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IN AN ASYMMETRIC WORLD

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This paper contains preliminary findings from research work still in progress and should not be quoted without prior approval of the authors.

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"Trade in the Presence of Endogenous Intermediation in an Asymmetric World"

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INTRODUCTION

The growing importance of the service sector in most Western economies and the issue of trade in services scheduled for discussion in the next round of GATT talks has spawned a large body of literature in this area. The literature can be broken into three main areas. The first concentrates on descriptions and definitions of services (e.g., Bhagwati (1984), Melvin (1985), and Stern (1985)). The second area is a large body of case studies in various branches of trade in services such as technology, financial services, communications, etc., of Swan (1985), Dobell et al. (1986).

The third area, that of theoretical models, has not received much attention as yet. The exceptions are papers by Deardorff (1985) and Melvin and Markusen (1986). This paper continues in this vein and focuses on a theoretical model of mediation services. The principal debate in the theoretical area is whether services can be modelled in the same fashion as goods in conventional models.

In the wake of Debreu (1959) many writers were concerned about the introduction of non-convexities such as transactions costs into the general equilibrium model. In the early 1970's writers such as Foley (1970), Hahn (1971), Heller (1972), and Starr (1970) showed that with large numbers of agents, competitive equilibria were reasonable approximations for non-convex economies.

Kurz (1974) considered the possible existence of specialized transactors in a single market exchange economy with transactions costs and money. However from our point of view there are many problems with Kurz's analysis. Neither the trading environment itself nor the function of money within the
environment is specified in any way and thus the generation of specialized traders is ad hoc. Further his contention that "the act of establishing money is fundamentally an act of social choice"\(^1\) is more pertinent to fiat money rather than to the sales record keeping devices that he refers to as money in his model. Thus there seems no good reason (unless we incorporate moral hazard) why such private contracts (inside money) should not arise.

Rubenstein and Wollinsky (1985) develop a model where mediators emerge endogenously due to an externality in the exchange process. In their model the more agents that are in the market place at any given time the more likely one is to make a transaction. Thus servicers make profits by eliminating time agents may have to spend if they wish to trade. Unfortunately Rubenstein and Wollinsky have to pay a high price in terms of structure to get this result.

The model in this paper is more closely related to the recent work in the financial intermediation literature. Boyd and Prescott (1985), Diamond (1984) and Williamson (1986) all have models in which intermediaries arise endogenously due to cost advantages in specialization.

In our case the model is of a three-sector, single-factor, n-agent economy. Two of the sectors, the x and y sectors, produce consumer goods, x and y, respectively. The third sector produces a service that provides a link between separated producers and consumers. Specifically, a service must be employed by an agent in order to consume a good which he himself does not produce.

Thus the service may be thought of as any coordinating activity that bridges gaps of space, information, and (with suitable reinterpretation) time. Therefore we may think of the servicer as a transport company, an auctioneer-market, a shop, a broker, or even as a financial or refrigeration
servicer.

The principal element in the structure of the model is that agents are forced by increasing returns to scale to specialize either in production of a final good or in the provision of mediation services. Given that each agent is specialized in one sector he/she must acquire goods he/she does not produce via trade. The exchange technology is defined in the following manner. In any given time period a servicer meets with a producer, collects a maximum of $s$ units of the goods and the payment. He/she consumes the payment immediately and then services the output (carries it to the other consumer/producer). There the process is repeated and the servicer returns to the first producer with a maximum of $s$ units of the other consumer good. The consequent asymmetry in consumption possibilities implied by this trading process is an important aspect of the model. It can be defended either as describing the problem facing individuals or specialized regions within a country.

The nature of equilibrium in this model provides some new insights into the trading process. Because services are demanded indirectly the equilibrium price and quantity demanded depend more upon demand considerations than on the service technology itself. In particular any asymmetry either in demand, production or in service technology may lead to excess capacity in the service sector in equilibrium.

