Agricultural productivity and trade: Argentina and the U.S.A.

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A B S T R A C T

We study labor productivity in agriculture within a two-region, two factor and two commodity economy. Increases in productivity can lead either to higher or to lower agricultural prices, depending on the internal structure of the economy. We give necessary and sufficient conditions for either outcome; these depend on technologies, factor endowments and export levels. In a developing economy, improvements in productivity generally lead to higher agricultural prices, i.e. to better terms of trade between agriculture and industry.

In an industrial economy increasing productivity leads instead to lower agricultural prices. The sign of one expression determines the turning point between these two opposite price responses and allows us to explain the effects of trade and investment policies on domestic output and welfare. Simulations of the model are reported with data for Argentina and the U.S.A. circa 1970.

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AGRICULTURAL PRODUCTIVITY AND TRADE

Argentina and the U.S.A.

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Contents

1. Introduction

How does an increase in productivity affect prices? Generally, one would expect higher productivity to lower the price of output: when inputs are used more efficiently costs decrease, and with them prices. This intuition seems well suited to the history of agriculture in the industrial economies. In regions where agricultural productivity is high, the relative price of food is low.

Yet the opposite intuition has been applied to developing economies. W. A. Lewis, (1978) explains that higher labor productivity in agriculture improves the terms of trade of agriculture vis-a-vis other sectors thus leading to higher rather than lower agricultural prices. Higher labor productivity in agriculture, Lewis argues, improves the terms of trade for an agricultural exporter.[1]

It appears therefore that increasing productivity in agriculture can have either of two opposite effects: in industrial countries to decrease agricultural prices, while in developing countries to increase them. It may seem puzzling that in either case higher productivity is expected to increase welfare, even though it has opposite effects on prices.

This paper provides an explanation for this non-monotonic price response to changes in productivity. The price response depends on the sign of a simple expression reflecting key structural characteristics of the economy: export levels, domestic technologies and factor endowments. Necessary and sufficient conditions are obtained for productivity growth in agriculture to lead to higher agricultural prices. This means better terms of trade for agriculture vis-a-vis industry, and leads to higher employment and increased overall consumption in the agricultural exporting economy. Confirming Lewis' intuition, the conditions under which prices increase are typical of developing countries. Moreover, we show that in such economies, increasing exports <u>without</u> improving agricultural productivity leads to negative outcomes: lower terms of trade, export revenues, real wages and domestic consumption. Increasing productivity is therefore a prerequisite for successful export-led policies.

The two-signed response of prices to productivity change can be explained as follows. Higher labor productivity does increase supply and this tends to lower prices. But wages increase and thus the demand for food will increase as well. These income effects increase the demand for food and may eventually lead to higher rather than lower food prices. The final price response depends therefore on the relative magnitudes of changes in supply and in demand and this is precisely what is measured by our necessary and sufficient conditions.

We show that in industrial economies with homogeneous technologies and relatively low levels of agricultural exports, supply effects tend to dominate income effects. Therefore, increasing labor productivity in agriculture leads to <u>lower</u> food prices. It also leads to higher profits and to an expansion of the industrial sector. The sign of one expression determines the "turning point" at which the price-productivity relationship reverses: that is, the sign of this expression predicts when agricultural prices increase or decrease with improvements in labor productivity.

The rest of the paper is organized as follows. The second section defines the model, which is that of Chichilnisky (1981). The third section presents the data and discusses simulations of trade policies for Argentina and the U.S.A. near 1970. Both countries are agricultural exporters, but have rather different structural characteristics. About 75% of Argentina's exports are grain and livestock products, and 25% manufactures, while for the U.S.A. these proportions are approximately reversed, thus providing two contrasting case studies. The fourth and fifth sections present the comparative statics results that explain the outcome of the simulations in theoretical terms. We conclude with a brief discussion of alternative export policies.

