Strategic Investment and Trade in an Oligopolistic Setting

Ioana Veronica ALEXA*, Simona Valeria TOMA**, Daniela Anuța ȘARPE***

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ABSTRACT

This paper analyses the international trade dynamics between two countries as a two-player, non-zero sum, cooperative game. The reason behind this type of approach is that we consider game theory as an important instrument for the analysis of international trade dynamics. The model that we develop in this paper follows the multi-sectorial general-equilibrium model of oligopoly and trade. We will analyze the case where trade takes place because of oligopolistic interaction and comparative advantage. Even though we follow the general framework, the main departure from the existing models on the subject is that in our model both labor and capital are used in production and that the firms have a choice between specializing in labor or capital-intensive goods by choosing weather or not to invest in capital and therefore use two factors of production. As required by a general equilibrium model, we will try to establish an equilibrium on both labor and capital markets and we will try to determine the labor and capital intensity in both countries as well as the equilibrium level of the wage and rental rate.

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1. Introduction

The aim of this paper is to find an intelligent way of using to factors of production in a GOLE model, as well as developing a strategic investment component of the model which will allow for a strategic cooperative, non-zero sum game between at least two players.

As required by a general equilibrium model, we will try to establish an equilibrium on both labor and capital markets and we will try to determine the labor and capital intensity in both countries as well as the equilibrium level of the wage and rental rate.

Brander [1] is one of the first economists who use a partial equilibrium model to analyze strategic interactions between firms in intra-industry trade with similar products, while developing Rotemberg and Saloner [2] and later, Fung [3] have developed partial equilibrium models in oligopoly that analyze strategic interactions between countries.

Krugman [4] has shown that the effects on competition may also occur in a general-equilibrium model with differentiated products, on free entry markets and with additively-separable demand functions. However, most subsequent studies of international trade in general equilibrium model have used the Dixit-Stiglitz model of monopolistic competition, which assumes that price-cost margins of firms, and thus the competitiveness of an economy, are independent of market size.

The model developed by Melitz [5] introduces firms heterogeneity in the Dixit-Stiglitz model and demonstrates that trade liberalization promotes efficient firms at the expense of less efficient. But this is a result of consumer choice rather than one of competitiveness since each firm has the same benchmark.

In the 2008 article, Melitz and Ottaviano [6] use a quadratic demand system but since they assume that preferences are quasi-linear, they do not model the impact on factor markets.

According to Neary and Tharakan [7] one of the oldest themes in international economics is that larger or more open economies are likely to be more competitive. This notion has been formalized in a variety of ways but in our opinion this type of models should use two factors of production.

Of course, there are general equilibrium models that use two factors of production. Neary's 2002 model [5], Koska and Stahler's 2012 model [8] and the more recent and above mentioned 2012 model developed by Neary and Tharakan [7].

Neary and Tharakan have used the capacity constraint based on Maggi's model of capacity-price competition in which the equilibrium outcome ranges from the Bertrand to the Cournot outcome as capacity constraints become more important. [9]

However in all the models mentioned above we consider that the second factor of production has been introduced in an artificial way.

* ** ** *** Dunarea de Jos University of Galati, Romania. E-mail addresses: ioana.alexa@ugal.ro (I. V. Alexa), simona.toma@ugal.ro (S. V. Toma), daniela.sarpe@ugal.ro (D. A. Sarpe)
The model developed by in 2009 Eckel and Neary [10] and by Eckel et al. [11] in 2011 have allowed us to use the second factor of production as a strategic investment which has an effect on utility and therefore on the whole model.

According to Kerr and Gaisford [12], game theory can explain the states’ choices of strategies and the action they take as part of their trade policy, but also during international negotiations.

We will keep Neary and Tharakan’s [7] basic assumption regarding the case of free trade between two identical economies. However, instead of considering that trade takes place because of oligopolistic interaction and product differentiation, we will analyze the case where trade takes place because of oligopolistic interaction and comparative advantage.