Secondly, and as a consequence of the above, if free trade makes the world more symmetrical then there is an added gain from trade over and above the conventional gains.

Another interesting result is that an improvement in the service technology may in fact lead to a fall in the production of final goods. This arises because an improvement that reduces the cost of market activity may
cause the demand for services to rise such that new agents enter the service sector.

Finally we find that the principal propositions of trade theory still hold under trade with mediation services. The layout of the paper is as follows. Part I sets out the basic single country model in a perfectly symmetrical world and defines the equilibrium. Part II then considers some comparative static and other single country results. In Part III we consider the effect of relaxing our symmetry assumptions and hence derive our two country trade model.

PART I

The Model

The Production Sector

For the service sector to play a role in this economy, an agent must have an incentive to specialize, a notion that has some empirical validity. Thus we assume that agents face increasing returns to scale for individual output in each sector.

We assume there are \( n \) agents in the economy with identical tastes. Each agent \( i \) is endowed with one unit of labour which she/he can allocate across the three production sectors such that

\[
\sum_{j} \tilde{L}_{ij} = \tilde{L}_i = 1,
\]

where \( \tilde{L}_{ij} \) is the amount of labour allocated by an agent \( i \), to sector \( j \), \( i \in \{1, \ldots, n\}, j \in \{x, y, s\} \).
The most general specification of the production technology allows for various degrees of returns to scale to the industry and the individual. Output of $x$, $y$ and $s$ by an individual agent is given by

$$x_i = f(L_{ix}; L_x)$$

$$y_i = g(L_{iy}; L_y)$$

$$s_i = s(L_{is}; L_s)$$

where $L_j = \sum_{i} L_{ij}$, $j \in \{x, y, s\}$ is the number of agents employed in the $j$ industry. Output then depends not only on individual inputs but also on the number of agents in the industry. For the economy as a whole, output is given by

$$x = \sum_i f(L_{ix}; L_x)$$

$$y = \sum_i g(L_{iy}; L_y)$$

$$s = \sum_i s(L_{is}; L_s)$$

Initially we assume constant returns to scale in all sectors at the industry level, thus $x_i$ depends only on $L_{xi}$. In Ryan (1986a) we show that agents will choose either autarky or specialization depending of the service technology and the degree of returns to scale faced by the individual. In particular we show that production and servicing will always be dominated by specialization as long as there is increasing returns to scale in either the
production or the service sector at the individual level. Thus in this paper we will consider only the case where agents specialize, i.e., \( L_{ij} = 1 \) or 0. Consequently we will ignore any intermediate case from now on and we will note the appropriate conditions for autarky where relevant. Thus, the simplest specification of individual output of \( x \) and \( y \) are that

\[ x_i = L_{ix}; \quad y_i = L_{iy}; \quad s_i = sL_{is}. \]

The above assumptions yield

\[ x = \sum_i L_{ix} \quad (1) \]

\[ y = \sum_i L_{iy} \quad (2) \]

\[ s = sL = \sum_i L_{is} \quad (3) \]

**Consumption**

Each agent's utility function is defined over the two consumer goods \( x \) and \( y \)

\[ U = U(x,y). \]

The budget constraints facing the agents in each sector are:

for \( x \) producers:

\[ x_i = 1 = x^i + p_x y^i \quad (4) \]

for \( y \) producers:
\[ y_i = 1 = p^y x^i + y^i \] (5)

for servicers:

\[ (p^x - 1)s = x^i \quad \text{and} \quad (p^y - 1)s = y^i \] (6)

where \( x^i \) is the amount of \( x \) consumed by an agent \( i \)
\( y^i \) is the amount of \( y \) consumed by an agent \( i \)
\( p^j_k \) is the price of a good \( k \in (x, y) \) to an agent in sector \( j \)

Note we normalize \( p^i_i = 1 \).

