Modelling Free Trade Zones and Strategic Trade Policy

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Abstract

This paper develops System Dynamics models to explore various scenarios when there is an entrant attempting to capture part of a monopolised market. The models developed are first tested against a classical duopoly model , the Cournot Model, and then used to test government attempts to boost exports via subsidies or defend industry with tariffs. The models yield interesting results regarding the pattern of trading outcomes with government intervention to protect or defend domestic producers operate with delay lags in the presence of linear and non-linear demand patterns. A 'Prisoner's Dilemma" type game is revealed where both traders are better off when working together rather than pursuing independent trading patterns..

Keywords Duopoly, Subsidy, Dynamic Equilibrium, System Dynamics, Free Trade Zones

1. Introduction

Much trade policy is piecemeal in nature, involving tariffs and subsidies to make politically powerful industries more profitable, to keep beleaguered industries afloat or allow governments to maintain high agricultural support prices. Beyond these basically reactive policies are national policies to establish and strengthen comparative advantage in certain areas at the expense of foreign trade. Such designs carry various labels including strategic trade policy, trade targeting, managed trade and "picking winners'.

All these names describe some sort of collaboration and co-operation among business and governments, to alter more quickly than the free market would the existing pattern of relative trade efficiencies. The tools for doing this usually involve a combination of subsidies and /or home market protection by means of tariffs , quotas, V.E.R.s and so on to accelerate the development of some chosen industry. The subject has caused a lengthy debate among economists and represents a new challenge for the proponents of free trade{1}

In this paper we initially develop a version of the Brander-Spence trading model of duopoly with homogeneous goods. The basic model is initially developed algebraically then contrasted with a Systems Dynamics model simulated in Powersim.. The systems model is validated against the basic linear mathematical model and then used to explore various scenarios involving non-linearities, delays, subsidies and tariffs. The power of the Systems Dynamics methodology is revealed once non-linear demand configurations and delay lags are introduced The models show the maximum profits to be obtained when strategic trade policy initiatives are introduced first in one country via subsidy then with retaliation by tariffs from the trading partner. Hence the system framework is ideal for displaying potential instabilities in the trading world of duopoly. {2}

2. The Cournot Model

2.1 The Mathematical Model

This model assumes that the only decision variable is output. In the classic Cournot model, price is not the strategic decision variable. Each player adjusts output to maximise profit assuming the rivals output is fixed. Price in the Cournot model is simply the market clearing vector resulting from successive additions or reductions in output from the duopolists

We illustrate this by the following example. Assume that there are two countries, the UK and the Ukraine (UKR) with one coal producer in each country: British Coal (BC) and Donbass coal (DC). Each country uses the same technology and has identical linear cost and demand curves. Initially there is no trade between each country. The profit maximising condition for each monopolist under autarky can be calculated mathematically as follows.

The monopolists total revenue and costs can both be expressed as functions of output:

$$R=R(q) \quad C=C(q)$$

the monopolist profit, π , is thus given by $\pi = R(q) - C(q)$ (1)

To maximise π we set the derivatives of (1) to zero thus obtaining

$$R'(q) = C'(q) \qquad (2)$$

Simple algebra will then predict that with a linear demand function, maximum profit will be obtained when the monopolist supplies half the market.

2.2 The Systems Dynamics Model

This behaviour is now replicated by using System Dynamics. Figure 1 is the causal loop diagram for a simple monopolist in the UK. It can be noted that there are two positive loops P1 and P2 and three negative loops B1, B2 and B3. The initial behaviour of the model will thus be one of growth but because of the effect of the decreasing linear demand function (represented by B1) the long-term behaviour will be an equilibrium state. Figure 2 shows the System Dynamics model resulting from the causal diagram. It has the further assumption that everything produced is sold. The form of the demand function was taken as :

$$P = a-b\,Q \qquad (5)$$

Initially we took a-6 and b=1/80 which results in a market of 480. The model introduces a weekly production rate per employer and the number employed is set at 100. Sales are calculated monthly and these are used as the value of the variable Q in equation 5 to calculate the price for the next month. The demand function was input using the graphical tool..