Furthermore, according to Neary, “a consistent approach to modeling oligopoly in general equilibrium requires the firms to be large in the small but small in the large” [13] and we will maintain this key assumption of the GOLE model, so that we consider the firms large enough to play a strategic game against their foreign competitors, but they are too small to influence factor prices and therefore they will take them as given.

2. The Model

On the demand side, following Neary and Tharakan [7] we will consider an economy with a continuum of sectors indexed by $z$, where $z \in [0, 1]$.

In specifying the consumers’ preferences we will consider Eckel and Neary’s approach [10] as well as the utility function presented by Eckel et al. [11] The former specification of preferences combines the continuum-quadratic approach to symmetric horizontal product differentiation [14] with the absence of a numéraire good [15], while the latter presents an additive function of utility that depends on a the quantities consumed and on the interaction between quantity and quality.

In combining the two approaches presented above we will consider a market where each consumer’s utility will be of an additive form, where the first component, $u_1$, depends of the quantity consumed, $x(z)$, while the second component, $u_2$, will depend on the quality of the goods consumed.

Therefore can write the utility function as:

$$U(z) = u_1(z) + \beta u_2(z)$$

The sub-utility function depending on the quantity consumed will be of the form:

$$u_1(z) = a \int_0^1 x(z) dz - \frac{1}{2} b [(1 - e) \int_0^1 x(z)^2 dz + e \int_0^1 x(z) dz^2]$$

Where $a$, $b$ and $e$ are parameters assumed to be non-negative and identical for all consumers, $x(z)$ is the consumption level of a single variety produced in industry $z$ and $\int_0^1 x(z) dz$ denotes total consumption.

We follow Eckel and Neary [10] in considering $a$ as the consumer’s maximum willingness to pay, while $e$ represents an inverse measure of product differentiation ranging from zero (for heterogeneous goods) to one (for homogeneous products). [7]

The second-tier utility function, $u_2$, can be written as:

$$u_2(z) = (1 - e) k(z) dz + e \int_0^1 k(z) dz$$

where $k(z)$ denotes the level of investment each firm in industry $z$ will make in order to produce a single variety, while $\int_0^1 k(z) dz$ represents the total level of investment.

As we can see from equation (3), $u_2$ depends on the level of investment that each firm will make but also on the total level of investment in the economy. This is consistent with our previous statement that the utility function depends on the interaction between quantity and quality, because we consider that each firm will make an investment in order to improve the quality of the goods it produces.

Using the first and second-tier utility functions from (2) and (3) we can rewrite the utility function as:

$$U(z) = ax - \frac{1}{2} b [(1 - e) \int_0^1 x(z)^2 dz + eX^2] + \beta [(1 - e) k(z) dz + eK]$$

where $X = \int_0^1 x(z) dz$ and $K = \int_0^1 k(z) dz$ denote the total levels of output and investment, respectively. Each consumer maximizes utility subject to a budget constraint:

$$\int_0^1 p(z) x(z) dz \leq I$$
where \( p(z) \) represents the price of a single variety and \( I \) denotes the consumer's income. Therefore the inverse demand function will be of the form:

\[
p(z) = \frac{a}{\lambda} - \frac{b}{\lambda} \left[ (1 - e)x(z) + eX + \beta(1 - e)k(z) + eK \right]
\]

where \( \lambda \) represents the marginal utility of income, the Lagrange multiplier attached to the maximization problem given by the budget constraint.