Each agent who specializes in one of the production sectors can consume the good he/she produces at the normalized price of 1. To purchase the other good he/she must pay \( p^j_k \). The budget constraint for a servicer is determined in the following manner. He/she collects \( p^y_x \) units of \( x \) from an \( x \) producer and will carry \( s \) of these units to trade with \( y \). Thus the servicer's consumption of \( x \) is \((p^x - 1)s\). When the servicer meets the \( y \) producer he/she exchanges \( s \) units of \( x \) for \( p^x_y \) units of \( y \). The servicer must return with \( s \) units of \( y \) to the \( x \) producer, thus consumption of \( y \) is \((p^y - 1)s\).

**Equilibrium**

When agents maximize their utility subject to these budget constraints, we obtain the following indirect utility function

\[ v(p^j_x, p^j_y, I) \quad \text{for all agents.} \]

where \( I \) is the income of the agent. We assume free mobility of labour across
the three sectors within any given country.

A competitive equilibrium is a labour allocation vector 

\( L(x_i, y_i, s_i) \) for each agent \( i \), and a consumption vector for each agent 

\( i \) such that the utility of all agents are equal

\[
V(1, p^x_y, 1) = V(p^y_x, 1, 1) = V(1, 1, (p^y_x - 1)s + (p^x_y - 1)s)
\]

the commodity market clears

\[
L_x x_i = L_x = L_x x(1, p^x_y, 1) + L_y x(p^y_x, 1, 1) + L_s x(1, 1, (p^y_x - 1)s + (p^x_y - 1)s)
\]

\[
L_y y_i = L_y = L_x y(1, p^x_y, 1) + L_y y(p^y_x, 1, 1) + L_s y(1, 1, (p^y_x - 1)s + (p^x_y - 1)s)
\]

and the factor market clears

\[
L_x + L_y + L_s = n
\]

where \( x_i = y_i = 1 \) by assumption and \( x(p^j_{x, p^j_y, I}) \) is the 
demand function of an agent in sector \( j \). Thus

\( x(1, p^x_y, 1) \) is an \( x \) producers' demand for \( x \)

\( x(p^y_x, 1, 1) \) is a \( y \) producers' demand for \( x \)

\( y(1, 1, 2(R-1)s) \) is a servicers' demand for \( y \).

etc. etc.
PART II

Suppose for simplicity that $u$ is symmetric in $x, y \Rightarrow p_x^y = p_y^x = R$ in equilibrium. Thus

$$V(1, R, 1) = V(1, 1, 2(R-1)s).$$

(7)

Taking total derivatives

$$V_2 \, dR = V_3 [2s dR + 2(R-1) ds]$$

where $V_i$ is the partial derivative with respect to the $i^{th}$ argument of $V$.

Rearranging

$$\frac{dR}{ds} = \frac{2(R-1)V_3}{V_2 - 2V_3 s}.$$

(8)

Now we note that $V_2 < 0$, $V_3 > 0$ and $R > 1$, and that as the cost of transportation diminishes,

$$\text{Lt. } R = 1,$$

$s \rightarrow \infty$

i.e., if there were no cost to transportation $R$ would be 1 in this model.

Therefore

$$\frac{dR}{ds} < 0$$
This implies that an improvement in the service technology means that the welfare of all agents improves.

**Proof:**

For the \( x \) and \( y \) producers

\[
\frac{dV}{ds} = V_1(R,1,1) \frac{dR}{ds} = V_2(1,R,1) \frac{dR}{ds} \tag{9}
\]

and since

\[
V_1 = V_2 < 0 \implies \frac{dV}{ds} \geq 0 .
\]

For the servicers

\[
\frac{dV}{ds} (1,1,2(R-1)s) = 2 V_3 \{(R-1) + s \frac{dR}{ds} \} \tag{10}
\]

\[
= \frac{2 V_3 V_2 (R-1)}{V_2 - 2V_3 s} \geq 0 . \tag{11}
\]

