Strategic Procurement, Openness and Market Structure*

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Abstract

We examine strategic procurement behaviour by governments and its effect on market structure in sectors, such as defence, where the government is the dominant consumer. In a world economy with trade between producers, and between producers and non-producers, we use a modified Dixit-Stiglitz utility function with an independent taste for variety. Governments can, in effect, choose the number of domestic firms and their size by adjusting the procurement price. Unlike the standard model with no independent taste for variety and no external sector of non-producers, there are incentives for subsidies, openness impacts on industrial structure and there are potential gains form procurement coordination between producer countries.

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Contents

1 Introduction

Government procurement constitutes an important share of a typical country's GDP (up to 20% in some cases). In some industries, domestic government procurement is also the most important source of sales and this is clearly the case in the defence and pharmaceutical industries. Governments have traditionally used government procurement as a policy tool to promote 'strategic' domestic industries. As the World Trade Organization (WTO) expands the restrictions over traditional protectionist trade policies, procurement practices can be used as a less obvious trade policy tool; the government's preference for maintaining a domestic provider base within 'sensitive industries' can provide an international justification for maintaining such practices. However, the recognition of discriminatory procurement policies as a protectionist tool has led the WTO to gather support for a multilateral agreement to eliminate preferential treatment to national suppliers in procurement deals.

The Government Procurement Agreement (GPA) is a multilateral WTO agreement with 25 members at present.[1] This Agreement was negotiated in the Uruguay Round and took effect on 1 January 1996. The GPA precludes countries from using domestic supplier preferential treatment to achieve goals such as promotion of local industrial sectors or business groups. Parties to the GPA are required to give products, services and suppliers of any other Party to the Agreement treatment no less favourable than that they give to their domestic products, services and suppliers of other parties to the Agreement. (Article III:1). However, article XXIII of the GPA specifies the exceptions to the Agreement, which include procurement indispensable for national security or for national defence purposes. The pharmaceutical industry is also seen by producer countries as a 'strategic' industry, with government regulations openly having as an objective the maintenance of a domestic producer base (see e.g., Kyle (2003)).

Our paper aims to capture the main features of international procurement in defence and pharmaceutical industries where governments are the most important domestic clients.[2] Consequently, government procurement policies can have an impact on the struc-

[1] See www.wto.org for information on the GPA.

[2] Another relevant sector where the government can influence market structure through the procurement process is the media sector where it may believe there to be important externalities associated with public service broadcasting or press freedom.

ture of these industries and this relationship is the focus of the paper. According to Kyle (2003), in many producer countries, the price for prescribed drugs to be paid by domestic health authorities is set high enough to support the local pharmaceutical industry, which is a big employer and important export earner. The defence industry is an even clearer example of domestic firms survival directly depending on government purchasing commitments (see Dunne *et al.* (2002)).

In order to examine this link between international procurement and market structure we construct a model of strategic public procurement and international trade. There are both producer and non-producer countries. Governments in producer countries buy products from the domestic firms and also import from the rest of the world, governments in non-producer countries cover their public procurement needs through imports.

In a standard Dixit-Stiglitz monopolistic competition model of trade only involving producers, the procurement price turns out to be the world market price, the bias for domestic rather than imported procured goods, the inverse of 'openness' in our terminology, has no effect on market structure and the non-cooperative procurement equilibrium is efficient. As a result of two features of our model, these results no longer hold: first we allow for an external market of non-producers importing goods from producers and second we use a modified Dixit-Stiglitz utility function as in Benassy (1996) to incorporate a taste for variety effect that is independent of the elasticity of substitution.

We assume that governments endogenously choose the number of firms that compose the domestic procurement sector by committing to a domestic procurement price that ensures the existence of the chosen number of domestic firms[3]. We find that an increase in openness and in the relative size of the external market reduces the number of firms in equilibrium. This result provides a theoretical explanation for the recent increases in concentration in both the defence and the pharmaceutical industry. In the defence industry, for the top 100 firms, Dunne *et al.* (2002) report falls in the inverse Herfindahl index from 49 to 22, between 1990 and 1998. For the pharmaceutical industry, Matraves (1999) reports an increase in global market shares of the top 10 pharmaceutical companies from 25% to 31% between 1988 and 1995, also firms in ranked places from 11th to 20th

[3]The ability of government to commit to a procurement price for domestic firms prior to them competing in the exports market has been extensively used as an assumption in the strategic trade and procurement literatures.

saw increases in their market shares (also see Kyle (2003) for more recent concentration data). Although increased development costs may be among the factors that could be determining such trends, our modified Dixit-Stiglitz framework shows that they may also be explained by the increased openness of producer countries to trade and an increase in the size of the external market.

The rest of the paper is organized as follows. Section 2 summarizes the related literature. Section 3 provides the basic set-up and the sequence of moves in the procurement game with governments and firms as players. Section 4 solves the subgame-perfect, non-cooperative equilibrium for the case where governments, in their procurement decisions, but not firms, in their pricing decisions, act strategically. Section 5 allows firms to act strategically, an important effect only for small firm numbers. Section 6 studies the co-operative equilibrium and compares it with the non-cooperative equilibrium. Section 7 provides concluding remarks.

2 Related Literature

Our modelling of the world trade in the procurement good uses a 'like-for-variety' model, first introduced by Dixit and Stiglitz (1977) and examined further by Benassy (1996). In this paper, we allow both for the original monopolistic competition version of the model and the strategic interactions version, later introduced by Yang and Heijdra (1993). The impact of trade and industrial policies on firm numbers across countries has also been considered within the trade literature (see e.g. Eaton and Grossman (1986) and Venables (1987)). One such policy, the procurement decision, has received special attention in this literature.

Our research is mostly linked to a branch[4] of the procurement and trade literature starting with Baldwin (1970). This literature studies the impact of unilaterally home

[4]A second branch of the procurement literature focuses on the interaction between firms and procurer in a environment characterized by the existence of asymmetric information (examples of that literature are McAfee and McMillan (1989), Anton and Yao (1992), Laffont and Tirole (1993), Branco (1994), McGuire and M.H. (1995) and Vagstad (1995)). Our paper abstracts from such issues. A third strand analyzes the interaction between domestic defence procurement and firm competition for international arms trade (see e.g., Levine and Smith (2000), Garcia-Alonso (1999, 2000) and Levine *et al.* (2000)). However, this literature does not analyze the impact of government policies on concentration.

biased procurement on the patterns of international specialization. Baldwin (1970, 1984) show that a unilateral home bias in favour of domestic producers is inconsequential to the patterns of specialization under the assumption of perfect competition. Later papers prove that this neutrality result does not necessarily hold with imperfect competition. Brulhart and Trionfetti (2001) prove that if a country has a unilateral home bias towards a domestic monopolistic sector, it will also have more firms in that sector relative to the other country (see e.g. Miyagiwa (1991) for impact on trade volumes). In our paper, we prove that, in the presence of bilateral home bias, a symmetric increase in home bias will increase firm numbers across the world, which is in accordance with that result.

Our framework differs from this literature in a number of respects. First we restrict ourselves to the case where all national and international demand comes from governments and there is no private demand. Consistently with this, governments actually set domestic prices so as to allow whichever number of firms they would like to keep to survive. Our procurement expenditure, as far as firms decisions are concerned, is then given to firms and influences their actions through its impact on firm numbers. Second we allow for both strategic procurement decisions by government and strategic pricing by firms. Third, we introduce an independent like-for-variety element, as in Benassy (1996), and a trade structure that allows for two way trade between producers and one way trade towards non-producers. The independent like-for-variety element and the external market of non-producers drive our non-neutrality result of home bias on firm numbers. Finally unlike other procurement papers, we show there are gains from international cooperation in procurement decisions.