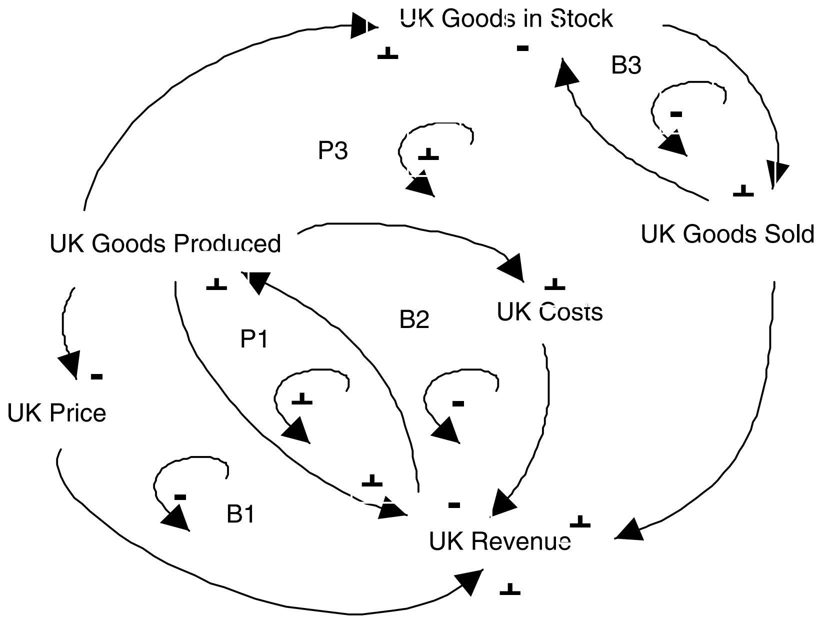

Figure 1 Causal Loop Model for Monopoly

This model was built using Powersim which does not have a maximising function. The model was therefore run via the spreadsheet Excel.. The production rate was set at 0 and increased to a maximum of 1.2 (maximum production of 480) in steps of 0.1. At each step, Excel called Powersim, ran the program and recorded the profit This model showed a maximum profit of 8640 occurs when the monopolist took 240 units (half the market share) at a price of 3 units (which matches the mathematical solution). The model was then run for various values of a and b . These values were then graphed to give figure 2. In all cases , maximum profit occurs at half market share.

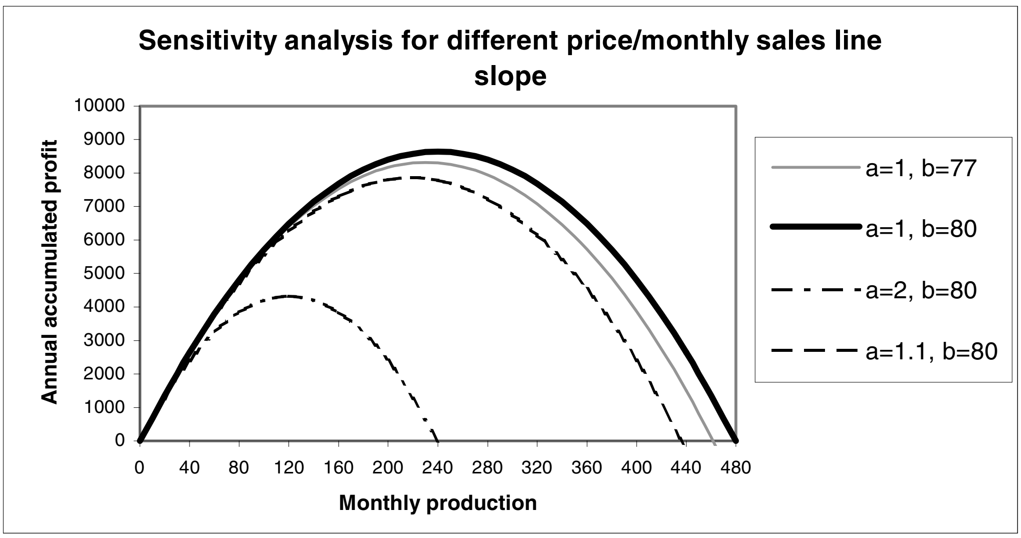

Figure 2 Profit Curves for various forms of Linear Demand

As the model behaves as predicted by the mathematics, one is confident to perform “what if” experiments when assumptions are relaxed which might be mathematically more difficult. . The linear demand curve was therefore replaced by the curves shown in figure three. Here, it is assumed that there is a quantity of coal that must be sold and there is a price below which it is impossible to go.