2. The North-South Model

This section summarizes briefly the model of Chichilnisky (1981). Each region is described by behavioral assumptions and equilibrium conditions. Consider first the economy of the South. It produces basic goods denoted B and industrial goods denoted I, using labor L and capital K:

$$B^S = \min (L^B/a_1, K^B/c_1)$$

$$I^S = \min (L^I/a_2, K^I/c_2)$$

In the simulation, basic goods are an aggregate of agricultural products and consumption goods. Assuming producers are competitive the following price equations will hold in equilibrium,

(1) $$p_B = a_1 w + c_1 r$$

(2) $$p_I = a_2 w + c_2 r$$

Factors supplies depend on their rewards:

(3) $$L^S = \alpha(\frac{w}{p_B}) + \bar{L}, \ \alpha \geq 0$$

(4) $$K^S = \beta r + \bar{K}, \ \beta \geq 0$$

where w denotes wages, p_B the price of basics and r the rental rate of capital. To these four behavioral assumptions we add equilibrium or market clearing conditions for factors and commodities:

(5) $$L^S = L^D$$

(6) $$K^S = K^D$$

(7) $$L^D = a_1 B^S + a_2 I^S$$

(8) $$K^D = c_1 B^S + c_2 I^S$$

(9) $$B^S = B^D + X_B^S, \text{ where } X_B^S \text{ denotes exports of B}$$

(10) $$I^D = X_I^D + I^S, \text{ where } X_I^D \text{ denotes imports of I}$$

and the balance of payments condition

(11) $$p_B X_B^S = p_I X_I^D,$$

where the superscripts S and D denote equilibrium supply and demand, respectively. It is worth noting that in equilibrium, Walras Law or the National Income Identity is always satisfied in each region:[2]

(W) $$p_B B^D + p_I I^D = p_B(B^S - X_B^S) + p_I(I^S + X_I^D) \text{ from (9) and (10);}$$

$$= (a_1 w + c_1 r)B^S + (a_2 w + c_2 r)I^S \text{ from (1), (2) and (11);}$$

$$= wL + rK \text{ from (7) and (8).}$$

The North is specified by the same equations (1) to (11), except for possibly different parameters in the technology and supplies of factors. In a world equilibrium the prices of traded goods are equal, and exports match imports. This yields four more equilibrium conditions:

(12) $$p_I(S) = p_I(N)$$

(13) $$p_B(S) = p_B(N)$$

(14) $$X_B^S(S) = X_B^D(N)$$

(15) $$X_I^D(S) = X_I^S(N)$$

where the letters S and N in brackets denote North and South respectively.

There are therefore eight exogenous parameters in each region: a_1, c_1, a_2, c_2, α, $\bar{L}$, β, $\bar{K}$, and fourteen endogenous variables, p_B, p_I, r, w, B^S, B^D, X_B^S, I^D, I^S, X_I^D, L^S, L^D, K^S, and K^D. There are eleven equations (1 to 11) in each region plus four international market clearing conditions (12 to 15). Note that the balance of payments equation (11) for the North is automatically satisfied when (12) to (15) hold and (11) holds in the South. We have therefore a total of 25 independent equations for the two region economy. We add the normalization condition

(16) $$p_I = 1$$

i.e., the industrial good is the numeraire, and obtain a total of 26 independent equations for the North-South model. Since there are fourteen endogenous variables in each region, we have a total of 28 endogenous variables.

The system is undetermined up to two variables, which is not surprising since demand functions have not been defined for either region. This can be done in several ways: one is to choose utility functions; another is to choose equilibrium levels of demand for I goods in both regions as in Chichilnisky (1981). A third alternative, is to set exogenously the equilibrium volume of basic goods traded $X_B^S(S) = X_B^D(N)$ and the South's industrial demand in equilibrium, $I^D(S)$. This latter demand specification yields two additional equations,

$$I^D(N) = \overline{I^D} \tag{17}$$

and

$$X_B^S(S) = \overline{X_B^S}. \tag{18}$$

This makes a total of 28 equations in 28 variables and the model is thus closed.

Yet another treatment of demand is to assume that in the South all basic goods are consumed by wage earners. In this case equation (18) is replaced by a demand equation for basics in the South:

$$p_B B^D = wL. \tag{18a}$$

By Walras' Law this implies $p_I I^D = rK$ in equilibrium, so that industrial demand is $I^D = rK/p_I$. Exports X_B^S are now endogenously determined. This second closure is used in Section 4 and was studied previously in Chichilnisky and Cole (1978), Chichilnisky (1981), (1983) and Heal and McLeod (1983).

An increase in labor productivity in agriculture in this model corresponds to a decrease in the labor-output parameter a_1. By varying the parameter a_1, we obtain a new equilibrium with different levels of prices of goods and factors, different outputs, employment, income and demand in the South.

