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ABSTRACT

Harrison, Rutherford and Tarr (1997) use a multiregional Computable General Equilibrium (CGE) model with a CES multistage demand system, imperfect competition, increasing returns to scale (IRS), and two endogenous price elasticities of demand perceived by a firm in each national market, in order to quantify the reforms of the Uruguay Round, when firms compete in a quantity setting oligopoly with constant conjectures. This paper argues that the derivation of the price markups is based on two incorrect assumptions, which might affect their empirical results, especially on output and welfare.

KEYWORDS: Price markup, Computable General Equilibrium analysis.
JEL classification: D43, D58.

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1. Introduction

Glenn Harrison, Thomas Rutherford and David Tarr (henceforth, HRT) use a multiregional CGE model to quantify the economic impact of the reforms of the Uruguay Round under two alternative market regimes: perfect competition and constant returns to scale, and imperfect competition with free entry/exit and IRS (HRT, 1997). The model with imperfect competition and IRS at firm level assumes that "Firms compete in a quantity adjusting oligopoly framework where the quantity conjectures are calibrated to be identical for all firms in each sector and in each country, and do not change in the counterfactual" (HRT, 1997, pp. 1419-1420). They employ the Lerner formula to set endogenously the price markup above the marginal cost, and derive the perceived price elasticity of demand under the assumption that domestic goods and imports are imperfect substitutes. This latter finding is very important as, in order to capture intraindustry trade, most of CGE models employ the Armington specification, which states that goods produced by industries located in different countries, but which compete in the same market, are imperfect substitutes (Armington, 1969). However, HRT derive the markup by using two inappropriate assumptions: firstly, they assume the perceived price elasticities independent of conjectural variations; and secondly, they postulate that the aggregate price elasticity is equal

to one.[1] I show that both these assumptions are inconsistent with their model. I point out that the markup prices, in both the domestic and the export markets, are not set optimally, and this might compromise the numerical results, mainly on output and welfare.

2. Modelling framework

Since the HRT markup formula is derived for each national market, its formulation is also valid in the case of a single country open economy model. The single-country assumption allows me to simplify by a great deal the HRT notation and the formal derivation provided in their model (HRT, 1995, Appendix C).

Assume that within a domestic industry (*i*) firms face fixed costs, f_i, and produce two differentiated commodities, one supplied in the domestic market, d_i, and the other exported to the Rest of the World (RoW), e_i.

The profit function of a representative firm (π_i) takes the following form:

$$\pi_i = pd_i d_i + pwe_i e_i - c_i\left(d_i + e_i\right) - f_i, \tag{1}$$

[1] Also in a previous multiregional CGE model, which has been used to quantify the completion of the market of the European Union (HRT, 1996), HRT assume Cournot competition but wrongly set the vector of aggregate price elasticity equal to unity.

where pd_i and pwe_i denote the prices of domestic output and exports, respectively; and c_i the marginal cost, which is independent of output. The first order conditions yield the price cost margins in both the domestic and the export markets

$$\frac{pd_i - c_i}{pd_i} = \frac{1}{|\tau_i|}, \qquad \tau_i < -1, \tag{2}$$

$$\frac{pwe_i - c_i}{pwe_i} = \frac{1}{|\delta_i|}, \qquad \delta_i < -1, \tag{3}$$

where τ_i and δ_i represent the price elasticities of domestic and export demands perceived by a firm, respectively. HRT (1997, pg. 1420) argue that $(pd_i - c_i)/pd_i = (1+\Omega_i^d)/|\tau_i|$ and $(pwe_i - c_i)/pwe_i = (1+\Omega_i^e)/|\delta_i|$, where Ω_i^d and Ω_i^e denote the conjectural variations in the domestic and export markets, respectively (with $\Omega_i^d = \Omega_i^e = 0$ representing the Cournot case). However, they implicitly make an incorrect assumption, which is that τ_i and δ_i are independent of conjectural variations parameters. Conversely, as suggested by Smith and Venables (1988), τ_i and δ_i also depend on the perceived effect of the firm's action on industry aggregate supply.[2] More precisely, I show in the next section

[2] Smith and Venables (1988) derive the perceived price elasticity under the alternative Cournot and Bertrand conjectures, by assuming an isoelastic aggregate demand curve.

that τ_i and δ_i are each a function of two conjectural variations parameters, since domestic firms also have conjectures about how foreign firms respond.