Next we wish to focus on the allocation of \( L \) to the various sectors. Recall that the economy-wide constraints are

\[
L_x^i = L_x = x(1,R,1)L_x + x(R,1,1)L_y + x(1,1,2(R-1)s)L_s \tag{12}
\]

\[
L_y^i = L_y = y(1,R,1)L_x + y(R,1,1)L_y + y(1,1,2(R-1)s)L_s \tag{13}
\]
\[ n = L_x + L_y + L_z \]  \hspace{1cm} (14)

Now since we have assumed that \( U \) is symmetrical we have

\[ x(1,R,1) = y(R,1,1), \]

\[ x(R,1,1) = y(1,R,1), \]

and \[ x(1,1,2(R-1)s) = y(1,1,2(R-1)s). \]

Solving for \( L_z \) we get

\[ L_z = \frac{n}{1 + \frac{2x(1,1,2(R-1)s)}{1 - x(1,R,1) - x(R,1,1)}} \]  \hspace{1cm} (15)

Therefore

\[
\frac{dL_z}{ds} = n \left\{ \frac{1}{1 + \frac{2x(1,1,2(R-1)s)}{1 - x(1,R,1) - x(R,1,1)}} \right\}^2 \left( \frac{1}{1 - x(1,R,1) - x(R,1,1)} \right)
\]

\[
\left\{ \frac{2x(1,1,2(R-1)s)}{1 - x(1,R,1) - x(R,1,1)} \left[ - \frac{\partial x(1,R,1)}{\partial s} - \frac{\partial x(R,1,1)}{\partial s} \right] - 4 \frac{\partial x(1,1,2(R-1)s)}{\partial (R-1)s} \right\} \left[ R-1 + \frac{sdR}{ds} \right].
\]
Signing this:

\[
\frac{dL_s}{ds} = \{ \geq 0 \} \{ > 0 \} \{ ? \}
\]

Note:

\[
\frac{\partial x(1,R,1)}{\partial R} \geq 0 \quad \text{if } x \text{ is a substitute for } y
\]

\[
\frac{\partial x(R,1,1)}{\partial R} \leq 0 \quad \text{if } x \text{ is not a giffen good}
\]

and

\[
\frac{\partial x(1,1,2(R-1)s)}{\partial (R-1)s} \geq 0 \quad \text{as long as } x \text{ is not an inferior good}
\]

Thus the sign of \( \frac{dL_s}{ds} \) will be ambiguous and will depend on the magnitude of these three derivatives. This is to be expected. The improvement in the service technology means that trade is now relatively cheaper, leading to an increase in the total number of trades. However the number of agents required to carry out this new higher level is indeterminate. The fall in price \( R \) can lead to more of both goods being allotted to the service sector in equilibrium and thus to more agents entering the service sector.

We can see from the graph (Figure 1) that the elasticity of substitution of goods \( x \) and \( y \) will determine how the \( L_s \) function behaves under CES technology. When \( \sigma = 0 \), i.e., the consumption technology is Leontief, the two goods are completely independent and thus even as \( s \to 0 \) \( L_s \) rises. Agents expend as much energy as possible in an attempt to get the other good.
The allocation of labour to the service sector under C.E.S. technology

FIGURE 1
The same happens when \( \sigma = -1 \), i.e., the technology is Cobb-Douglas. It should be noted here that since neither Cobb-Douglas nor Leontief indifference curves touch the axis that either agents revert to autarky for large values of \( R \) (low values of \( s \)) or else we need strong degrees of returns to scale for the individual for \( L_s \) to approach \( n \) as \( s \) approaches 0. In particular autarkic production must be on the boundary of the positive quadrant. Of course these restrictions must apply to all utility functions to some degree if agents are not to revert to autarky as \( s \) approaches 0.

At the other end of the scale is the case where both goods are complete substitutes in terms of utility. Then \( \sigma = \alpha \) and \( L_s = 0 \) always since there is no incentive to trade. In this case the good produced is just as good as any other good we might be able to purchase. In between these extremes there will be \( L_s \) functions similar to the case where \( \sigma = -2 \). Here \( L_s \) rises initially as the service technology improves before reaching a maximum and then approaching 0 asymptotically like the others.