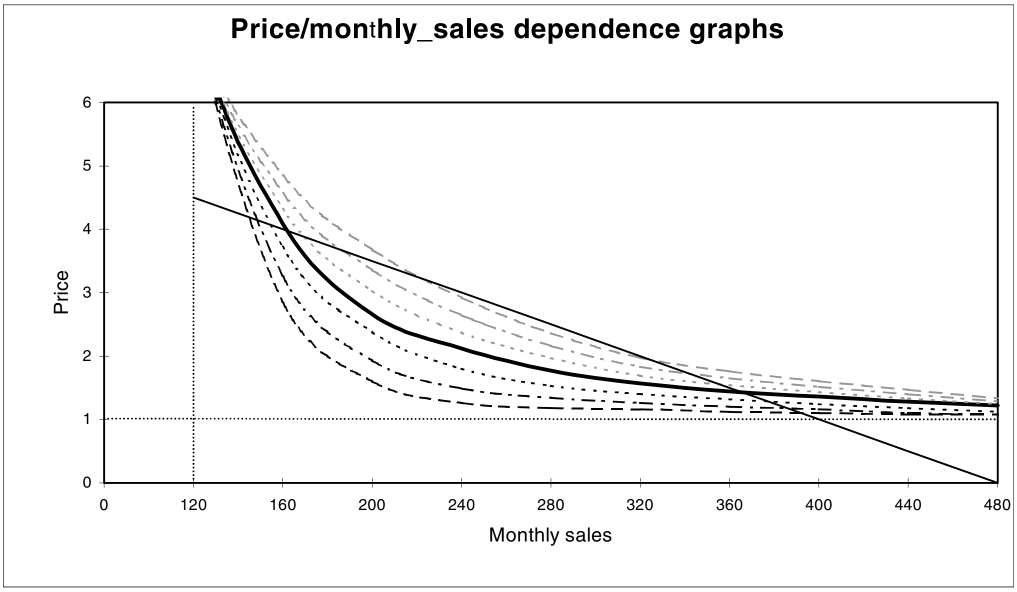

Figure 3 Non-Linear Demand Curve

The results are shown in figure four. There is a local maximum at 8640 as before but once the price reaches the minimum then profit increases indefinitely with increased production.