Assume that the structure of the demand is characterised by three stages. At the first stage, the final demand of the representative consumer (C_i) and the intermediate demand of industries (X_i) are satisfied by the supply of composite commodities (Q_i):

(4) $$C_i = \alpha_i \frac{I}{p_i}$$

(5) $$X_i = \sum_j a_{ji} Y_i$$

(6) $$Q_i = C_i + X_i ,$$

where α_i denotes household budget shares ($\sum_i \alpha_i = 1$), I household income, p_i the price vector of the Armington goods, Y_i output, a_{ji} the intermediate input-output coefficients. Equation (4) is derived by maximising the consumer's Cobb-Douglas utility function subject to his budget constraint, whereas the derivation of (5) is based upon the assumption that intermediate inputs are net complements

(i.e. Leontief specification). Both (4) and (5) are assumed in the HRT modelling framework. Equation (6) gives the equilibrium in the goods market. [3]

At the second stage, the aggregate demand for composite commodities is satisfied by the supply of domestic goods and imports, according to the CES Armington specification. At the upper level, the solution of the Armington-dual

[3] These assumptions are generally postulated by HRT (1994, 1995, 1996, 1997). In fact, HRT (1995) refer to their previous study in 1994 for the complete documentation of the model, where the equilibrium in the goods market is algebraically stated (HRT, 1994, pg. A-4). Intermediate demand and final demand have to comprise the aggregate demand in HRT models, because HRT derive two price markups for each representative firm (one for the domestic market and one for the export market). If the demand of an intermediate input and the demand of a final good were satisfied by differentiated goods supplied in two different markets, then four different price markups, plus a different specification for the demand of intermediate inputs, would be needed. In fact, if the price elasticity of demand is inelastic (as it is assumed by employing the Leontief specification), the price cost margin would not be finite. HRT (1996, 1997) also assume the presence of a single government agent in each region. Thus, (6) should incorporate public spending for the existence of the equilibrium in the goods market. However, HRT do not explain how government spending is modelled. So I disregard it from the analysis. But if government spending is set in real terms, the derivation of (22) in the subsequent section is not at all affected.

problem yields the demand for domestic goods, D_i, the demand for imports, M_i, and the Armington price, p_i:

(7) $$D_i = \varphi_i^{\varepsilon_i} \, pd_i^{-\varepsilon_i} \, p_i^{\varepsilon_i} Q_i,$$

(8) $$M_i = \left(1-\varphi_i\right)^{\varepsilon_i} \, pwm_i^{-\varepsilon_i} \, p_i^{\varepsilon_i} Q_i,$$

(9) $$p_i = \left[\varphi_i^{\varepsilon_i} \, pd_i^{1-\varepsilon_i} + \left(1-\varphi_i\right)^{\varepsilon_i} \, pwm_i^{1-\varepsilon_i}\right]^{1/(1-\varepsilon_i)},$$

where pwm_i denotes the world price of imports, ε_i the elasticity of substitution between imports and domestic goods, and φ_i the share parameter of the Armington function.

At the third stage, having decided the demand for domestic goods and for imports, consumers and industries purchase a variety of domestic goods and a variety of imports, based again on CES functions. In particular, the demand for domestic brands takes the following form:

(10) $$D_i = \left[\sum_{s=1}^{n} \beta_{is} \, \tilde{d}_{is}^{\,(\varsigma_i-1)/\varsigma_i}\right]^{\varsigma_i/(\varsigma_i-1)}, \qquad \varsigma_i > 1, \ \sum_{s=1}^{n} \beta_{is} = 1,$$

where β_{is} describes demand parameters, ς_i represents the elasticity of substitution among *n* domestic varieties, and $\tilde{d}_{is}$ denotes output of each domestic brand. The solution of the dual problem yields

(11) $$\tilde{d}_{is} = \beta_{is}^{\varsigma_i} \, pd_i^{\varsigma_i} \, \tilde{pd}_{is}^{\,-\varsigma_i} \, D_i,$$

$$(12) \qquad pd_i = \left[\sum_{s=1}^{n} \beta_{is}^{\varsigma_i} \tilde{pd}_{is}^{(1-\varsigma_i)} \right]^{1/(1-\varsigma_i)},$$

where $\tilde{pd}_{is}$ denotes the price vector of domestic brands.