Further since \( L_s = n-(L_x+L_y) = n-2L_x \) (by symmetry),

\[
\frac{dL_s}{ds} < 0 \text{ implies that } \frac{dL_x}{ds} \text{ and } \frac{dL_y}{ds} \text{ also have ambiguous signs and hence } \frac{dx}{ds} \text{ and } \frac{dy}{ds}
\]

can be positive or negative.

This is an important result of the analysis. In much empirical work writers have expressed concern at the fall of the productive sector's share of GNP relative to that of the service sector in Western economies. However this model suggests that a fall in the output of final goods is quite possible with an improvement in the service technology. The fact that servicing is now relatively cheaper means that agents can obtain goods produced by others at a lower cost causing an increase in the desire to trade. This increased demand
for mediation services may exceed the capacity of existing servicers even with their improved capabilities. Consequently agents may leave the productive sector and enter the service sector. Further in the new equilibrium the total share of the service sector in the consumption of the final goods will rise. However the fact that all agents, and those in the productive sectors in particular, have better access to the range of final goods more than compensates for the fall in the output of final goods and all agents are better off. Thus in spite of the fact that technology has been improving in all sectors, a sufficient condition for the current trend in developed economies to be consistent with this model is that service technology has been developing faster than productive technology. We will see later that this is by no means necessary and that technological advancements in the productive sector can also lead to a larger service sector.

There are several other arguments which could be put forward to reinforce the results of this model. For example if there are increasing returns to scale to the firm in production then improved service technology would allow producers to locate in one large plant rather than in small ones close to population centres. In this example one would expect both the output of final goods and services to increase, with services sector perhaps growing proportionately more.

PART III

Different Sectoral Services and Asymmetric Production

Different Sectoral Services

Suppose now that the technologies associated with trading x and y were
different from one another. How will this affect equilibrium? Consider the case where \( U \) is symmetric in its arguments. We would expect that the different service technologies will affect the prices agents are willing to pay and indeed we can formulate our model to reflect this. However, equilibrium requires that \( V(1,p_x^y,1) = V(p_y^y,1,1) \). Given our symmetry assumptions this implies that \( p_x^y = p_y^x = R \) must continue to hold in equilibrium. This implies that

\[
x(R,1,1) = y(1,R,1)
\]

i.e., the amount of traded goods actually arriving at each producer/consumer is the same. Further \( L_x = L_y \). The total amount of \( y \) to be carried is

\[
L_x y(1,R,1)
\]

and the total amount of \( x \) to be carried is

\[
L_y x(R,1,1)
\]

Thus if \( s_x > s_y \)

\[
L_s^x s_x > L_s^y s_y \geq L_x y(1,R,1) = L_y x(R,1,1)
\]  \hspace{1cm} (17)

That is, if \( s_x > s_y \) there is excess capacity in carrying \( x \) and this superior technology is not utilized. Thus while the income of a servicer is nominally \( (R-1)s_x + (R-1)s_y \) the additional service capacity in servicing \( x \)
is not employed. This is because while initially the tendency is for a servicer to try and carry more $x$ and to trade it for profit it will not be able to bring back sufficient $y$ to pay for it. Thus with $p^x_y = p^y_x$, $x$ agents will not supply any more than $p^x_y s^x_y$ to any servicer. Therefore

$$\frac{dR}{ds^x_x} = \frac{dv}{ds^x_x} = 0$$

(18)

$$\frac{dR}{ds^y_y} = \frac{2(R-1)v^3}{\sqrt{V_2 - 2V_3 s^y_y}} = \frac{dR}{ds}$$

(19)

and $$\frac{dv}{ds^y_y} = \frac{2(R-1)v^2 V^3}{\sqrt{V_2 - 2V_3 s^y_y}} = \frac{dv}{ds}$$

(20)

The effect of a change in $s^y_y$, given that $s^x_x > s^y_y$, is equivalent to a change in $s$ since the improvement in $s^y_y$ permits the employment of some of the superior $s^x_x$ technology.