3 The Set-up

3.1 The Model

We model an international market for a public service good, consisting of ℓ producing and importing countries and r non-producers who only import. The total budget in each country available for this particular public service good is given.[5] Producer country 1

[5]A constant share of GDP is devoted to defence or health can be defended as a realistic assumption, but as is typical in the literature we can start with a national welfare function of the form $U = U(C, C_0)$ where C is Dixit-Stiglitz index representing the output of a public service obtained from differentiated

produces differentiated goods $j = 1, 2, \cdots, n_1$, country 2 produces goods $j = n_1 + 1, n_1 + 2, \cdots, n_1 + n_2$ etc, so there are $\sum_{i=1}^{\ell} n_i = N$, say, goods in total. Governments procure from domestic firms (if they exist) and overseas firms who enter or exit the market freely.

It makes for a simpler presentation if we focus on decisions in producer country 1. Government 1 procures $d_{1j}, j = 1, 2, \cdots, n_1$ domestically produced goods and $m_{1j}, j = n_1+1, n_1+2, \cdot\cdot, N$ imported goods. The government utility takes the form of a generalized Dixit-Stiglitz CES function of the form

$$U_1 = [w_1 n_1 + (1-w_1)(N-n_1)]^{\nu} \left[w_1 \sum_{j=1}^{n_1} (d_{1j})^{\alpha} + (1-w_1) \sum_{j=n_1+1}^{N} (m_{1j})^{\alpha} \right]^{\frac{1}{\alpha}} \;;\; \alpha \in [0,1),\, \nu > 0 \qquad (1)$$

In (1) the weights w_1 and $1-w_1$, with $w_1 \in [\frac{1}{2}, 1]$, express the bias for domestic rather than imported procurement in country 1. When $w_1 = 1$ there is autarky between producers and $1 - w_1$ is a measure of openness in our set-up.[6] If we put $\nu = 0$ and $w_1 = \frac{1}{2}$, (1) reduces to the familiar Dixit-Stiglitz utility function used in the new trade and endogenous growth literatures. But as Benassy (1996) points out, this form of utility is restricted in that it implies an on-to-one correspondence between the taste for variety and the elasticity of substitution.

To see the significance of this generalized form of the Dixit-Stiglitz utility function, suppose there are two producer countries. Define a function $v_1(n_1, n_2)$ to represent the proportional capability gain from spreading a certain amount of output y say between all $n_1 + n_2$ varieties rather than concentrating a proportion w_1 on one variety in country 1 and a proportion $1 - w_1$ on one imported variety. i.e.,

$$\begin{aligned} v_1(n_1, n_2) &= \frac{[w_1 n_1 + (1-w_1) n_2]^{\nu} \left[w_1 \sum_{j=1}^{n_1} y^{\alpha} + (1-w_1) \sum_{j=n_1+1}^{N} y^{\alpha} \right]^{\frac{1}{\alpha}}}{(n_1 + n_2) y} \\ &= \frac{[w_1 n_1 + (1-w_1) n_2]^{\nu + \frac{1}{\alpha}}}{n_1 + n_2} \end{aligned}$$

inputs ((1) below) and C_0 is a numeraire good which in this context is remaining consumption. If the sector in question is defence then C would be military security; if the sector is pharmaceuticals, then C would be public health. If the utility is Cobb-Douglas (a standard assumption) then the expenditure on the public service is constant and the model reduces to the one in this paper.

[6] Note that(1) can be given an 'iceberg' technology interpretation by writing it as $U_1 = [w_1 n_1 + (1 - w_1)(N - n_1)]^{\nu} \left[\sum_{j=1}^{n_1} (d_{1j})^{\alpha} + \sum_{j=n_1+1}^{N} (T_1 m_{1j})^{\alpha} \right]^{\frac{1}{\alpha}}$, where $T_1 = \left(\frac{1-w_1}{w_1} \right)^{\frac{1}{\alpha}}$ is the fraction of the original good that actually arrives, the rest 'melting away' on route.

Suppose that the total number of varieties $N = n_1 + n_2$ increases, keeping the proportion $\frac{n_1}{n_2}$ fixed. Then putting $n_1 = kN$ and $n_2 = (1-k)N$, $v_1 = v_1(N) = [w_1 k + (1-w_1)(1-k)]^{(\frac{1}{\alpha}+\nu)} N^{(\nu+\frac{1}{\alpha}-1)}$. We now define the *taste for variety* by the elasticity $\frac{N dv_1}{v_1 dN} = \tau$ say given by

$$\tau = \frac{N dv_1}{v_1 dN} = \nu + \frac{1}{\alpha} - 1$$

The significance of the extra term in (1) is now apparent. If $\nu = 0$, then the taste for variety $\tau = \frac{1}{\alpha} - 1 = \frac{1}{\sigma - 1}$ which is determined solely by the elasticity of substitution $\sigma = \frac{1}{1-\alpha}$. Thus this formulation establishes an arbitrary link between different characteristics: taste for variety and elasticity of substitution, the latter, as we shall see, also determining the market power. Introducing the extra term breaks this link and has important consequences for the subsequent analysis.

Governments in producer countries procure from domestic and foreign firms, possibly at different prices. Let p_{1j} be the price of the procured domestic good and P_j be the world market price of the traded good of variety j produced by firms in all producing countries $j = 1, 2, \cdot\cdot, N$. Then the budget constraint for government in producer country 1 is:

$$\sum_{j=1}^{n_1} p_{1j} d_{1j} + \sum_{j=n_1+1}^{N} P_j m_{1j} = G_1 \tag{2}$$

where G_i is total procurement expenditure in country i.

For the non-producing country $i = \ell+1, \ell+2, \cdot\cdot\cdot, \ell+r$ utility is given by

$$U_i = N^{\nu} \left[\sum_{j=1}^{N} (m_{ij})^{\alpha} \right]^{\frac{1}{\alpha}} \tag{3}$$

and their budget constraint is:

$$\sum_{j=1}^{N} P_j m_{ij} = G_i \tag{4}$$

The model is completed by specifying the following cost structure for the firm. Firm j in producer country 1 produces d_{1j} units of variety j for its domestic government at a procurement price p_{1j} and exports x_{1j} units at a international market price P_j. The cost of producing total output $y_{1j} = d_{1j} + x_{1j}$ is assumed to be

$$C(y_{1j}) = F + c y_{1j} \tag{5}$$

The first term in (5) we associate with fixed capital costs and R&D, and the final term constitutes variable costs. It follows that the profit of this firm is

$$\pi_{1j} = p_{1j}d_{1j} + P_j x_{1j} - C(y_{1j}) \tag{6}$$

and since there is free entry and exit, we must impose the participation constraint $\pi_{1j} \geq 0$ on the procurement decision.

3.2 Sequencing of Events

We first consider the optimal decisions of a single government taking the decisions of other governments as given. The sequencing of events is as follows:

1. Domestic Procurement by Producers. Given total procurement expenditure, the government in producer country 1 procures domestic goods of quantity d_{1j} at price p_{1j}, for $j = 1, 2, \cdots, n_1$. It also formulates a time-consistent plan to import goods m_{1j}, for $j = n_1 + 1, n_1 + 2, \cdots, N$ at the world market equilibrium price P_j. All decisions are subject to a budget constraint and a non-negative profit participation constraint for domestic firms. The procurement price may be greater or less than the international market price. Firms already participating in the international market will always accept domestic procurement as long as the procurement price exceeds the marginal cost. In general, the world market price can depend on procurement decisions at this stage, but for large N (assumed in the first part of the paper) we have monopolistic competition with the price (set in stage 2 below) given by $P_j = P = \frac{c}{\alpha}$ which depends only on the marginal cost c and the elasticity parameter α.

2. The Price-Setting Equilibrium. With a commitment to producing d_{1j}, in a price-setting equilibrium of this stage of the game, firms in producer country 1 set world prices P_j and export quantity x_{1j} to countries $i = 2, \cdots, \ell + r$.

3. Military Spending by Non-Producers and Demand for Imports by all Countries. Given the world market price P_j, and military expenditure, governments in both producer and non-producer countries $i = 1, 2, \cdots, \ell + r$ procure imports of good, m_{ij}, $j = 1, 2, \cdots, N$, where $i \neq j$ for producer countries $i = 1, 2, \cdots, \ell$.

4 Monopolistic Competition

In this section we develop the non-cooperative equilibrium for the case where the number of firms is large and therefore we can ignore strategic pricing behaviour. To solve for the equilibrium[7] we proceed by backward induction starting at stage 3.