3. Perceived price elasticity under constant conjectures

The HRT 1997 markup formula is derived by assuming that firms compete in a quantity adjusting oligopoly with constant conjectures. Thus, assume that domestic and foreign firms do respond to rivals' output choices.

From (11), the inverse demand function can be log-linearised as

$$(13) \qquad \ln \tilde{pd}_{is} = \ln \beta_{is} + \frac{1}{\varsigma_i} \ln D_i - \frac{1}{\varsigma_i} \ln \tilde{d}_{is} + \ln pd_i .$$

By definition the derivative of (13) with respect to $\ln \tilde{d}_{is}$ yields the inverse of the price elasticity of domestic demand perceived by a firm, τ_i:

$$(14) \qquad \frac{1}{\tau_i} = \frac{1}{\varsigma_i} \frac{d \ln D_i}{d \ln \tilde{d}_{is}} - \frac{1}{\varsigma_i} + \frac{d \ln pd_i}{d \ln \tilde{d}_{is}} .$$

Given (10) and the fact that conjectural variations can be different from the Cournot case,

(15) $$\frac{\partial D_i}{\partial \tilde{d}_{is}} = \beta_{is} D_i^{1/\varsigma_i} \tilde{d}_{is}^{-1/\varsigma_i} \left[1 + \frac{\sum \left(\beta_{it} \tilde{d}_{it}^{-1/\varsigma_i} \right)}{\beta_{is} \tilde{d}_{is}^{-1/\varsigma_i}} \lambda \right],$$

where $\lambda = \partial \tilde{d}_{it} \Big/ \partial \tilde{d}_{is}$ denotes the conjectured reactions of other domestic firms, $t = 1,.....,n-1$. In addition, since from (11) $\beta_{is} D_i^{1/\varsigma_i} \tilde{d}_{is}^{-1/\varsigma_i} = \tilde{pd}_{is} \Big/ pd_i$, then

(16) $$\frac{d \ln D_i}{d \ln \tilde{d}_{is}} = \frac{\tilde{pd}_{is} \tilde{d}_{is}}{pd_i D_i} \left[1 + \frac{\sum \left(\beta_{it} \tilde{d}_{it}^{-1/\varsigma_i} \right)}{\beta_{is} \tilde{d}_{is}^{-1/\varsigma_i}} \lambda \right].$$

Since, by using the chain rule, $\frac{\partial pd_i}{\partial \tilde{d}_{is}} = \frac{\partial pd_i}{\partial D_i} \frac{\partial D_i}{\partial \tilde{d}_{is}}$, then

(17) $$\frac{d \ln pd_i}{d \ln \tilde{d}_{is}} = \frac{\tilde{pd}_{is} \tilde{d}_{is}}{pd_i D_i} \frac{D_i}{pd_i} \frac{\partial pd_i}{\partial D_i} \left[1 + \frac{\sum \left(\beta_{it} \tilde{d}_{it}^{-1/\varsigma_i} \right)}{\beta_{is} \tilde{d}_{is}^{-1/\varsigma_i}} \lambda \right].$$

Given the symmetry assumption, (17) and (16) into (14) yield

(18) $$\frac{1}{\tau_i} = -\frac{1}{\varsigma_i} + \frac{1}{n_i} \left(\frac{1}{\varsigma_i} + \frac{D_i}{pd_i} \frac{\partial pd_i}{\partial D_i} \right) \left[1 + \frac{\sum \left(\beta_{it} \tilde{d}_{it}^{-1/\varsigma_i} \right)}{\beta_{is} \tilde{d}_{is}^{-1/\varsigma_i}} \lambda \right].$$

By applying similar steps at the second stage of the demand tree, then

(19) $$\frac{D_i}{pd_i} \frac{\partial pd_i}{\partial D_i} = -\frac{1}{\varepsilon_i} + \Psi_i \left(\frac{1}{\varepsilon_i} - \frac{1}{\chi_i} \right) \left[1 + \frac{1 - \varphi_i}{\varphi_i} \left(\frac{M_i}{D_i} \right)^{-1/\varepsilon_i} \mu \right],$$

where $\Psi_i = pd_i D_i / \left(pd_i D_i + pwm_i M_i \right)$ represents the domestic industry market share, χ_i is the absolute value of the price elasticity of aggregate demand, and $\mu = \partial M_i / \partial D_i$ can be interpreted as the conjectured reactions of foreign firms.