3. Labor Productivity and Export Policy: A Simulation for Argentina and the United States circa 1970

It has been suggested that the effects of changes in labor productivity depend upon the structure of the economy under consideration. In this section we use the model developed above to explore this point further. We simulate the effects of labor productivity change on two major agricultural exporting economies: Argentina and the United States, countries which have rather different domestic economic structures.

Both countries are major grain exporters, with the U.S. providing 35-40% and Argentina some 10-15% of world exports during the 1970s. Argentina is also the principle exporter of livestock products worldwide. Exports of agricultural and related products are relatively more important in Argentina, where they amounted to 6-8% of GNP during the 1970s (compared to 1-2% of GNP in the U.S. over the same period). Within the two countries, production takes place under very different circumstances. Per capita income in Argentina is about one-fifth that of the United States, and in 1970 the average agricultural wage rate in Argentina was about $.31 per hour: only about one-eighth the U.S. level (ILO, 1980). Since wage income accounts for about the same share of total agricultural value added in both countries, agricultural labor appears to be much more productive in the United States.

In order to simulate the effect of export expansion and labor productivity change in these economies, a set of base year parameters were estimated for each region using procedures described in Appendix B. These parameter values are shown in Table 1. In addition to investment demand and export levels, eight parameters are required for each country:

(D = 4.01895)

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TABLE 1: Paramter Values for Argentina and the United States

Technological Parameters*	Argentina	United States
Basic Sector: Labor/Output (a_1)	1.5532	.14
Investment Goods: Labor/Output (a_2)	.82979	.12
Basic Goods: Capital/Output (c_1)	1.5	1.21
Investment Goods: Capital/Output (c_2)	3.3889	1.79
Factor Supply Parameters*		
Labor Response:		
Intercept $\bar{L}$	24.508	79.20
Slope α	6.4448	7.96
Capital Response:		
Intercept $\bar{K}$	45.848	902.2
Slope β	16.258	1445.0
Labor Supply		
Mean Point Elasticity	.11	.33
Capital Supply		
Mean Point Elasticity	.06	.28
Demand Parameters		
Investment Demand	10.425	342.8
Basic Good Exports	1.85 - 2.82 1.85291	65.0
Sectoral Wage Share in Value Added		
Basic Goods	.71	.70
Investment Goods	.39	.58

*See Appendix B for a discussion of how the parameter estimates were obtained.

the capital and labor output ratios a_1, a_2, c_1 and c_2, and the factor supply equation parameters: $\bar{L}$, $\bar{K}$, α, β. Note that the agricultural labor-output ratio is much lower in the United States. Argentina also displays greater variation in sectoral technologies as indicated by the sectoral wage shares. The implications of this technological dualism are discussed further in the next section.

Once the parameter values a_1, a_2, c_1, c_2, α, $\bar{L}$, $\bar{K}$ are given, a single resolving equation is used to compute the equilibrium value of the terms of trade p_B. This is shown in Section 4, equation (24). Once p_B is known, all of the other endogenous variables of the model can be determined.

The first column of Table 2 lists the base year solution values obtained for the United States, including income, output and employment levels. Note that the base year value for p_B is one: This is because of our definition of a physical unit of basic goods in 1970.

To simulate labor productivity improvement in the basic sector, we reduce exogenously the labor input parameter a_1 and compute the new equilibrium values of all endogenous parameters: p_B, r, w, B^S, B^D, X_B^S, I^S, I^D, X_I^D, L, K. As shown in Table 2, a reduction of 5% in the labor-output ratio (a_1) for U.S. agriculture causes the terms of trade p_B to fall by 6%. Export revenues, GDP, employment and real wages also decrease, while the rental rate for capital and output of both goods increases.