4.1 The Imports Decision at Stage 3

At stage 3, given the price P_j, and the number of differentiated goods, the importing government in non-producing producer country i chooses m_{ij} to maximize U_1 given by (1) subject to its budget constraint (2) where the procurement element is given. To carry out this optimization define a Lagrangian for non-producer country $i = \ell+1, \ell+2, \cdots \ell+r$

$$U_i - \lambda \left(\sum_{j=1}^{N} P_j m_{ij} - G_i \right)$$

where $\lambda \geq 0$ is a Lagrange multiplier. Then the first-order conditions are:

$$\frac{1}{\alpha} \left[\sum_{j=1}^{N} m_{ij}^{\alpha} \right]^{\frac{1}{\alpha}-1} \alpha(1-w_1) m_{ij}^{\alpha-1} = \lambda P_j \, ; \, j = 1, 2, \cdots N \tag{7}$$

Dividing the jth equation by the kth equation we have

$$\left(\frac{m_{ij}}{m_{ik}} \right)^{\alpha-1} = \frac{P_j}{P_k}$$

Substituting back into the budget constraint (3) we get

$$\sum_{k=1}^{N} P_k m_{ij} \left(\frac{P_k}{P_j} \right)^{-\frac{1}{1-\alpha}} = \sum_{k=1}^{N} P_k^{1-\sigma} P_j^{\sigma} m_{ij} = G_i$$

where $\sigma = \frac{1}{1-\alpha} > 1$. This results in the demand by government $i = \ell+1, \ell+2, \cdots, \ell+r$ for good $j = 1, 2, \cdots, N$ given by

$$m_{ij} = \frac{G_i}{P_j^{\sigma} \sum_{k=1}^{N} P_k^{1-\sigma}} \tag{8}$$

To interpret and manipulate (8) it is convenient to define

$$\tilde{P} = \sum_{k=1}^{N} P_k^{1-\sigma} \tag{9}$$

[7]Note that in the absence of procurement considerations the trade equilibrium corresponds exactly to a standard trade model, for example in Krugman (1979). Then stage 1 of our model is the free-entry process.

Then $\hat{P} = \tilde{P}^{\frac{1}{1-\sigma}}$ is the familiar price index of imported goods facing each non-producer country used in the product differentiation literature (see, for example, Beath and Katsoulacos (1991), chapter 3). Now (8) and (9) can be written

$$m_{ij} = \frac{G_i}{P_j^{\sigma} \hat{P}^{1-\sigma}} \tag{10}$$

The importance of (10) is that given $\hat{P}$, the elasticity of demand for variety j on the world market with respect to price is constant with elasticity $-\sigma$.

For any producer country $i = 1, 2, \cdots, \ell$ import demand for any good $j = 1, 2, \cdots, N$ can similarly be written as

$$\begin{aligned} m_{ij} &= \frac{[G_i - \sum_{j=n_{i-1}+1}^{n_{i-1}+n_i} p_{ij} d_{ij}]}{P_j^{\sigma} \sum_{k \neq [N_{i-1}, N_i]}^{N} P_k^{1-\sigma}}\,;\ j \neq N_{i-1}+1,\ N_{i-1}+2, \cdots, N_{i-1}+n_i \\ &= 0\,; \qquad j = N_{i-1}+1,\ N_{i-1}+2, \cdots, N_{i-1}+n_i \end{aligned} \tag{11}$$

where we have defined $N_i = n_1 + n_2 + \cdots + n_i$ for $i \geq 1$ (in which case $N_1 = n_1$ and $N_\ell = N$)). Thus country $i = 1, 2, \cdot\cdot, \ell$ produces varieties $j = N_{i-1}+1, N_{i-1}+2, \cdots, N_{i-1}+n_i = N_i$ and imports m_{ij} units of variety $j = 1, 2, \cdots, N_{i-1}, N_i+1, N_i+2, \cdots, N$ (defining $N_0 = 0$). Again we can define a price index of imported goods for producer countries as $\hat{P}_i = \left(\tilde{P}_i\right)^{\frac{1}{1-\sigma}}$ where

$$\tilde{P}_i = \sum_{k \neq [N_{i-1}, N_i]}^{N} P_k^{1-\sigma}\,;\ i = 1, 2, \cdots, \ell \tag{12}$$

4.2 Price Setting at Stage 2

Turning to stage 2 of the game, in producer country 1 firm $j = 1, 2, \cdots, n_1$ profit at stage 2 is given by

$$\pi_{1j} = (p_{1j} - c) d_{1j} + (P_j - c) x_{1j} - F\,;\ j = 1, 2, \cdots, n_1 \tag{13}$$

where exports to producers and non-producers are given by

$$x_{1j} = \sum_{i=2}^{\ell+r} m_{ij} = \sum_{i=1}^{\ell} \frac{[G_i - \sum_{j=n_{i-1}+1}^{n_{i-1}+n_i} p_{ij} d_{ij}]}{P_j^{\sigma} \tilde{P}_i} + \sum_{i=\ell+1}^{\ell+r} \frac{G_i}{P_j^{\sigma} \tilde{P}} \tag{14}$$

The first term in (14) consists of exports to other producing countries and depends on the procurement decisions already taken at stage 1 and on all prices set at stage 2 of the game. The second term consists of exports to non-producing countries and depend on the all prices set by firms at stage 2 of the game.

For producers let $\Gamma_i = G_i - \sum_{j=N_{i-1}+1}^{N_{i-1}+n_i} p_{ij}d_{ij}$ be the part of the government budget devoted to imports. Define $\Gamma_i = G_i$ and $\tilde{P}_i = \tilde{P}$ for non-producers. Then maximizing profits given by (13) with respect to P_j, gives the first-order conditions

$$(P_j - c)\frac{\partial x_{1j}}{\partial P_j} + x_{1j} = 0 \tag{15}$$

where from (10)

$$\frac{\partial x_{1j}}{\partial P_j} = -\frac{\sigma x_{1j}}{P_j} - \underbrace{P_j^{-\sigma}\sum_{i=2}^{\ell+r}\frac{\Gamma_i}{\tilde{P}_i^2}\frac{\partial \tilde{P}_i}{\partial P_j}}_{\text{strategic interaction term}} \tag{16}$$

In working out the effect of a change in the price of variety firm j considers two effects: the first term takes the total price index of imports facing other countries $\tilde{P}_i\,;\, i = 2, 3, \cdots, \ell + r$ as given. The second *strategic* term considers the effect on each of these price indices of the firms export price. In the first part of this paper we assume monopolistic competition. Then there are so many firms that we can ignore this strategic effect. In the second part of the paper we examine the small numbers case for which the strategic interaction term can no longer be ignored. Then substituting (16) back into (15), the first order condition becomes

$$\left[-\frac{\sigma(P_j - c)}{P_j} + 1 - \frac{(P_j - c)P_j^{-\sigma}\sum_{i=2}^{\ell+r}\frac{\Gamma_i}{\tilde{P}_i^2}\frac{\partial \tilde{P}_i}{\partial P_j}}{x_{1j}}\right] x_{1j} = 0\,;\, j = 1, 2, \cdots, n_1 \tag{17}$$

From (9) and (12) we have $\frac{\partial \tilde{P}_i}{\partial P_j} = (1-\sigma)P_j^{-\sigma}$. Hence using (14) we obtain from (17) the *Lerner Index* for any variety $j \in [1, n_1]$ in country 1 as

$$L_1 = \frac{P_1 - c}{P_1} = \frac{1}{\sigma + (1-\sigma)\frac{P_1^{1-\sigma}\sum_{i=2}^{\ell+r}\tilde{P}_i^{-2}\Gamma_i}{\sum_{i=2}^{\ell+r}\tilde{P}_i^{-1}\Gamma_i}}$$

Similarly for varieties produced in country i we have

$$L_i = \frac{P_i - c}{P_i} = \frac{1}{\sigma + (1-\sigma)\frac{P_i^{1-\sigma}\sum_{k=\ell,k\neq i}^{\ell+r}\tilde{P}_k^{-2}\Gamma_k}{\sum_{k=1,k\neq i}^{\ell+r}\tilde{P}_k^{-1}\Gamma_k}} \tag{18}$$

Equation (18) for $i = 1, 2, \cdots, \ell$ gives ℓ equations in ℓ prices, one for each country.