The marginal utility of income depends on income and on the distribution of prices:

\[
\lambda = \frac{a \mu_1^p - bI}{\mu_2^p}
\]

where \( \mu_1^p \) and \( \mu_2^p \) denote the first and second moment of the distribution of prices, respectively:

\[
\mu_1^p \equiv \int_0^1 p(z)dz \quad \mu_2^p \equiv \int_0^1 p(z)^2dz
\]

From equation (7) we notice that an increase in income or a fall in prices will reduce the Lagrange multiplier, the marginal utility of income and move the demand function outwards. Therefore, because of \( \lambda \), the demand function is highly non-linear in prices. [7]

However, we consider firms to be "large in their own markets but small in the economy as a whole" [16] they will take \( \frac{a}{\lambda} \) and \( \frac{b}{\lambda} \) as given. Therefore, from the individual sectors point of view the demand function is linear. [7]

Since \( \lambda \) depends only on economy-wide variables and not directly on the variables in sector \( z \) and is, therefore, endogenous to the economy as a whole, we will consider the consumer's marginal utility of income as numéraire, a standard practice in the GOLE literature. [16]

In doing so the income variables, such as profits, wages and rental rates will become real profits, wages or rental rates at the margin and their variation will have no effect on utility. [17]

We now turn to the supply side where we will suppose that each firm uses a single factor of production, labor. We will consider that each firm will play a two-stage game, first choosing an optimal level of investment and after observing each other's decision engaging in a Cournot competition.

Let \( a(z) \) denote the labor requirement for each unit of production and $w$ denote the economy-wide factor price, which is the same across sectors.

The marginal cost of production for each firm in industry \( z \) will then be:

\[
c(z) = w\alpha(z)
\]

Note that the labor requirement is not the same across sectors and is in fact increasing in \( z \). Furthermore, following Neary and Tharakan [7] we will assume that low-\( z \) sectors are more labor-intensive, while sectors with high values of \( z \) are more capital intensive. Therefore, we will consider that in the more capital-intensive sectors, the labor input necessary for a unit of production will be higher; inducing firms to invest \( \alpha(z) = \alpha_0 + \alpha_1z \)

By making an investment, each firm will incur an up-front quadratic cost of \( r\frac{k(z)^2}{2} \). [16] Therefore, the investment that affects the quality of the goods each firm produces will be considered as a fixed cost.

Based on the consideration above, each firm in sector \( z \) will obtain a profit equal to operating profits minus the fixed costs:

\[
\Pi(z) = [p(z) - c(z)]\alpha(z) - \frac{r k(z)^2}{2}
\]

where \( r \) denotes the rental rate, the price of the investment, which, as in the case of the wage, is economy-wide determined and is the same across sectors.

As we have stated before, each firm engages in a two-stage game, choosing its level of investment in the first stage and the level of output in the second. We will solve this problem in the usual backward manner, first determining the equilibrium output and then the optimal level of investment for each firm.

The first order condition for obtaining the Cournot equilibrium output is:
\[ \frac{\partial \Pi(z)}{\partial x(z)} = 0 \]  

(11)

The equilibrium output is sub-game perfect; firms take their decisions based on the anticipated levels of output and investment on the market they compete in.

\[ x^*(z) = \frac{a - b e X + \beta [(1 - e) k(z) + e K] - w \alpha(z)}{2 b (1 - e)} \]  

(12)

By using the equilibrium output from equation (12) in the inverse demand function we obtain:

\[ p^*(z) = \frac{1}{2} \left[ a - b e X + \beta [(1 - e) k(z) + e K] + w \alpha(z) \right] \]  

(13)

Substituting for \( x^*(z) \) and \( p^*(z) \) in equation (10) we can rewrite the firm's profit as:

\[ \Pi(z) = \frac{\left[ a - b e X + \beta [(1 - e) k(z) + e K] - w \alpha(z) \right]^2}{4 b (1 - e)} - \frac{r k(z)^2}{2} \]  

(14)

which is consistent with the usual result in the Cournot competition.

We can now solve for the equilibrium level of investment:

\[ k^*(z) = \frac{\beta \left[ a + b e X + \beta e K + w \alpha(z) \right]}{\beta^2 (1 - e) - 2 b r} \]  

(15)

And by substituting for \( k(z) \) in equation (12) we obtain:

\[ x^*(z) = \frac{r \left[ a - b e X + \beta e K - w \alpha(z) \right]}{(1 - e) \left[ \beta^2 (1 - e) - 2 b r \right]} \]  

(16)

As we can see from equation (16), the equilibrium output of each firm is directly dependent on the rental rate and indirectly dependent on the wage itself.