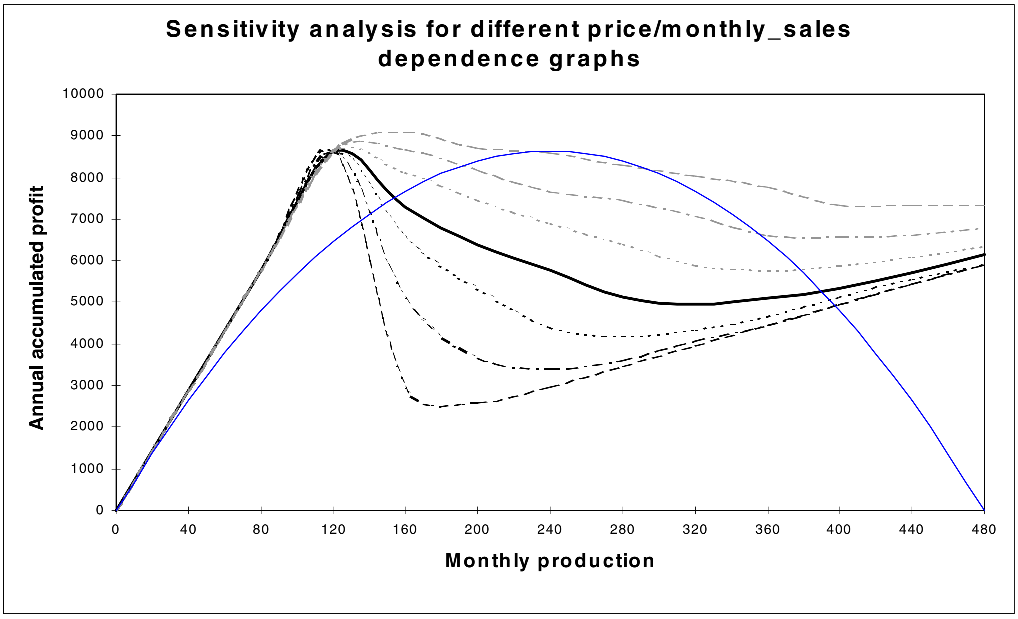

Figure 4 Profit Curves with Non-Linear Demand.

2.3 Classical Cournot Model of Duopoly

If now trade between the UK and UKR is opened via say the development of a free trade zone, then a duopoly in the each countries' coal market is established as both countries export coal to each other. Hence the domestic demand in each country is now satisfied by both the domestic monopolist and the foreign importer. Entry into each others domestic market occurs given the drive for profit maximisation, expanding revenues and constant costs.

The duopoly trade case is illustrated by Cournot's classical solution. Now each duopolist maximises profit on the assumption that the quantity produced by his rival is invariant with respect to his own quantity decision.. The duopolist A maximises π_A with respect to q_A treating q_B (B is the rival) as a constant whereas duopolist B behaves in a similar fashion. The total revenue for each duopolist depends on his own output and that of his rival

$$R_A = q_A f(q_A + q_B) \qquad R_B = q_B f(q_A + q_B) \qquad (3)$$

Thus

$$\pi_A = R_A(q_A, q_B) - C_A(q_A) \quad \pi_B = R_B(q_A, q_B) - C_B(q_B) \qquad (4)$$

Taking partial derivatives and equating to zero gives the equilibrium position which occurs when each duopolist takes one third of the market share. Hence the Cournot solution delivers a stable equilibrium for duopoly for linear demand curves where output changes are both instantaneous and simultaneous.

2.4 A System Dynamics model of Duopoly

The causal diagram in figure five shows an extension of the previous model when the UKR coal producers (DC) become an entrant to the UK coal market. Identical assumptions are made for each producer with regards to costs, production etc. and initially the previous linear demand function is used making the available market equal to 480 units. The UK price is now determined by the goods produced by both the UK and the UKR It is also assumed that the UKR has enough coal to easily satisfy its domestic market and is trying to sell its excess on the UK market. The modelling interest arises in the interplay between the two producers Using the results of the previous model, producers will maximise profit when taking half the market available to them

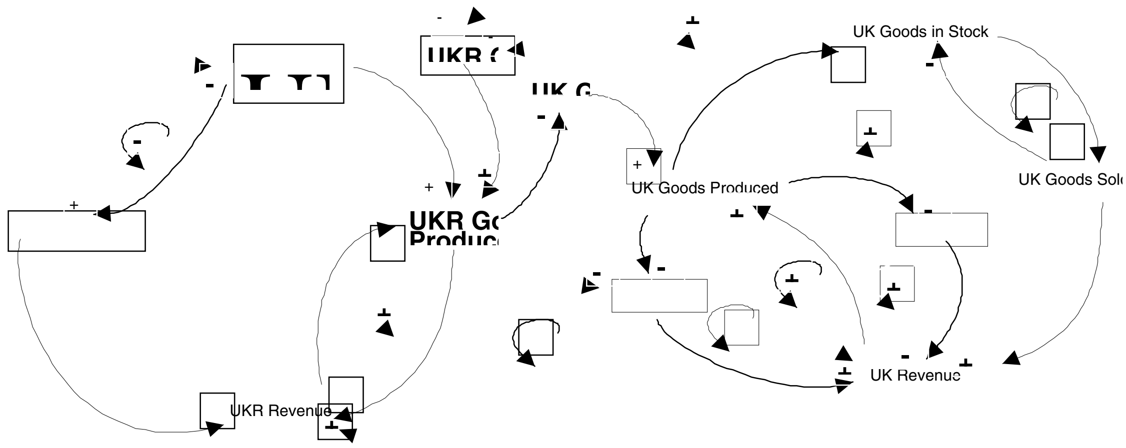

Figure Five The Duopoly Case

In the UK, BC is the incumbent trader taking half the market. This leaves a market gap, named UKGap, and this gap will become the target market for the UKR who will maximise his profit when producing half. The UK then retaliates, attacking what is named UKRGap. There are two positive loops in opposition to each other Again the initial behaviour of the model is expected to be oscillatory but eventually the balancing loops arising from the demand function should produce long term stability. Figure six shows each eventually taking one third of the market as predicted by Cournot.