The impact of a similar labor productivity change in Argentina is not as clear cut. As shown in Table 3, when export to GNP ratios are at the high end of the range observed during the 1970s, increasing labor productivity in actually leads to higher agricultural prices, employment,

TABLE 2: The impact of an Increase in Agricultural Labor Productivity Growth in the United States with a Fixed Level of Exports (1970 dollars unless otherwise specified)

Variable	Base Year Value	With Higher Labor Productivity	Percent Change
Labor/output ratio:	.15	.14	-5%
Basic Exports	65.00	65.00	exogenous
I Good Demand	342.80	342.80	exogenous
Price of Basics	1.00	.94	-6%
Output of Basics	601.00	624.00	4%
Output of I Goods	277.80	281.50	1%
GDP	879.00	870.00	-1%
B Good Demand	536.00	559.00	4%
Real Wage Rate	4.90	4.80	-2%
Profit Rate	.24	.26	10%
Employment*	119.40	118.70	-1%
Capital Stock	1224.00	1258.60	3%
Export Revenues	65.00	61.30	-6%
Exports/GNP	7.39	7.05	-5%

*in Billions of Person Hours.

TABLE 3: The impact of an Increase in Agricultural Labor Productivity Growth in Argentina with Higher Export Levels (1970 dollars unless otherwise specified)

Variable	Base Year Value	With Higher Labor Productivity	Percent Change
Labor/output ratio:	1.55	1.53	-1%
Basic Exports	2.82	2.82	exogenous
I Good Demand	10.43	10.43	exogenous
Price of Basics	1.00	1.15	15%
Output of Basics	14.13	14.73	4%
Output of I Goods	7.60	7.18	-5%
GDP	21.77	24.13	11%
B Good Demand	11.31	11.91	5%
Real Wage Rate	.47	.53	12%
Profit Rate	.18	.15	-18%
Employment*	28.25	28.61	1%
Capital Stock	46.90	46.43	-1%
Export Revenues	2.82	3.24	15%
Exports/GNP	12.39	13.44	4%

*in Billions of Person Hours.

real wages and total output. However, for lower export/GNP ratios, p_B falls as labor productivity increases, just as it does in the United States. Table 4 simulates the impact of productivity change at lower export levels. With an export/GDP ratio of 8%, the terms of trade p_B falls with increases in productivity. Note also that wages, employment and export revenues all decline.

On the other hand, when exports are 13% of GNP, then an increase in labor productivity leads to <u>higher</u> prices for basics p_B so that real wages, export revenues and employment all increase. Hence it appears that the economic impacts of productivity change depend on the level of exports.

The relationship between productivity growth and price changes as agricultural exports increase from 8 to 13% of GNP. This indicates the

TABLE 4: The impact of an Increase in Agricultural Labor Productivity Growth in Argentina with Lower Export Levels (1970 dollars unless otherwise specified)

Variable	Base Year Value	With Higher Labor Productivity	Percent Change
Labor/output ratio:	1.55	1.53	-1%
Basic Exports	1.85	1.85	0%
I Good Demand	10.43	10.43	0%
Price of Basics	1.00	.83	-17%
Output of Basics	13.13	12.79	-3%
Output of I Goods	8.59	8.90	4%
GDP	21.61	19.42	-10%
B Good Demand	11.28	10.94	-3%
Real Wage Rate	.47	.39	-16%
Profit Rate	.18	.22	18%
Employment*	27.52	27.05	-2%
Capital Stock	48.80	49.36	1%
Export Revenues	1.85	1.54	-17%
Exports/GNP	8.56	7.91	-8%

*in Billions of Person Hours.

existence of an important "turning point" or <u>critical level of exports</u> at which key structural relationships in the economy change. The theoretical details of this are developed in Section 4. It turns out that this "turning point" coincides exactly with a change in the slope of a quantity-price relation X_B^S. This curve X_B^S links prices p_B and the volume of exports of basics across equilibria (see Chichilnisky, 1981). By definition, X_B^S slopes upward when more exports are associated with better terms of trade. We show in Section 4 that when X_B^S is upward sloping improvements in agricultural productivity <u>reduce</u> the relative price of agricultural goods. This response is typical of industrial economies.

However, when X_B^S is negatively sloped, then higher productivity in agriculture <u>improves</u> agricultural prices at any given level of exports. This response is more typical of developing economies because it is in those countries that X_B^S is likely to be negatively sloped. As seen in Chichilnisky (1981), the slope of X_B^S has the sign of the expression $c_2/D - 2w/p_B$; a developing country which exhibit a significant level of dualism will have a large value of the determinant D, so that c_2/D is likely to be exceeded by $2w/p_B$. The opposite happens in industrial countries: D is small and c_2/D is more likely to exceed $2w/p_B$, so that X_B^S is positively sloped. The Argentinian economy shows both responses, at different levels of exports, as befits a semi-industrialized economy.