Equation (19) into (18) yields

$$\frac{1}{\tau_i} = -\frac{1}{\varsigma_i} - \frac{1}{n_i}\left[\frac{1}{\varepsilon_i} - \frac{1}{\varsigma_i}\right]\left[1 + \frac{\sum_{t \neq s}\left(\beta_{it}\, \tilde{d}_{it}^{\,-1/\varsigma_i}\right)}{\beta_{is}\, \tilde{d}_{is}^{\,-1/\varsigma_i}}\lambda\right] . \\ -\frac{\Psi_i}{n_i}\left[\frac{1}{\chi_i} - \frac{1}{\varepsilon_i}\right]\left[1 + \frac{1-\varphi_i}{\varphi_i}\left(\frac{M_i}{D_i}\right)^{-1/\varepsilon_i}\mu\right] \tag{20}$$

Similarly, it can be shown that the absolute value of the price cost margin in the export market is

$$\frac{1}{\delta_i} = -\frac{1}{\xi_i^{\,*}} - \frac{1}{n_i}\left[\frac{1}{\varepsilon_i^{\,*}} - \frac{1}{\xi_i^{\,*}}\right]\left[1 + \frac{\sum_{t \neq s}\left(\gamma_{it}^{\,*}\, \tilde{e}_{it}^{\,-1/\xi_i^{\,*}}\right)}{\gamma_{it}^{\,*}\, \tilde{e}_{is}^{\,-1/\xi_i^{\,*}}}\lambda^*\right] \\ -\frac{\Psi_i^*}{n_i}\left[\frac{1}{\chi_i^{\,*}} - \frac{1}{\varepsilon_i^{\,*}}\right]\left[1 + \frac{\varphi_i^{\,*}}{1-\varphi_i^{\,*}}\left(\frac{D_i^*}{E_i}\right)^{-1/\varepsilon_i^{\,*}}\mu^*\right] \tag{21}$$

where $\Psi_i^* = pwe_i E_i / \left(pwe_i E_i + pd_i^{\,*} D_i^* \right)$; E_i denotes exports; $pd_i^{\,*}$ is the composite price of RoW domestic goods, D_i^*; $\chi_i^{\,*}$ is the absolute value of the price elasticity of aggregate demand faced by the RoW; $\lambda^* = \partial \tilde{e}_{it} / \partial \tilde{e}_{is}$ denotes

the conjectured reactions of other domestic firms; $\mu^* = \partial D_i^* / \partial E_i$ can be interpreted as the conjectured reactions of foreign firms; γ_{is}^* describes demand parameters for exported brands, $\tilde{e}_{is}$; ε_i^* and φ_{is}^* are the foreign Armington elasticity of substitution and share parameter, respectively; and ξ_i^* is the elasticity of substitution among *n* exported brands. [4]

Equations (20) and (21) are consistent with the theory, which argues that a more collusive outcome is obtained for positive conjectural variations, if respectively $\varsigma_i > \varepsilon_i > \chi_i$ and $\xi_i^* > \varepsilon_i^* > \chi_i^*$. However, no mathematical condition can be derived when the relation between price cost margin and entry in considered. In fact, if $\lambda = \mu = \lambda^* = \mu^* = 0$ (Cournot competition)

$$\frac{\partial 1/|\tau_i|}{\partial n_i} = -\frac{1}{n_i^2}\left[\frac{1}{\varepsilon_i} - \frac{1}{\varsigma_i}\right] - \frac{\Psi_i}{n_i^2}\left[\frac{1}{\chi_i} - \frac{1}{\varepsilon_i}\right]\left[1 - \frac{n_i}{\Psi_i}\frac{\partial \Psi_i}{\partial n_i}\right] - \frac{\Psi_i}{n_i \chi_i^2}\frac{\partial \chi_i}{\partial n_i}$$

and

$$\frac{\partial 1/|\delta_i|}{\partial n_i} = -\frac{1}{n_i^2}\left[\frac{1}{\varepsilon_i^*} - \frac{1}{\xi_i^*}\right] - \frac{\Psi_i^*}{n_i^2}\left[\frac{1}{\chi_i^*} - \frac{1}{\varepsilon_i}\right]\left[1 - \frac{n_i}{\Psi_i^*}\frac{\partial \Psi_i^*}{\partial n_i}\right] - \frac{\Psi_i^*}{n_i \chi_i^{*2}}\frac{\partial \chi_i^*}{\partial n_i}.$$

[4] Note that in a multiregional framework, δ_i is also affected by the ratio between domestic firms' exports and total exports to a given region. In a single country case, this ratio is obviously equal to one.