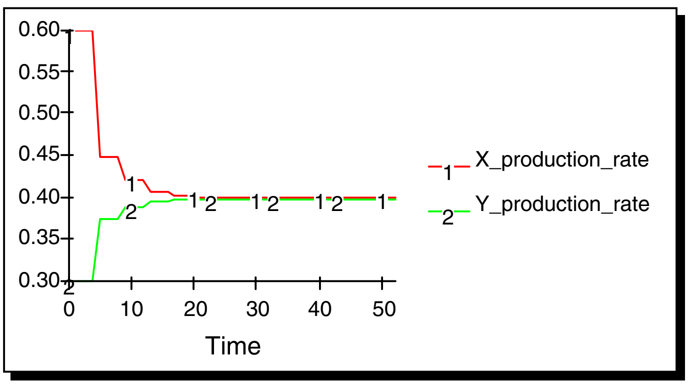

Figure 6 Duopoly Equilibria

Figure seven shows the results when the non-linear demand function in figure three is used. There is a small period of uncertainty but then the same equilibrium point is reached at one third of the market.

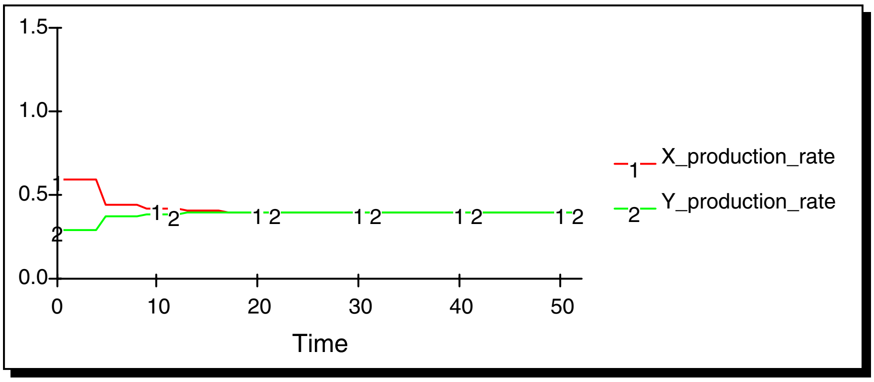

Figure Seven Duopoly: Non Linear Demand

It is interesting to see the effect of delay lags. DC and BC cannot respond instantaneously so a delay lag of three months is introduced and the results shown in figure eight.

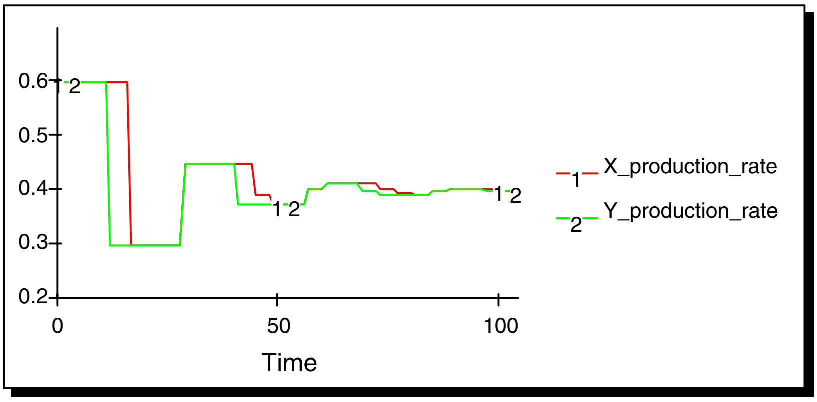

Figure Eight Duopoly with Delay Lags

It is observed that equilibria is reached but it takes a long period to do so. If in that time, one of the producers loses his nerve and starts to take extraordinary actions then instabilities may occur.