We have now set out the *price equilibrium* in stage 2 of the game, and in general it can be asymmetric. In our set-up asymmetries can arise from differences in G_i and w_i[8]

[8] It is also straightforward to allow for different marginal costs replacing c with c_i in (18)

In a symmetric equilibrium with identical producer countries, $n_1 = n_2 = \cdots = n$ and $\tilde{P} = \ell n P^{1-\sigma}$ for non-producers and $\tilde{P} = (\ell - 1) n P^{1-\sigma}$ for producers. Then with identical non-producers each spending G^{np}, the Lerner index becomes

$$L = \frac{P - c}{P} = \frac{1}{\left[\sigma + \frac{1-\sigma}{\ell n}\left[\frac{\ell^3(G^p - npd) + r(\ell-1)^2 G^{np}}{(\ell-1)[\ell^2(G^p - npd) + (\ell-1) r G^{np}]}\right]\right]} \tag{19}$$

Equation (19) gives the Lerner index for the symmetrical price equilibrium in its most general form where the world market price depends on all the procurement decisions at stage 1 of the game. To make the model tractable we focus on two opposite cases. The first is where the external market of non-producers dominates on the demand side, i.e., $rG^{np} >> \ell(G^p - npd)$,[9] a condition satisfied as the domestic preference parameter w approaches unity, then we have

$$L = \frac{P - c}{P} = \frac{1}{\left[\sigma - \frac{\sigma-1}{\ell n}\right]} \tag{20}$$

The opposite extreme to the domination of the external market is to assume it is non-existent. Then $G^{np} = 0$ in the model and the Lerner index becomes

$$L = \frac{P - c}{P} = \frac{1}{\left[\sigma - \frac{\sigma-1}{(\ell-1)n}\right]} \tag{21}$$

Whereas (20) is valid for $\ell = 1$, (21) only holds for $\ell > 1$. The reason we must exclude the single-country case for a model of producers only is that the market at stage 3 is created by importers and we therefore need at least two countries for a market price to exist.

For both assumptions, since $\sigma > 1$, this Lerner index $L > \frac{1}{\sigma}$ and is decreasing in n. Hence compared with the standard model of monopolistic competition (i.e., without strategic interaction by firms) the price is now higher which, in turn, encourages entry and results in more firms in equilibrium.[10] From (20) the condition for the non-strategic pricing assumption to be a good approximation in a symmetric equilibrium whether producers or non-producers dominate on the demand side is that

$$n(\ell - 1) \gg \frac{\sigma - 1}{\sigma} \tag{22}$$

[9]From (19) the precise condition for the external market to dominate the pricing decision is: $\frac{rG^{np}}{\ell(G^P - npd)} >> \left(\frac{\ell}{\ell-1}\right)^2$.

[10]See Beath and Katsoulacos (1991), chapter 3.

For large numbers of firms (22) will hold even for $\sigma = \frac{1}{1-\alpha}$ large (i.e., α close to unity where goods become close substitutes). Even for small numbers of firms the condition will hold if σ approaches unity (the Cobb-Douglas case) where $P \to \infty$. In the next subsection we study the full equilibrium under the assumption that (22) is satisfied in equilibrium so that all varieties sell at the same mark-up over marginal costs $P_j = P = \frac{c}{\alpha}$. The case of procurement when (22) is not satisfied and strategic pricing behaviour by firms is significant is examined in section 3.4.

4.3 The Procurement Decision at Stage 1

We now complete the equilibrium by evaluating the optimal decision of the government in country 1 at the procurement stage 1 of the game. The government when choosing the procurement price, p_1, relaxes or tightens the firms' participation constraint and, in effect, chooses the number of domestic firms. Imposing symmetry between identical domestic firms $d_{1j} = d_1$ for all domestic varieties. Moreover, given the symmetry between all firms in within each country $i = 2, 3, \cdots, \ell$ in the international market, government 1 will choose the same amount of imports of each variety from country i, m_{1i} say. We examine a Nash equilibrium of stage 1 of the game and a subgame perfect equilibrium of the whole game, where for country 1, the government's independent decision variables are d_1 and n_1.[11]

The optimization problem of the government in country 1 is to maximize utility

$$U_1 = [w_1 n_1 + (1 - w_1)(N - n_1)]^{\nu} \left[w_1 n_1 d_1^{\alpha} + (1 - w_1) \sum_{i=2}^{\ell} n_i m_{1i}^{\alpha} \right]^{\frac{1}{\alpha}} \tag{23}$$

with respect to independent choice variables d_1 and n_1, given the world prices $P_i = P = \frac{c}{\alpha}$ of each variety from country i, the corresponding decisions of other countries, and two constraints. These are the budget constraint (BC_1) and the representative domestic firm's

[11] Any two from four possible decision variables, d_1, m_1, p_1 and n_1 can be assumed, but will lead to different Nash equilibria. Our particular choice, d_1, and n_1 is made partly, for analytical convenience, but can be also justified by the need to *observe* decision variables in a more realistic incomplete information setting, where the process of dynamic adjustment towards the equilibrium, for example of a Cournot-type, needs to be addressed. It is plausible to assume that the domestic procurement decision, d_i, and the number of firms supported, n_i, $i = 1, 2, \cdots, \ell$ are more readily observed that the procurement price, p_i, $i = 1, 2, \cdots, \ell$, which involves a possibly hidden subsidy.

participation constraint (PC_1) given by

$$
\begin{aligned}
BC_1 &: \quad p_1 n_1 d_1 + \sum_{i=2}^{\ell} P_i n_i m_{1i} = G_1 \\
PC_1 &: \quad \pi_1 = (p_1 - c)d_1 + (P_1 - c)x_1 - F \geq 0
\end{aligned}
$$

Clearly the PC constraint must bind so the procurement price is given by

$$
p_1 = c + \frac{F - (P_1 - c)x_1}{d_1} = c + \frac{F - R(x_1)}{d_1} \tag{24}
$$

where we have written export net revenue $(P_1 - c)x_1 = R(x_1)$. It is useful to note that exports $x_1 = x_{1j}$ of each home variety j can be written in terms of decision variables as the sum of exports to other producers (x_1^p) and to non-producers (x_1^{np}) as follows:

$$
\begin{aligned}
x_1 = \sum_{i=2}^{\ell+r} m_i &= \sum_{i=2}^{\ell} m_i + \sum_{i=\ell+1}^{\ell+r} \frac{G_i}{P(n_1 + n_2 + \cdots + n_\ell)} \\
&= x_1^p + x_1^{np} \qquad (25)
\end{aligned}
$$

Since we are assuming a Nash equilibrium in independent decision variables d_1 and n_1 we can eliminate the procurement price p_1 using the PC_1 constraint. The BC_1 constraint now becomes

$$
BC_1 \,:\, n_1(cd_1 + F - R(x_1)) + \sum_{i=2}^{\ell} P_i n_i m_{1i} = G_1 \tag{26}
$$

and the government now maximizes U_1 given by (23) with respect to d_1 and n_1, given (26), and the corresponding decision variables and constraints of other governments.[12]

To carry out this constrained optimization, define a Lagrangian

$$
\begin{aligned}
\mathcal{L}_1 = U_1 \quad &- \quad \lambda_1[n_1(c_1 d_1 - R_1(x_1)) + \sum_{i=2}^{\ell} P_i n_i m_{1i} - G_1] \\
&- \quad \sum_{i=2}^{\ell} \mu_i [n_i(c_i d_i - R_i(x_i)) + \sum_{j=1,\, j\neq i}^{\ell} P_j n_j m_{ij} - G_i]
\end{aligned}
$$

where $\lambda_1 \geq 0$ is a Lagrange multiplier country 1 assigns to its own budget constraint, and $\mu_{1i} \geq 0,\ \ i = 2, 3, \cdots, \ell$ are Lagrange multipliers assigned to the other countries' budget constraints. Then country 1 maximizes $\mathcal{L}_1$ with respect to independent decision variables d_1, n_1, and with respect to endogenous variables $\{m_{ij},\, \lambda_i, \mu_i\}$, $i, j = 1, 2, \cdots, \ell$, $j \neq i$, given the independent decision variables of the other countries $\{d_i,\, n_i\}$, $i = 2, 3, \cdots, \ell$.