Thus, even in the Cournot case, the sign of the latter two expressions is ambiguous. Consequently, a multiregional numerical model with no zero conjectures is consistent with the theory under the following necessary, but not sufficient, conditions: $\varsigma_i > \varepsilon_i > \chi_i$ and $\xi_i^* > \varepsilon_i^* > \chi_i^*$. So modellers must carefully verify if the results of the counterfactuals are consistent with the other economic principle according to which a firm faces a more elastic demand curve with entry.

The absolute value of (20) and (21) correspond to the HRT 1997 price cost margin formula if, and only if, $\lambda = \mu = \lambda^* = \mu^* = 0$ (Cournot competition) and $\chi_i = \chi_i^* = 1$. In fact, by using (4)-(6),

$$\chi_i = -\frac{\partial Q_i}{\partial p_i}\frac{p_i}{Q_i} = \frac{C_i}{Q_i}, \qquad 0 \le \chi_i \le 1. \tag{22}$$

χ_i would be equal to unity only in two extreme cases: (i) $Y_i = 0$, which implies that the economy would not exist; (ii) $a_{ji} = 0$, which implies that the intermediate flows would be neglected by the model. Both these extreme cases are not in the HRT models. Most importantly, HRT claim that conjectures have been endogenously calibrated, therefore it is unlikely that they are zero. So the fact that the aggregate price elasticities are less than one, and that conjectural variations parameters differ from zero, these imply that the calibrated values of the price

markups in the HRT models are not set optimally. In addition, if products are used only as intermediate goods, χ_i and χ_i^* would be equal to zero, and the price cost margin would be equal to infinite.[5]

I have computed the ratios between consumer final demand and aggregate demand for 24 regions and for those 13 sectors, which according to the HRT study are characterised by IRS at firm level.[6] I have derived these ratios by using the version 3 (with 37 regions) of the GTAP database 1992. I have obviously aggregated sectors and regions such that the data set is consistent with that used by HRT (1997).[7] Almost 81% of the ratios have a value of less than 0.5; whilst 36% of them have a value of less than 0.1. These ratios are very low in sectors such as primary iron and steel, non-ferrous metals, fabricated metals and minerals, whose output is mainly used as an intermediate input by other sectors. In some cases, the aggregate price elasticity is equal to zero, which implies that

[5] This is because if the demand for a good is inelastic (i.e. Leontief specification for the demand of intermediate inputs), buyers would purchase the commodity at any price.

[6] The aggregate demand is defined as a sum of consumer final demand, intermediate demand, government demand and investment for composite commodities. Hence, the ratios should be interpreted as upper bounds of the sectoral price elasticity of aggregate demand.

[7] HRT (1997) calibrate their model by primarily using the version 2 (with 24 regions) of the GTAP data base 1992.

the price cost margin would be equal to infinite and, as a result, the numerical model would not converge. This leads to the conclusion that the price markups for each sector and each region in HRT (1997) are not set optimally.

A further striking result is that χ_i and χ_i^* vary within the model structure, as policy simulations are performed. A shock in the system, which would affect the ratio between consumer final demand and aggregate demand, would have an impact on the price cost margin, which indirectly would affect output and, as a result, welfare.

4. Summary

HRT (1997) employ a multiregional CGE model to examine the regional impact on output and welfare of the reforms of the Uruguay Round, when firms compete in a quantity setting oligopoly with endogenously calibrated constant conjectures. However, they implicitly and incorrectly assume that (i) the vector of price elasticities of demand perceived by a firm in the domestic and export markets are independent of conjectural variations parameters and (ii) the vector of aggregate price elasticity of demand is unity. In contrast, I show that the perceived elasticities are a function of the conjectured reactions of the rival domestic and

foreign firms and that the vector of price elasticity of aggregate demand is equal to the ratio between consumer final demand and aggregate demand.

The use of the incorrect formula might compromise the results on output and welfare obtained by HRT in their study for two reasons: firstly, the price markup for each representative firm in each nation is not set optimally; and secondly, any policy experiment would also affect the optimal price markup, by having an impact on the endogenously determined price elasticity of aggregate demand.

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