3. Strategic Trading.

3.1 Subsidies

Suppose the UKR wants to set an export subsidy for coal in the free trade zone to stabilise employment for miners and raise profitability. Assuming no retaliation initially from the UK, a direct subsidy to coal production in the Ukraine raises coal export production by cutting artificially Ukrainian pit-head production costs. The systems Dynamics model shows this boost in coal exports to the UK and the loss of market share in the UK coal market for British Coal. Paradoxically, we see here that, on the platform of a palpable free trade zone, a government can maximise national industrial profitability by capturing in a sense some of the foreign monopoly profit. The Ukrainian decision to subsidise the production costs of coal to enhance exports to the UK seeks to enhance the Ukrainian coal industry's profit by more than the costs of the subsidy (3)

Effectively, the subsidy allows for the Ukrainian coal industry to lower its price in the UK. Consequently, BC loses market share. Profits for DC rise since costs fall. To achieve success with the subsidy policy depends on a number of conditions viz.:

- the policy has to be credible. If BC does not believe the subsidy will actually be paid, or will be paid for only a short while, it may not contract its output and thus DC will not capture additional profits
- the subsidy should only be paid where high monopoly profits are earned abroad
- an industry with initially high capital requirements forming substantial entry barriers are most suited to export subsidies
- subsidies paid to declining industry might stave off foreign rivals for a time but result in no advances at their expense
- the optimal outcome of subsidy policy would be if foreign rivals had many other alternative markets because then foreign output would fall consistently as prices fall. It would be most favourable if the DC model moved quickly down steep cost and learning curves as its output expands. This would create additional employment. (4)

The System Dynamics models are thus developed as quantity adapter output models so we assume that if a subsidy of 30% is granted to say the Ukrainian producers, then they can increase output by this amount without affecting prices.

The causal model for this case is shown in figure nine and some results are shown in Figure 10. DC has managed to boost sales from 160 to 230 whilst decreasing BC sales to 125 at a common UK price of 1.56. DCs profits are then more than the equilibrium position but BC are well below. BC would not allow this to continue for long and would retaliate.