Somewhat different results are obtained if it is assumed that servicers service only one good, that is, they are either $x$ servicers or $y$ servicers. If we are to have equivalent technology to the single-servicer case then each agent could make two trips with goods and return empty. They would then get their own supplies of the good they do not service by costlessly trading with a servicer of the opposite type. As we show in Ryan (1986b) however this adds an extra restriction on the payment to servicers which complicates the model in a fundamental way and thus the whole nature of equilibrium is altered. In this case if $s^x_x > s^y_y$ the number of servicers in the $x$ service sector falls, allowing them to be reallocated across all other sectors. However relative prices in each production/consumption sector would change.
equiproportionally. Thus now an improvement in either sector increases welfare but excess space capacity (trucks returning empty) still exists.

Asymmetric Production

In this section we wish to consider the preceding single country model model where output is not symmetrical in the x and y sectors. This is similar to the case where the service technology differs between sectors. However it allows us to introduce the possibility of servicers trading on their own behalf and to see the consequences of the symmetrical utility assumption. Suppose now that agents in the x sector can produce \( f \geq 1 \) units of x each and that agents in the y sector can produce \( g \geq 1 \) units of y.

The individual budget constraints for the agents in the x and y sectors are

\[
f = x + p_y^x Y
\]

(21)

\[
g = p_x^y X + y
\]

(22)

The budget constraint for agents in the service sector is now more complicated. To see this, first consider the conditions necessary for equilibrium in the x and y sectors.

Equilibrium requires that

\[
V(1,p_y^x,f) = V(p_x^y,1,g)
\]

(23)
Depending upon the nature of the utility function we may write

\[ p_y^x = \phi(f, g, p_x^y) \quad (24) \]

where

\[ \phi_f > 0, \quad \phi_g < 0, \quad \phi_{p_x^y} > 0. \quad (25) \]

Letting \( R = p_x^y \), and if we restrict the servicer to servicing goods for producer/consumers only, then a servicer's consumption bundle is

\[ x^s = (\phi(f, g, R) - 1)s, \]

\[ y^s = (R-1)s. \]

Suppose now we relax this restriction and allow the servicer to adjust his/her consumption bundle to the prevailing prices. If the servicer delivers \( s \) units of \( y \) to \( x \) she/he will receive \( \phi(f, g, R)s \) units of \( x \) in return.

The servicer can then choose to consume

\[ (\phi(f, g, R) - \alpha_1)s \]
units of $X$, where $a_1 \leq 1$, as long as $a_1 s$ (the amount of $x$ he delivers to $y$) is such that $a_1 R s \geq s$.

Thus the maximum $x$ a servicer can consume is

$$(\phi(f,g,R) - \frac{1}{R}) s$$

which implies that $y = 0$.

Similarly the maximum amount of $y$ a servicer can consume is

$$(R - \frac{1}{\phi(f,g,R)}) s$$

in which case $x = 0$. Thus a servicer can trade for $x$ and $y$ at prices $R$ and $\frac{1}{\phi(f,g,R)}$ respectively.

Recalling the case where the production of $x$ and $y$ were symmetrical we see that this re trading presents no problem, given our assumption of a symmetrical utility function. To see this consider Figure 2. The bundle that the servicer can trade lies on the $45^\circ$ line. Thus with prices $R$ for $x$ and $\frac{1}{R}$ for $y$ the purchase of further units of $x$ or $y$ cannot yield higher utility.

When output is not symmetrical, this is no longer the case. This can be seen by considering Figure 3. When the servicer is restricted to carrying bundles that producers/consumers wish to trade, servicers receive the bundle $A = \{(\phi-1)s, (R-1)s\}$. However if the servicer is permitted to trade for
Figure 2.