[12]Since the procurement price is eliminated it is apparent that the payment to the firm can also be treated as a lump sum of amount $p_1 d_1$.

This optimization problem is greatly simplified as a result of the following Lemma:

Lemma

In a subgame perfect equilibrium (SPE) of the game $\mu_{1i} = 0$, $i = 2, 3, \cdots, \ell$.

Proof

The first-order condition with respect to m_{1i} is given by

$$\frac{\partial U_1}{\partial m_{1i}} = U_1^{1-\alpha}[w_1 n_1 + (1-w_1)(N-n_1)]^{\alpha\nu}(1-w_1)n_i m_{1i}^{\alpha-1} = \lambda_1 P_i n_i - \sum_{j=2}^{\ell} \mu_j n_j \frac{\partial R_j}{\partial m_{1j}} \; ; \; i > 1 \tag{27}$$

In (27) we have for country i that export net revenue is given by $R_i = (P_i - c)x_i = (P_i - c)(x_i^p + x_i^{np})$. From the counterpart of (25) for country i, we have $x_i^p = \sum_{j \neq i}^{\ell} m_{ji}$. Hence $\frac{\partial R_i}{\partial m_{1i}} = (P_i - c)$. Then dividing the $i = r$ equation by the $i = s$ equation, the relative demand by country for imported goods from countries $i = r, s$ is given by

$$\frac{m_{1r}}{m_{1s}} = \left[\frac{\lambda_1 P_s - \frac{1}{n_s}\sum_{j=2}^{\ell} \mu_{1j} n_j (P_j - c)}{\lambda_1 P_r - \frac{1}{n_r}\sum_{j=2}^{\ell} \mu_{1j} n_j (P_j - c)}\right]^{\sigma} \tag{28}$$

However from (11) at stage 3 of the game, the relative demand by country 1 for two imported goods from countries $i = r, s$ is given by

$$\frac{m_{1r}}{m_{1s}} = \left(\frac{P_s}{P_r}\right)^{\sigma} \tag{29}$$

where prices are now out of equilibrium as defined in stages 2 and 1. In a SPE we must have agreement with the *anticipated* decision on imports given by (28) and the *actual* decision taken at stage 3 given by (29). This requires $\sum_{j=2}^{\ell} \mu_{1j} n_j (P_j - c) = 0$. Since $P_j > c$ and $\mu_{1i} \geq 0$ it follows that $\mu_{1i} = 0$ for all $i = 2, 3, \cdots, \ell$. □

If at stage 1 the governments could commit to both domestic and overseas contracts, then imports of the later would satisfy the first-order condition (27) with $\mu_{1i} > 0$. According to (27), the marginal benefit (the left-hand-side) equals the marginal budgetary cost. The first term of the latter, on the right-hand-side, equals the shadow price of BC_1 multiplied by the procurement price. The second term equals the sum of the shadow price of BC_i, $i > 1$ multiplied by the marginal revenue gain to each foreign country from exporting to country 1. Exports to country 1 relax these budget constraints and bring benefit to that country through allowing for more imports. Taking this into consideration lowers the effective cost of imports and therefore increases their volume.

Having made this commitment to importing more than it would in the absence of these strategic considerations, at stage 3 country 1 has a given import budget $G_1 - p_1 n_1 d_1$. If it were to re-optimize given world market prices, it would choose imports given by (11) and therefore set $\mu_{1i} = 0\,;\, i > 1$. The ex ante optimal contract at stage 1 is no longer optimal ex post at stage 3. The equilibrium is not subgame perfect in other words. The subgame perfection condition imposes $\mu_i = 0$, $i > 2$ and implies that at stage 1 country 1 ignores the budget constraints of other countries. Alternatively it implies that country 1 takes exports to other producers x_1^p as given.[13]

With $\mu_i = 0$, $i > 2$, and $P_i = P = \frac{c}{\alpha}$ in the equilibrium at stage 1, the remaining first-order conditions for an internal solution (where $n_1 \geq 0$ and $d_1 \geq 0$ and are not binding, but BC_1 does bind) are then

$$d_1 \;:\; \frac{\partial U_1}{\partial d_1} = U_1^{1-\alpha}[w_1 n_1 + (1-w_1)(N-n_1)]^{\alpha\nu} w_1 d_1^{\alpha-1} = \lambda c \tag{30}$$

$$\begin{aligned} n_1 \;:\; \frac{\partial U_1}{\partial n_1} &= \frac{U_1^{1-\alpha}}{\alpha} w_1 d_1^{\alpha}[w_1 n_1 + (1-w_1)(N-n_1)]^{\alpha\nu} + \nu w_1 U_1 [w_1 n_1 + (1-w_1)(N-n_1)]^{-1} \\ &= \lambda(c d_1 + F - R(x_1) - n_1 \frac{\partial R_1}{\partial n_1}) \end{aligned} \tag{31}$$

$$m_1 \;:\; \frac{\partial U_1}{\partial m_1} = U_1^{1-\alpha}[w_1 n_1 + (1-w_1)(N-n_1)]^{\alpha\nu}(1-w_1) m_1^{\alpha-1} = \lambda P \tag{32}$$

These 3 equations plus the constraint BC_1 solve for the decision variables n_1, d_1, m_{1j} and for λ. Note from (25) we have $\frac{\partial x_1}{\partial n_1} = -\frac{\sum_{i=\ell+1}^{\ell+r} G_i}{PN^2}$. Using this and dividing (31), and (32) by (30), in turn, we can eliminate the shadow price λ to obtain

$$d_1 = \frac{\left[F - R(x_1) + \frac{n_1 \sum_{i=\ell+1}^{\ell+r} G_i}{\sigma N^2}\right]}{P\left[1 - \alpha + \frac{\alpha\nu}{[w_1 n_1 + (1-w_1)(N-n_1)]^{1+\alpha\nu}} \left(\frac{U_1}{d_1}\right)^{\alpha}\right]} \tag{33}$$

$$m_1 = d_1 \left(\frac{c(1-w_1)}{P w_1}\right)^{\sigma} = \phi_1 d_1 \tag{34}$$

where we have defined

$$\phi_1 = \left(\frac{c(1-w_1)}{P w_1}\right)^{\sigma} = \left(\frac{\alpha(1-w_1)}{w_1}\right)^{\sigma} \tag{35}$$

[13] As it turns out in equilibrium, x_1^p which equals imports by other producers, is a linear function of decision variables d_i and the equilibrium world price P. For the monopolistic competition assumption the latter is a constant so in that case taking x_1^p as given is valid. With strategic pricing by firms however x_1^p depends on n_1 through its effect on the world price. The subgame perfect condition is then essential for this case.

and used $P = \frac{c}{\alpha}$. Similarly for country i imports of all varieties j are $m_i = \phi_i d_i$ where

$$\phi_i = \left(\frac{\alpha(1-w_i)}{w_i}\right)^{\sigma} \tag{36}$$

To complete the solution we note that exports of country 1 can now be written

$$x_1 = \sum_{i=2}^{\ell} m_i = \sum_{i=2}^{\ell} \phi_i d_i + \sum_{i=\ell+1}^{\ell+r} \frac{G_i}{NP} \tag{37}$$

The budget constraint

$$n_1 = \frac{G_1 - PNm_1}{p_1 d_1 - Pm_1} \tag{38}$$

completes the solution for the single economy given the decisions on d_i, m_i and n_i by the other countries.