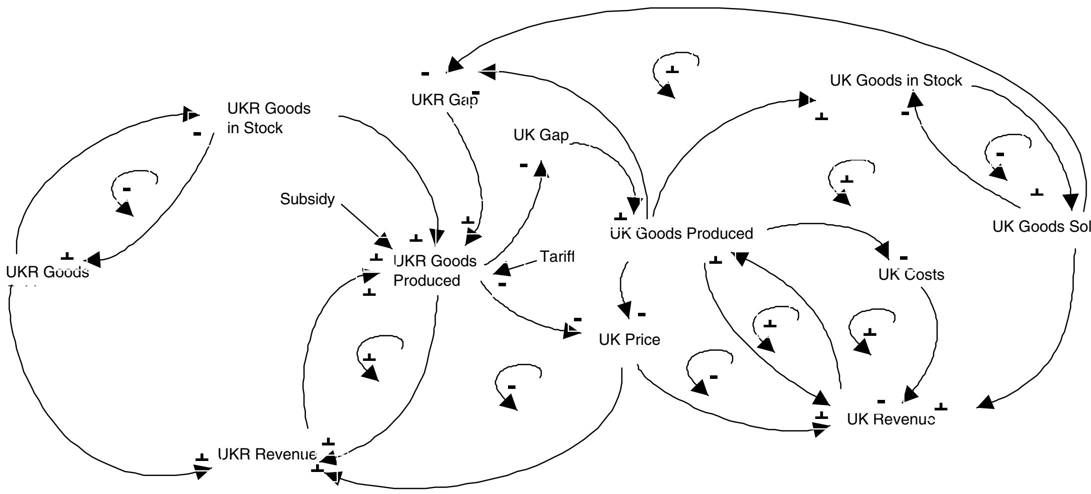

Figure 9 Causal Model with Subsidies and Tariffs

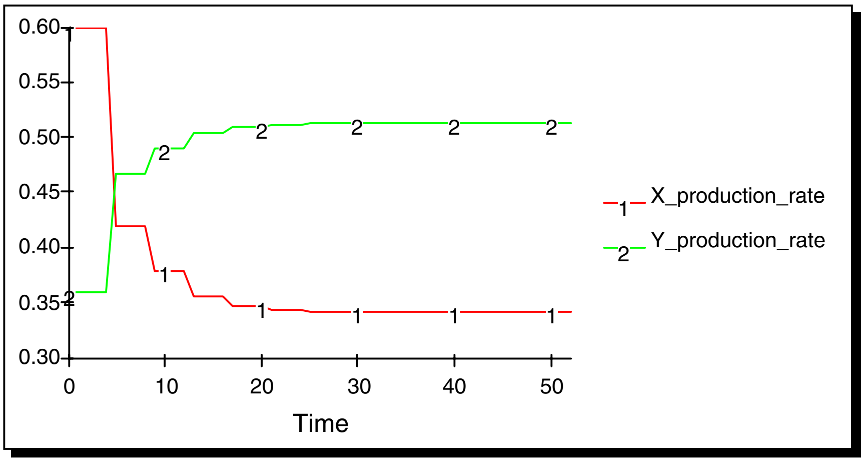

Figure 10 Duopoly with Subsidy

It can be seen that DC increases its market share from 160 to 206 at the expense of BC which decreases from 160 to 137. The UK price has now dropped form 2 to 1,71 pounds. This model assumes that BC will respond to the increase in Dc imports instantaneously and according to the previous rule of taking half the available market. Table 1 shows the effects of BC delaying its response to the entrant. The last row corresponds to BC ignoring the entrant completely and continuing to produce at the monopoly rate. Because the increase in D sales, the price reduces and so although BC can keep its production rate (and thus avoid redundancies) its profits fall by almost 50%. According to the Cournot model, it should decide on market share alone.

Subsidy	Delay in BC-Response	BC Sales	DC Sales	Price	BC Profit	DC Profit
0	0	240	0	3	8640	0
0	0	160	160	2	3840	3840
20	0	137	206	1.71	2811	4227
20	12	146	200	1.67	2925	4008
20	26	168	187	1.56	3144	3149
20	52	240	144	1.2	3456	2073

Table 1 Delays in responding to subsidy

If both countries play a subsidy game for their coal industries, then BC and DC find themselves playing a four player subsidy game. In this game, the two governments move first and simultaneously decide subsidy rates for export production. The duopolists then observe the subsidy rates granted by both governments and play a Cournot game in each market (7)

3.2. BC Defence against Predatory Subsidies

The predatory nature of an export subsidy to Ukrainian experts of coal designed to capture profits at the expense of BC means that the UK, facing such an active policy, needs to consider how to retaliate (5) A major aim of UK policy might be to convince the UKR government that a predatory strategy is dangerous and uncertain. Thus the UK might retaliate with its own pit-head or hidden subsidies to the producer hurt by foreign strategy or could impose protection against the subsidised goods. Indeed, Game Theorists have shown that in these circumstances, a "tit for tat" strategy may be the most effective defence. (6) The systems Dynamics model shows that if the UK replies with Tariff protection for BC, this countervails the UKR subsidy strategy. By contrast, a direct subsidy in the UK for coal production simply raises the cost of trading, though consumers in the UK would gain from lower prices in the short run.

If a retaliatory tariff of 40% is added to the previous model with a subsidy of 30%, Dcs trade falls to 140 whereas BC is boosted to 170 at a price of 2.13. This is on the assumption of an instantaneous response and using the half the available market strategy. BC recaptures its share of the market at the expense of DC The results so far are summarised below

Subsidy	Tariff	BC Sales	DC Sales	Price	BC Profit	DC Profit
0	0	240	0	3	8640	0
0	0	160	160	2	3840	3840
30	0	125	230	1.56	2415	4306
30	40	170	140	2.13	4328	3288

Table 1

. We can now use the model to investigate the effect of delays in the response of BC to DC's behaviour, DC's response to BC's behaviour and the case when they both delay their responses. These results are summarised in tables 2,3 and 4

Subsidy	Tariff	Delay in BC-Response	BC Sales	DC Sales	Price	BC Profit	DC Profit
0	0	0	240	0	3.00	8640	0
0	0	0	160	160	2.00	3840	3840
20	30	0	170	140	2.13	4345	3578
20	30	12	174	138	2.10	4385	3478
20	30	26	186	132	2.02	4508	3200
20	30	52	240	108	1.65	4752	2138

Table 2 BC delays in responding to DC

A similar analysis was performed as before. Table 2 shows that by ignoring DCs behaviour, BC keeps it market share but at a lower price.