It is shown in Section 4 that the slope of the curve X_B^S depends crucially on the initial level of real wages, on factor supply response and upon the level of technological dualism between agriculture and industry. In economies which display the characteristics of developing countries the curve X_B^S may slope downwards. In advanced industrial economies with relatively homogenous technologies among sectors, the X_B^S curve is much more likely to slope upwards.

The actual location of the "turning point" (export/GDP level) for the Argentine economy depends of course on the accuracy of our parameter estimates and aggregation procedures. It also depends, of course, on starting levels. However, it is possible to show how changes in labor productivity affect the location of this turning point. To simulate economic growth, the level of industrial demand I^D in Argentina was increased exogenously so that both prices and the volume of exports are endogenous. As the share of exports in GNP increased, the slope of the X_B^S curve changed. As shown in the next section, the relationship between the terms of trade, p_B and productivity, a_1 changes at the exact point at which the slope of the curve X_B^S changes its slope. That is, when the volume of exports increases with p_B, higher labor productivity leads to lower food prices. However, if the volume of exports decrease with p_B, then improvements in productivity lead instead to higher agricultural prices.

Figure 1 plots the slope of the quantity-price curve X_B^S at different export/GNP ratios for Argentina. For the observed agricultural labor/ output ratio of 1.55, the turning point is reached when basic goods exports amount to about 10.4% of GNP. At levels greater than 10.4%, labor productivity improvements lower the terms of trade for agriculture: for export shares below this level the opposite occurs.

Figure 2 shows the effect of an increase in labor productivity on the location of this turning point. According to these estimates a 10% improvement in labor productivity changes the turning point, or critical export share of Argentina from 10.5 to 12% of GNP.