We now solve for a symmetric non-cooperative equilibrium in which all producer countries and all non-producing countries are identical. Then $w_i = w$, $G_i = G^p$ say, for producers $(i = 1, 2, \cdots, \ell)$ and $G_i = G^{np}$ for non-producers ($i = \ell+1, \ell+2, \cdots, \ell+r$). Then $d_1 = d_2 = \cdots = d$, $n_1 = n_2 = \cdots = n$ etc, $N = \ell n$, $\phi_i = \phi = \left(\frac{\alpha(1-w)}{w}\right)^{\sigma}$ and $\frac{U_i}{d_i} = \frac{U}{d} = n^{\nu+\frac{1}{\alpha}}[w + (1-w)(\ell-1)]^{\nu}[w + (1-w)(\ell-1)\phi^{\alpha}]^{\frac{1}{\alpha}}$ for producing countries. The first-order condition (33) now becomes

$$d = \frac{(F - R + \Theta_1)}{P(1 - \alpha + \Theta_2)} \tag{39}$$

where we have defined

$$\begin{aligned}
\Theta_1 &= \frac{rG^{np}}{\sigma \ell N} \\
\Theta_2 &= \frac{\alpha\nu[w + (1-w)(\ell-1)\phi^{\alpha}]}{[w + (1-w)(\ell-1)]}
\end{aligned}$$

Substituting for $F - R$ from (39) into (24) we arrive at the procurement price in the non-cooperative symmetric equilibrium

$$p = P(1 + \Theta_2) - \frac{\Theta_1}{d} \tag{40}$$

Hence for a 'traditional' Dixit-Stiglitz utility function where $\nu = \Theta_2 = 0$ and in the limit as the external market becomes small (but still of sufficient size to determine the world market price), $\Theta_1 \to 0$ and we have that $p = P$; i.e., the procurement price equals the market price. Generally however the procurement price can be above or below the world market price.[14] A high taste for variety ν encourages the former and whilst a large external market encourages the latter. The intuition behind this external effect is that increasing the number of differentiated goods, each produced by a single firm, reduces the net export revenue to the external market per firm and tightens the participation constraint. In a non-cooperative equilibrium each government takes into account only their own contribution to the world supply of differentiated goods and, through reducing the procurement price, lowers its optimal number of domestic firms as the external market becomes more important. We summarize this result as:

Proposition 1: The Procurement Price

In a symmetric, non-cooperative equilibrium without strategic pricing by firms, the procurement price may be above or below the world market price. A high taste for variety encourages the former and a large external market encourages the latter.

To derive the full solution to the non-cooperative equilibrium put $x_1 = x = (\ell-1)\phi d + \frac{rG^{np}}{NP}$. Then using (33), (40) and the budget constraint (38) some algebra leads to

$$\begin{aligned} d &= \frac{\left[F - \frac{rG^{np}}{\sigma \ell n}\left(1-\frac{1}{\ell}\right)\right]}{P\left[(1-\alpha)(1+(\ell-1)\phi)+\Theta_2\right]} \\ &= \frac{G^p + \frac{rG^{np}}{\sigma \ell^2}}{nP\left(1+(\ell-1)\phi+\Theta_2\right)} \end{aligned}$$

Hence we can solve for the equilibrium number of differentiated goods (equals the number of firms), n, and hence the total world number $N = \ell n$. We express the following result for N in terms of the total world expenditure $G = \ell G^p + rG^{np}$ and the relative size of the external market of non-producers $\frac{rG^{np}}{G}$:

$$N = \frac{G}{F}\left[\theta - \frac{rG^{np}}{G}\left(\theta\left(1-\frac{1}{\sigma\ell}\right) - \frac{1}{\sigma\ell}(\ell-1)\right)\right] \tag{41}$$

where we have defined

$$\theta = \frac{(1-\alpha)(1+(\ell-1)\phi)+\Theta_2}{1+(\ell-1)\phi+\Theta_2} \in ((1-\alpha),1)$$

[14] As long as $p > c$, the firm having incurred the fixed cost of entry will benefit from the procurement contract and in a free-entry equilibrium of identical firms, those relying only on the export market will not be able to survive. Thus through the procurement process, the government can choose the number of firms in equilibrium.

Again the model reduces to a special case of a 'traditional' Dixit-Stiglitz utility function where $\nu = \Theta_2 = G^{np} = 0$. Then $\theta = 1-\alpha$ and we have that $N = \frac{G(1-\alpha)}{F}$, a familiar result for a closed economy monopolistic competition model. From (41) and the definition of Θ_1 given after (39) we can now examine the effect on the world number of firms of changes in the taste for variety parameter ν, the preference for domestic supply parameter $w \in [\frac{1}{2}, 1]$ and the relative size of the external market $\frac{rG^{np}}{G}$. First note that $\theta \in [1-\alpha, 1]$ as ν increases from 0 to ∞. Furthermore, from (41), N is increasing in θ if $1 > \frac{rG^{np}}{G}\left(1 - \frac{1}{\sigma\ell}\right)$. Since $\frac{rG^{np}}{G} < 1$, $\sigma > 1$ and $\ell \geq 1$ this condition is satisfied. Hence it follows that N is an increasing function of ν and we arrive at the intuitive result that an increase in the taste for variety in producer countries increases the number of differentiated goods.

Next consider an increase in w. In the range $w \in [\frac{1}{2}, 1]$, ϕ falls from α^{σ} to 0 and Θ_2 goes from $\frac{\alpha\nu[1+(\ell-1)\alpha^{\sigma\alpha}]}{\ell}$ to $\alpha\nu$. Since $\alpha^{\alpha\sigma} < 1$, $\frac{1+(\ell-1)\alpha^{\sigma\alpha}}{\ell} < 1$ and therefore this represents an increase in Θ_2 and therefore θ. We have already shown that N is an increasing function of θ. It follows that as producer countries become less concerned with domestic supply, Θ_2 falls and therefore the equilibrium number of firms, N, falls.

Finally from (41), N decreases with the relative size of the external market, $\frac{rG^{np}}{G}$, if the following condition is satisfied:

$$\theta > \frac{1}{\sigma\ell}(\theta + \ell - 1) \tag{42}$$

Since $\theta < 1$, the right-hand side of (42) is an increasing function of ℓ and at $\ell = \infty$ equals $\frac{1}{\sigma}$. But $\theta > 1 - \alpha$. Hence (42) holds.

A willingness to procure from abroad, ' openness' in our terminology, and the growing relative size of the international market of non-producers as production becomes more concentrated are two features one may associate with globalization. In that sense we may conclude that our results suggest that globalization is associated with a *decrease* in the number of firms in the world market. Summarizing our results:

Proposition 2: The Number of Firms

In a symmetric, non-cooperative equilibrium without strategic pricing by firms, the number of firms increases as the taste for variety by producer countries increases. An increase in openness, in the form of a reduction in preferences of producer countries for domestic supply, and an increase in the relative size of the external market results in a decrease in the number of firms.

5 Strategic Pricing by Firms

In our previous calculations, at stage 1 the governments either were, in effect, price-takers in the world market because the world price $P_j = \frac{c}{\alpha}$ was independent of the decisions taken at that stage, or they were constrained to procure at the world market price. In fact in the Bertrand equilibrium described by (18) the equilibrium price depends on decisions made at stage 1. A symmetric strategic equilibrium is at least partially tractable if we confine ourselves the the case where the demand for imports by producers is small compared with that of non-producers and the condition for this, $\frac{rG^{np}}{\ell(G^P - npd)} >> \left(\frac{\ell}{\ell-1}\right)^2$, is satisfied. Then $P_1 = P_2 = \cdots = P$. Furthermore, in a symmetric equilibrium, country 1 does not distinguish between the remaining counties and assumes $n_2 = n_3 = \cdots = n_\ell = n$, say. Therefore it sees the effect of its own procurement decision on the world market price (obtained from (20)) through the relationship:

$$P = \frac{[N\sigma + 1 - \sigma]c}{[N-1](\sigma - 1)} = \frac{[(n_1 + (\ell-1)n)\sigma + 1 - \sigma]c}{[(n_1 + (\ell-1)n) - 1](\sigma - 1)} \tag{43}$$

which introduces new terms into the first-order condition (31). Now with strategic procurement by the governments and strategic pricing by firms (31) is generalized to:

$$\begin{aligned} n_1 \quad : \quad \frac{\partial U_1}{\partial n_1} &= \frac{U_1^{1-\alpha}}{\alpha} w_1 d_1^{\alpha}[w_1 n_1 + (1-w_1)(N-n_1]^{\alpha\nu} + \nu w_1 U_1 [w_1 n_1 + (1-w_1)(N-n_1]^{-1} \\ &= \lambda\left(cd_1 + F - R(x_1) - n_1 \frac{\partial R_1}{\partial n_1} + (\ell-1)nm_1\frac{\partial P}{\partial n_1}\right) \end{aligned} \tag{44}$$

whilst (30) and (27) remain as before, as does the relationship

$$m_1 = \phi_1 d_1 \tag{45}$$

where $\phi_1 = \phi_1(P) = \left(\frac{c(1-w)}{Pw}\right)^{\sigma}$. Exports from country 1 are given as before by the import demand of the rest of the world:

$$x_1 = \sum_{i=2}^{\ell} m_i + \frac{rG^n}{P_1^{\sigma}\tilde{P}_i} = x_1^p + \frac{rG^n}{P_1^{\sigma}\tilde{P}_i} \tag{46}$$