Figure 3. $f > g$
more $y$ at the price $\phi(f,g,R)$ or $x$ at the price $R$, then their consumption bundle can be altered to increase utility, e.g., point B.

Given our assumption of a symmetrical utility function and the fact that in the absence of servicer trading $R \geq 1$ (= 1 in the limit as $s \to \infty$), agents will never want to purchase more $x$. Consequently a servicer's budget constraint is given by the line from $A$ to the $y$ axis. More formally, the servicer's problem (for $f > g$) is

$$\text{Max } u(x,y)$$
$$x, y$$

s.t. $x + \phi(f,g,R)y = [(\phi(f,g,R) + 1)R - 2]s$ (27)

and $x \leq (\phi(f,g,R) - 1)s$ (28)

$y \geq (R - 1)s$ (29)

where $\phi(f,g,R)$ and $R$ are taken as given. For $f > g$, equilibrium requires that

$$\frac{U_1}{U_2} - \frac{1}{\phi(f,g,R)} \geq 0$$ (30)

$$\lambda_2 \geq 0$$ (31)

and

$$\left( \frac{U_1}{U_2} - \frac{1}{\phi(f,g,R)} \right) \lambda_2 = 0$$ (32)
where $\lambda_2$ is the Lagrange Multiplier on the second constraint. Note the third constraint is implied by the other two. The equivalent conditions for $g > f$ are

\[ R - \frac{U_1}{U_2} \geq 0 \]  

(33)

\[ \lambda_2 \geq 0 \]  

(34)

and

\[ (R - \frac{U_1}{U_2}) \lambda_2 = 0 \]  

(35)

We may rewrite this problem as follows. A servicer maximizes

\[ U((\phi - 1)s_1, (R-\alpha)s) \]  

(36)

with respect to $\alpha$

s.t. $\alpha \leq 1$

First order conditions imply

\[ U_1 \phi - U_2 = 0 \]  

(37)
If the conditions for the implicit function theorem are met then we may write

\[ \alpha = \alpha(f,g,R,s) \]  \hspace{1cm} (38)

Thus general equilibrium requires that

\[
V(1,\phi(f,g,R),f) = V(R,1,g) \\
= U[1,\phi(f,g,R)\alpha(f,g,R,s)-1)s, (R-\alpha(f,g,R,s))s]\]. \hspace{1cm} (66)

Assuming these functions are continuous and differentiable, total differentiation implies that

\[
V_2 \phi_R \, dR + (V_2 \phi_f + V_3) \, df + V_2 \phi_g \, dg \\
= V_1 \, dR + V_3 \, dg \\
= [U_1(\phi_R \alpha + \phi_R \alpha) + U_2(1 - \alpha_R) \, ds] \, dR \\
+ [U_1 \phi_R \alpha + U_2 \phi_R \alpha - U_2 \alpha_R \, ds] \, df \\
+ [U_1 \phi_R \alpha + U_2 \phi_R \alpha - U_2 \alpha_R \, ds] \, dg \\
+ [U_1(\phi_R - 1) + U_2(R - \alpha) + U_2 \phi_R - U_2 \alpha_R \, ds].
\]

Invoking the envelope theorem we can write
\[
\frac{dR}{ds} = \frac{U_1(\phi - 1) + U_2(R - \alpha)}{U_1 \phi R - U_2 s} \leq 0 \quad (39)
\]

\[
\frac{dR}{df} = \frac{U_1 \phi f s}{U_1 \phi R - U_2 s} \leq 0 \quad (40)
\]

\[
\frac{dR}{dg} = \frac{U_1 \phi g s - V_3}{U_1 \phi R - U_2 s} \geq 0 \quad (41)
\]

