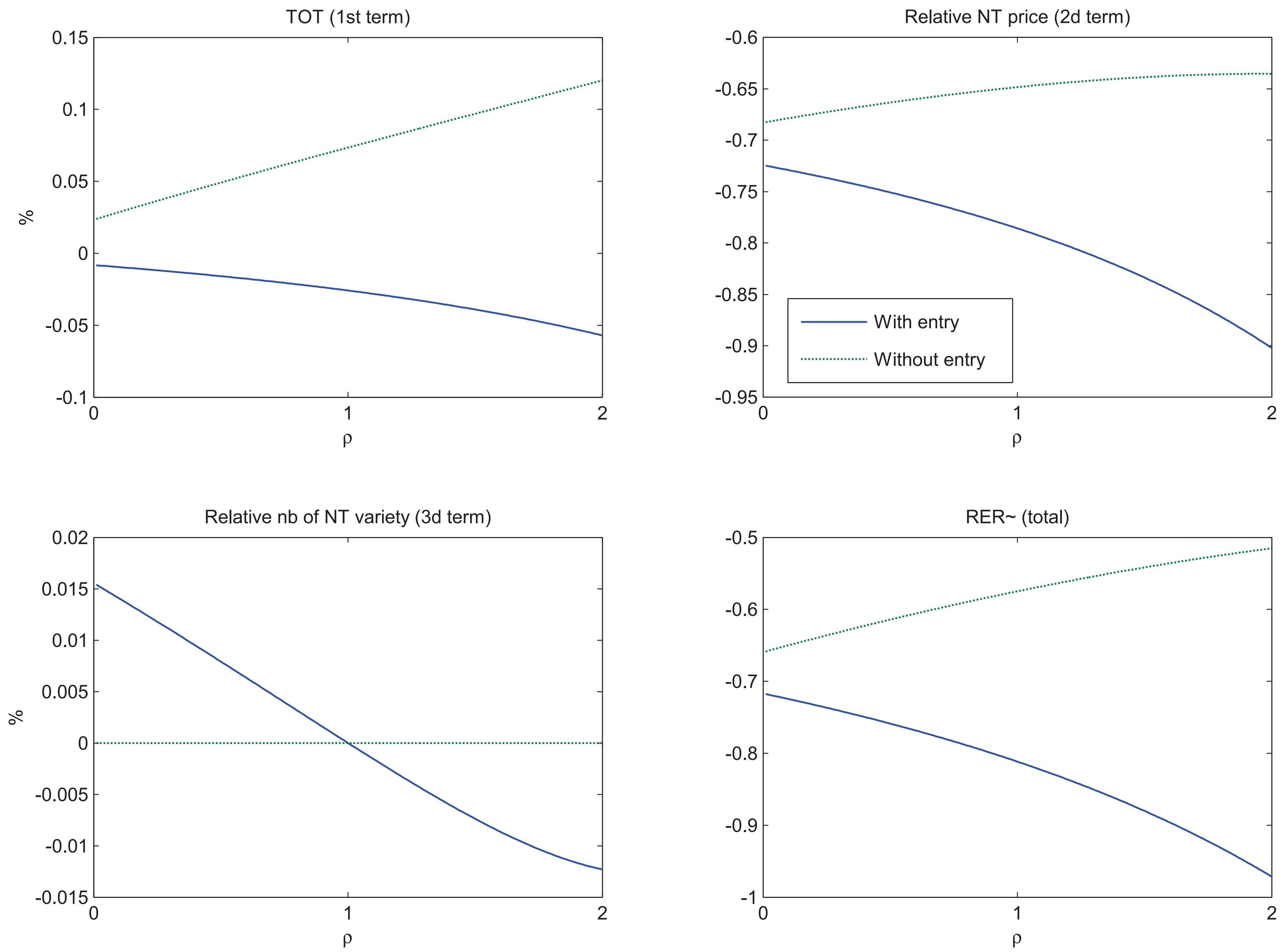

Figure 3: Decomposition of the HBS effect with different traded non-traded elasticity