To interpret (44) write the condition as

$$\frac{\partial U_1}{\partial n_1} = \lambda\left[p_1 d_1 - n_1\frac{\partial R_1}{\partial n_1} + (\ell-1)nm_1\frac{\partial P}{\partial n_1}\right] \tag{47}$$

The left-hand-side of (47) is the marginal benefit to utility from a marginal increase in the number of firms. The right-hand-side is the marginal budgetary cost. In the absence of the second and third strategic procurement terms this marginal cost is simply the shadow price of the BC (λ) multiplied by the cost of the procurement from the marginal firm. The strategic terms *reduce* this budgetary cost by raising export revenue (the second term) and reducing the cost of imports through lowering P, the third term.

Given the decisions of the remaining countries, the PC_1 and the BC_1 conditions:

$$p_1 = c + \frac{F - R(x_1)}{d_1} \tag{48}$$

$$G_1 = p_1 n_1 d_1 + (\ell - 1) n P m_1 \tag{49}$$

complete the formulation of the first order conditions for country 1.

We now calculate the symmetric equilibrium for ℓ identical countries making the same strategic procurement decisions as country 1. First, partially differentiate $R_1 = (P_1 - c)x_1$ keeping m_i and n_i, $i = 2, 3, \cdots, \ell$ (the decision variables of the other countries) fixed to give, in a symmetric equilibrium,

$$\begin{aligned}\frac{\partial R_1}{\partial n_1} &= \frac{\partial P}{\partial n_1} x_1^p + (P - c)\frac{\partial x_1^{np}}{\partial n_1} + x_1^{np}\frac{\partial P}{\partial n_1} \\ &= \frac{\partial P}{\partial n_1} x_1^p - \frac{rG^{np}}{NP}(P - c)\left(\frac{1}{N} + \frac{1}{P}\frac{\partial P}{\partial n_1}\right) + x_1^{np}\frac{\partial P}{\partial n_1}\end{aligned} \tag{50}$$

where $x^p = (\ell - 1)\phi d$ and $x^{np} = \frac{rG^n}{NP}$ are exports per firm to other producing and non-producing countries respectively. To complete the solution of the symmetric equilibrium we require partial derivative of (43):

$$\frac{\partial P}{\partial n_1} = -\frac{c}{(N - 1)^2(\sigma - 1)} \tag{51}$$

In a symmetric equilibrium terms involving exports to other producers on the right-hand-side of (44) are

$$-n_1 x_1^p \frac{\partial P}{\partial n_1} + (\ell - 1) n m_1 \frac{\partial P}{\partial n_1} = 0$$

since internal trade between producers balances. The first-order condition (39) is now

$$d = \frac{(F - R + \Theta_1 + \Theta_3)}{P(1 - \alpha + \Theta_2)} \tag{52}$$

where

$$\begin{aligned}\Theta_1 &= \frac{rG^{np}}{\sigma \ell N} \\ \Theta_2 &= \frac{\alpha\nu[w + (1 - w)(\ell - 1)\phi^\alpha]}{[w + (1 - w)(\ell - 1)]} \\ \Theta_3 &= -\frac{rG^{np}}{\ell P}(1 - L)\frac{\partial P}{\partial n_1} = \frac{rG^{np}}{\ell}\frac{(1 - L)}{(N - 1)(1 + (N - 1)\sigma)}\end{aligned}$$

Again substituting for $F - R$ from (52) into (24) we arrive at the procurement price in the non-cooperative symmetric equilibrium with strategic pricing by firms:

$$p = P(1 + \Theta_2) - \frac{\Theta_1 + \Theta_3}{d} \quad (53)$$

Compared with (40) there is now a new term in Θ_3 in the procurement price equation. This has the effect of strengthening the 'external market' effect referred to in proposition 1. Whereas strategic pricing has the effect of increasing the world market price P, the desire to extract more revenue from the external export sector sees producers lowering firm numbers further by lowering the procurement price relative to P. Hence the new proposition:

Proposition 3: The Procurement Price with Strategic Pricing

In a symmetric, non-cooperative equilibrium with strategic pricing by firms, the procurement price again may be above or below the world market price. A high taste for variety encourages the former and a large external market encourages the latter. Strategic pricing by firms enhances the external market effect and further lowers the procurement price relative to the market price.

The extra strategic pricing term involves a term in $\frac{1}{(n\ell-1)(1+(n\ell-1)\sigma)}$ and the price P is now longer fixed at stage 1, but now depends on n. These changes precludes an analytical solution for the equilibrium number of firms and for the rest of the equilibrium.[15] However analytical results comparing the non-cooperative equilibrium with a benchmark optimum producers would reach, if they were to cooperate over procurement decisions at stage 1 of the game, are possible. This we now consider.

6 Cooperation Between Producers

In a symmetric cooperative agreement at stage 1, ℓ identical producers would choose $d_1 = d_2 = \cdots = d_\ell = d$, $n_1 = n_2 = \cdots = n_\ell = n$ and $m_1 = m_2 = \cdots = m_\ell = m$ to maximize $U_1 = U_2 = \cdots = U_\ell = U$ where

$$U = [w + (1-w)(\ell-1)]n^{\nu+\frac{1}{\alpha}}[wd^\alpha + (1-w)(\ell-1)m^\alpha]^{\frac{1}{\alpha}} \quad (54)$$

[15] A working paper version of this paper, Garcia-Alonso and Levine (2004), provides numerical results for the full strategic pricing equilibrium.

subject to budget constraints $BC_1 = BC_2 = \cdots, = BC$ and participation constraints $PC_1 = PC_2 = \cdots = PC$ where

$$BC \;:\; n[pd + P(\ell - 1)m] = G^p$$

$$PC \;:\; \pi = (p - c)d + R(x) - F = 0$$

In PC the net revenue is given by

$$R(x) = (P - c)x = (P - c)(x^p + x^{np}) = (P - c)\left[(\ell - 1)m + \frac{rG^{np}}{\ell nP}\right] \tag{55}$$

where again assuming that $\frac{rG^{np}}{\ell(G^P - npd)} >> \left(\frac{\ell}{\ell-1}\right)^2$ and the external market dominates on the supply side, the price is given by the Lerner index

$$L = L(n) = \frac{P - c}{P} = \frac{1}{\sigma - \frac{\sigma - 1}{\ell n}} \tag{56}$$

Using (55) we can consolidate the BC and PC constraints as

$$n[c(d + (\ell - 1)m) + F) = L(n)\frac{rG^{np}}{\ell} + G^p \tag{57}$$

Hence the optimal procurement decision for the producers together is found by maximizing $n^{\nu + \frac{1}{\alpha}}[wd^\alpha + (1 - w)(\ell - 1)m^\alpha]^{\frac{1}{\alpha}}$ with respect to n, d and m subject to the consolidated constraint (57).