Subsidy	Tariff	Delay in DC-Response	BC Sales	DC Sales	Price	BC Profit	DC Profit
0	0	0	240	0	3.00	8640	0
0	0	0	160	160	2.00	3840	3840
20	30	0	170	140	2.13	4345	3578
20	30	12	168	140	2.16	3641	3396
20	30	26	162	156	2.07	3102	3644
20	30	52	132	216	1.67	2423	3854

Table 3 DC delays in responding to BC

The more important factor in this case would be DCs response to the tariff. Table 3 shows the outcomes for varying degrees of indifference. DC can bear the tariff and increase imports but at a lower price.

Subsidy	Tariff	Delay in Response	BC Sales	DC Sales	Price	BC Profit	DC Profit
0	0	0	240	0	3.00	8640	0
0	0	0	160	160	2.00	3840	3840
20	30	0	170	140	2.13	4345	3578
20	30	12	172	132	2.02	3470	2632
20	30	26	132	183	1.83	2560	1960
20	30	52	240	216	0.30	846	761

Table 4 Both delay in responding to each other

If they both attempt to continue as before but with the subsidy tariff existing, then it is disastrous for them both. This is then a prisoners dilemma type game as each will do better by co-operating with each other than by ignoring each other.

The power of the Systems Dynamics methodology and the clear counterintuitive insights revealed is evident in the analysis presented in tables 2,3 and 4. If both duopolists delay their "best " response to either the subsidy or the tariff, the strong elements of conflict and potential instability are clear. Thus with reference to Table 4, both BC and DC have a vested interest in lobbying their respective governments for a return to free trade with no subsidies and tariffs. However, if this was accomplished, stable free trade could be compromised by either party using hidden tariffs or subsidies. If this happened, both BC and DC could be once again on the horns of a Prisoners Dilemma as both duopolists have dominant strategies to increase output in all markets. Prices would drop drastically until capacity constraints in both countries were reached. At this point, both producers would want to cut production down to 160 units. Price would return to maximum profit levels. Once again, at this point, a whole new round of output expansion could arise causing market prices to permanently fluctuate from 3 to 0.3. This is Edgeworth instability. This instability reduces with quick response times and increases with slower response times. The System Dynamics methodology shows that even in the context of the inherently stable Cournot model. permanent oscillations in prices and outputs can occur in dynamic games. Hence the zero-sum nature of the Cournot game becomes the variable sum game of the Prisoners Dilemma. Stability can only come from a W.T.O. brokered peace.

.5 Conclusions

The models developed show the reasoning behind the general popularity of free trade zones and export subsidies. They also show the paradoxical desire of governments in the W.T.O to negotiate bilateral trade agreements with major trading partners. The dynamic runs of the Systems Dynamics model show the potential for instability and collapse of trading arrangements if subsidies and ' tit-for tat' retaliations via tariffs with variable leads and lags. Pricing chaos and Edgeworth type instability would occur if capacity constraints are placed on domestic or foreign production in either market.

If both countries play a subsidy game, this resembles the Prisoners Dilemma. Hence, the strictly dominant strategy equilibrium in which both subsidise exports results in both countries being worse off then if they had not intervened in the market. Clearly, balanced reductions in subsidies/tariff in the W.T.O can make both countries better off. (8) The present trade war between the USA and the EU could easily spiral out of control since the USA regards the EU policy of banning imports of US beef as projectionist since it effectively protects the domestic market for EU farmers. The USA could easily reply to this with prohibitive tariffs placed on EU producers. In the end, this issue would need to be resolved by the W.T.O

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