Further

\[
\frac{dV}{ds} = V_1 \frac{dR}{ds} \geq 0 \quad (42)
\]

\[
\frac{dV}{df} = V_1 \frac{dR}{df} \geq 0 \quad (43)
\]

\[
\frac{dV}{dg} = V_1 \frac{dR}{dg} + V_3 \geq 0 \quad (44)
\]

If \( \alpha < 1 \) then servicers are operating at less than full capacity in one direction. They service as of a producer/consumer's good (e.g., \( x \)) and \((1-\alpha)s\) units of their own payment of \( x \) initially. However on the return journey they will service only as units of the \( y \) producer's good. Thus an improvement in service technology will lead to an increase in the total number of trades. However some of this trading may now be on behalf of servicers rather than producers/consumers. Further the presence of a differential trading technology may not be as damaging here as it was in the
case of the symmetric production technology. In particular if \( s_x \leq s_y < s_x \) equilibrium will not be affected. If \( s_x > s_y \) then welfare is bounded by the lower \( S_y \) trading technology.

**International Trade**

In Ryan (1986b) we show that the standard trade propositions in relation to comparative advantage and gains from trade hold for a two-country trade model. There are however some interesting features to the two-country equilibrium. One is that a country specializing in services would, in general engage in a discriminating game between \( x \) and \( y \) producers. This work is considered initially in Ryan (1985) and is the subject of on-going analysis. In this paper however we wish to highlight another interesting outcome.

Consider a two-country world where servicers from either country can service producers/consumers from the other. Further suppose that country \( A \) has a comparative advantage in the production of \( x \) and country \( B \) has a comparative advantage in the production of \( y \). Service technology is identical in both countries. Under autarky equilibrium in country \( A \) is given by

\[
V(1, \phi^A(A^A), 1) = V(R^A, 1, 1)
\]

\[
= U((\phi \alpha - 1)s, (R^A - \alpha)_s) \tag{45}
\]

and equilibrium in country \( B \) is given by

\[
V(1, R^B, 1) = V(\phi^B(B^B), 1, B^B)
\]

\[
= U((R^B - \alpha)_s, (\phi \alpha - 1)s) \tag{46}
\]
where $\phi^j$ is the price of the good in which country $j$ has a comparative advantage

$R^j$ is the price of the other good in country $j$

$f^A > 1$ is the output of an $x$ producer in country $A$

$g^B > 1$ is the output of a $y$ producer in country $B$

and $g^A = f^B = 1$ is the output of a $y$ producer/$x$ producer in countries $A$ and $B$ respectively.

If $f^A = g^B$

then

$$R^A = R^B \quad \phi^A = \phi^B$$

and

$$\phi^A > R^B; \quad \phi^B > R^A$$

That is, the price an $x$ producer is prepared to pay for a unit of $y$ in $A$ is greater than an $x$ producer is prepared to pay in $B$ in autarky and the price a $y$ producer is prepared to pay for a unit of $x$ in $B$ is greater than a $y$ producer is prepared to pay in $A$. If trade is then permitted, services will want to pick up $x$ in country $A$ and trade with $y$ producers in country $B$. The new equilibrium is given by

$$V(1, \phi^F(f^A, g^B, R^F, F), f^A) = V(R^F, 1, g^B)$$

$$= U((\phi^F(f^A, g^B, R^F) - 1)s, (R^F - \alpha)s) \quad (47)$$

where $\phi^F$ is the new world price of $x$ and $R^F$ the new world price of $y$.

Note we are assuming agents in $A$ specialize in $x$ and servicing, agents in $B$
specialize in y and servicing, and $L_x^A < n^a, L_y^B < n^B$. This is possible given our assumptions.

Unlike conventional trade models there are two possible sources of gains from trade here. The first is from the improved world output that we usually see. The second is that since $(F^A - g^B) < (f^A - 1) = (g^B - 1)$, the world is now less asymmetrical. Consequently there is less trading on behalf of producers/consumers. Consequently the move to free trade not only captures the benefit of better final good production but also has an "as if" improvement in service technology associated with it.
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