3. Factor Markets

As usual in a general equilibrium model, we now turn towards the factor markets, in our case, the labor and the capital market, in order to determine the equilibrium level for the rental rate and the wage.

We will consider the total level of labor and capital supply as exogenous to our model, depending on each country's endowment with factor of production.

On the labor market, equilibrium requires that total labor supply, \( L \), must equal the aggregate demand for labor, \( L(z) \), which is given by the sum of all sectors' outputs multiplied by their labor requirement:

\[ L(z) = \alpha(z) x^*(z) = \frac{r \alpha(z) \left[ a - b e X + \beta e K - w \alpha(z) \right]}{(1 - e) \left[ \beta^2 (1 - e) - 2 b r \right]} \]  

(17)

Evaluating the integral yields:

\[ L = \frac{r \left[ \mu_1 (a - b e X + \beta e K) - w \mu_2 \right]}{(1 - e) \left[ \beta^2 (1 - e) - 2 b r \right]} \]  

(18)

where \( \mu_1 \equiv \int_0^1 \alpha(z) \, dz \) and \( \mu_2 \equiv \int_0^1 \alpha(z)^2 \, dz \) are the first and second moments of the distribution of technology.

We can isolate the rental rate from equation (18) that will allow for equilibrium on the labor market:
We proceed in a similar manner for the capital market, where total demand is given by the sum of investments made across sectors, so $K(z) = k^*(z)$, and evaluating the integral we obtain:

$$K = \frac{\beta (a + beX - \beta K) + w\mu_1}{\beta^2 (1 - e) - 2br} \quad (20)$$

As we did for the labor market we can obtain the equilibrium level of the rental rate that allows for equilibrium on the capital market:

$$r = \frac{\beta (a - beX + \beta K) + w\mu_1}{2bK} \quad (21)$$

The only unknown left in our model is the wage, which we can determine from equations (19) and (21) and which will allow for equilibrium on both labor and capital markets:

$$\frac{bL(1 - e)}{\mu_2} - \frac{\mu_i (a + beX - \beta K)}{2\mu_1} = \frac{\beta (a + beX - \beta K)}{2\mu_1} + \sqrt{4b\mu_1 a - beX + \beta K \left[ 2bL(1 - e) + \mu_i (a - beX + \beta K) + \mu_i (a - beX + \beta K) + \beta \mu_1 (a - beX + \beta K) \right]} \quad (22)$$

Substituting in equation (21) we obtain the rental rate which determines equilibrium on both labor and capital market.

4. Conclusion

Even though we follow the general framework, the main departure from the existing models is that in our model both labor and capital are used in production and that the firms have a choice between specializing in labor or capital-intensive goods by choosing whether or not to invest in capital and therefore use two factors of production.

In this paper we have tried to develop a new model which could allow the full use of two factors of production, labor and capital. In this model, the second factor of production is not introduced in an artificial way as we consider that has been the case for the other existing models.

The second factor of production, capital, is used as a strategic investment and has an impact on utility and therefore on the equilibrium output.

Furthermore, we consider that the model we have tried to develop in this paper has another major contribution since it allows us to calculate the equilibrium levels of output and investment as a function of rental rate and wage.

More importantly, we go further than the other models and we try to calculate the equilibrium levels for the rental rate and wage as a function of $L$ and $K$, i.e. the labor and capital endowments.

This is another important departure from the existing models, which will allow the use of this model in an international trade analysis, where each country will assume the role of a player in a strategic, cooperative non-zero sum game.

In this paper we have tried to develop a multi-sectorial general-equilibrium model of oligopoly and trade in line with the ones already available in the last year's literature. We have considered trade between two identical and symmetrical countries, which depends on oligopolistic interaction and comparative advantage.

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