To carry out this optimization define a Lagrangian

$$n^{\nu + \frac{1}{\alpha}}[wd^\alpha + (1 - w)(\ell - 1)m^\alpha]^{\frac{1}{\alpha}} - \lambda\left[n[c(d + (\ell - 1)m) + F) - L(n)\frac{rG^{np}}{\ell} - G^p\right]$$

where $\lambda \geq 0$ is a Lagrangian multiplier. The first-order conditions are:

$$n \;:\; (\nu + \frac{1}{\alpha})n^{(\nu + \frac{1}{\alpha} - 1)}[wd^\alpha + (1 - w)(\ell - 1)m^\alpha]^{\frac{1}{\alpha}} = \lambda\left[c(d + (\ell - 1)m) + F - L'(n)\frac{rG^{np}}{\ell}\right]$$

$$d \;:\; n^{(\nu + \frac{1}{\alpha})}[wd^\alpha + (1 - w)(\ell - 1)m^\alpha]^{\frac{1}{\alpha} - 1}wd^{\alpha - 1} = \lambda nc$$

$$m \;:\; n^{(\nu + \frac{1}{\alpha})}[wd^\alpha + (1 - w)(\ell - 1)m^\alpha]^{\frac{1}{\alpha} - 1}(1 - w)(\ell - 1)m^{\alpha - 1} = \lambda nc(\ell - 1)$$

Dividing the first and the third first-order condition by the second we arrive at:

$$m = \left(\frac{1 - w}{w}\right)^\sigma d \;=\; \bar{\phi}d, \text{ say} \tag{58}$$

$$cd\left[\left(\nu + \frac{1}{\alpha}\right)(w + (1 - w)(\ell - 1)\bar{\phi}^\alpha - w(1 + (\ell - 1)\bar{\phi})\right] \;=\; w\left[F - L'(n)\frac{rG^{np}}{\ell}\right] \tag{59}$$

where from (56) we have

$$L'(n) = -\frac{\ell(\sigma-1)}{\ell\left(n\sigma - \frac{\sigma-1}{\ell}\right)^2} \tag{60}$$

Equations (58), (59), (60) together with the constraint (57) characterize the optimal cooperative procurement agreement.

Equation (59) can be simplified somewhat by noting that $[w + (1-w)(\ell-1)\bar{\phi}^{\alpha}] = w\left[1 + \left(\frac{1-w}{w}\right)(\ell-1)\bar{\phi}^{\alpha}\right] = w\left[1 + \left(\frac{1-w}{w}\right)^{\frac{1}{1-\alpha}}(\ell-1)\right] = w[1 + \bar{\phi}(\ell-1)]$. Then substituting into (59), a little algebra results in

$$N = \frac{(1-\alpha+\alpha\nu)G\left[1 - \frac{rG^{np}}{G}\left(1 - \frac{L(n)}{\ell}\right)\right]}{\left[F(1+\alpha\nu) - \frac{\alpha L'(n) r G^{np}}{\ell}\right]} \tag{61}$$

An interesting result follows from (61). The right-hand-side is a decreasing function of n and is *independent of the domestic production bias parameter, w.* Therefore the solution, given by the fixed point of this function, is unique and is independent of w. Since imports $m = \bar{\phi}d$ where $\bar{\phi} = \frac{1-w}{w}$, an increase in w has no effect on the total number of firms (varieties) in the cooperative arrangement and only affects the trade between producers.[16] Note that this contrasts with the non-cooperative arrangement where an decrease in w leads to a decrease in the total number of firms (see proposition 2). As with the non-cooperative equilibrium, however, since $L(n) < 1$, from (61) we can see that an increase in the relative size of the external market leads to a lower total number of firms under cooperative, and comparing (61) with (41), cooperation enhances this 'external effect' on the total firm number. To summarize:

Proposition 4: Optimal Cooperative Procurement

In the optimal cooperative procurement arrangement, the total number of firms is independent of the preferences of producer countries for domestic supply. As with the non-cooperative equilibrium, an increase in the relative size of the external market leads to a lower total number of firms under cooperation. The effect of strategic pricing by firms is to lower the number of firms chosen by governments in the procurement process.

[16] Compare the trade equation in the non-cooperative equilibrium, where $m = \phi d$ and $\phi = \frac{c(1-w)}{Pw}$. With cooperation, trade is valued not at the world market price, but at the marginal cost, resulting in *more* trade.

6.1 Comparison of Cooperative and Non-Cooperative Equilibria

Denote the firm number per country in the cooperative and non-cooperative equilibria given by (61) and (41), divided by ℓ, by n^C and n^{NC} respectively. We can derive analytical results for the difference $n^C - n^{NC}$ for the large firm numbers case without strategic pricing (where $L = \frac{1}{\sigma}$ and therefore $L'(n) = 0$) given by (41). First, putting $\ell = 1$ in the latter expression we find, as expected, that $n^C = n^{NC}$; i.e., the non-cooperative equilibrium and the cooperative arrangement are the same if there is only one country.

Now suppose that there is no external market. Putting $r = 0$ in (61) and (41) a little algebra shows that $n^C \geq> n^{NC}$ for $\nu \geq 0$. In the case of $\nu = r = 0$ and monopolistic competition we arrive at the familiar Dixit-Stiglitz result that the non-cooperative equilibrium is efficient and therefore there are no gains from cooperation in the procurement decision. If $\nu > 0$ but there is no external market the non-cooperative equilibrium is inefficient: each country fails to internalize external benefit to other countries from producing variety and result is that too few varieties are produced.

We can analyze the case where there is an external market but the Dixit-Stiglitz utility function is conventional ($\nu = 0$). Then it is straightforward to show the opposite is true: $n^C < n^{NC}$. Now the non-cooperative equilibrium is again inefficient but this time there are *too many* varieties produced compared with the efficient cooperative equilibrium. The reason for this is that given total demand is fixed, competition for the external market sees revenue from external exports *per firm* rise as the total number of firms falls. This occurs because firms then compete less intensively and can spread their fixed costs over a larger market share. Under non-cooperation, governments in choosing firm numbers choose to have more firms compared with the optimum because governments acting independently can only affect competition between their own domestic firms. We can summarize our results as follows:

Proposition 5. Comparison of Cooperative and Non-Cooperative equilibria under Monopolistic Competition.

Comparing the cooperative and non-cooperative equilibria without strategic pricing by firms, with no external market, taste for variety ($\nu > 0$) results in too few firms in the non-cooperative equilibrium. If $\nu = 0$ competition is the external market results in too many firms in the non-cooperative equilibrium.

7 Conclusions

This paper has explored the strategic procurement behaviour by governments who can, in effect, choose the number of firms and their size by adjusting the procurement price. In a standard Dixit-Stiglitz monopolistic competition model with no external market of non-producers the procurement price turns out to be the world market price, openness has no effect on market structure and the non-cooperative equilibrium is efficient. With an external market and a modified Dixit-Stiglitz utility function to incorporate a taste for variety effect, this is no longer the case. The latter generates an incentive to subsidize and the non-cooperative equilibrium is inefficient with too few firms. The external market has the opposite effect on firm numbers. Now governments have an incentive to reduce fixed costs and cut back on the number of varieties that are produced since collectively variety number incurs no benefit in the external market. Acting individually countries will be deterred from reducing varieties produced and exported because of the loss of market share in the external sector. Acting collectively there is no such inhibition and then firm numbers will be cut further. With strategic pricing by firms this raises the price countries receive from the external market and the incentive to reduce the number of firms is strengthened.

In a symmetric, non-cooperative equilibrium, the number of firms is influenced by a number of factors. We show how the number of firms increases as the taste for variety by producer countries increases. In addition, an increase in openness, in the form of a reduction in preferences of producer countries for domestic supply, and an increase in the relative size of the external market results in a decrease in the number of firms and therefore an increase in concentration. Under cooperative procurement though, symmetric changes in home bias across countries do not affect concentration.

The positive implication of our results are that the marked increase in concentration in the military sectors of the US and the EU can be explained by a increase in openness and the increased importance of the external sector of arms importers. To some extent this also helps to explain concentration trends in the pharmaceutical industry as well. The normative implication is that there may well be significant gains from procurement coordination in these sectors in, for example, the EU context.

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