Figure 1: Base Year Labor Productivity $a_1 = 1.55$

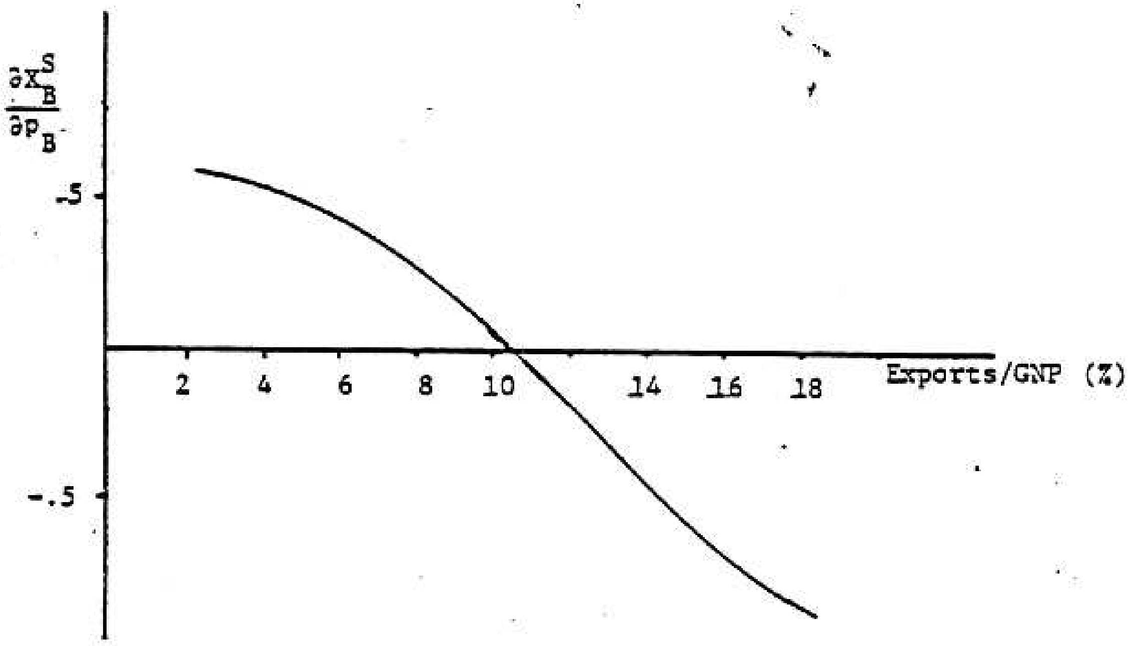
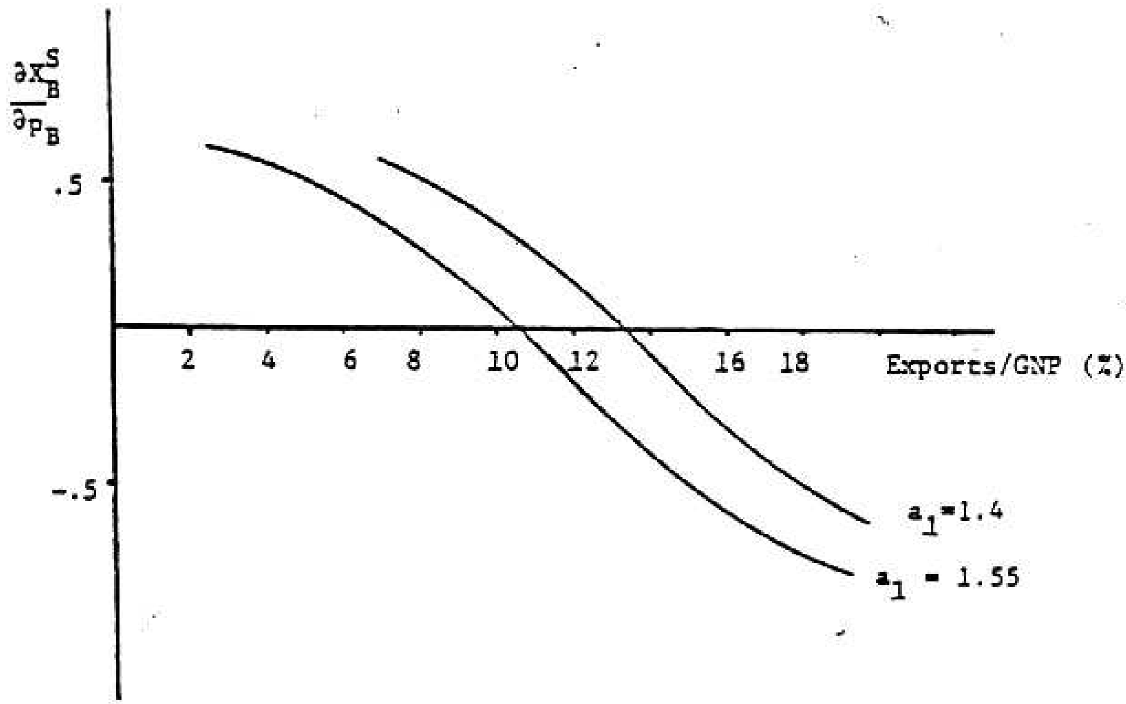


Figure 2: Effect of Increase Labor Productivity on Export Supply Response



Thus, for any given level agricultural productivity, there is an implied "optimal" export/GNP ratio. Before this point is reached, increases in exports are associated with higher export revenues, wages and employment. However, once this level of exports is exceeded, increases in exports are accompanied by lower export revenues, agricultural prices, wages and employment (although profits and the demand for capital increase).

Moreover, as indicated by figure 2, a higher level of initial agricultural productivity pushes this "turning point" outward, implying that, with higher productivity a higher level of exports can be sustained without negative outcomes.

Although the usual caveats apply to the parameter estimates, the qualitative implications of these results for economic policy are strikingly clear: Ideally exports should expand in step with the growth of labor productivity in agriculture. Too rapid an expansion in exports or lagging productivity growth in agriculture may have serious negative consequences for domestic incomes and employment.

It appears also that at high levels of industrialization and productivity, while the impact of an increase in a_1 on GDP is negative, it is not nearly as great as at low levels.

We now turn to the theoretical analysis of the results of the simulations.

4. Asymmetric Effects of Labor Productivity

The task of this section is to explore the directions of change for all the endogenous variables as labor productivity increases in agriculture. The following stylized assumptions are made regarding the exogenous parameters of the North and the South. In the South technologies differ significantly between sectors so that $D(S) = a_1c_2 - a_2c_1$ is positive and large. The opposite is true in the North: D(N) is positive but small, i.e., technologies are relatively homogeneous. The basic sector in the South uses few capital inputs (c_1 small).

The first theorem gives necessary and sufficient conditions for an improvement in the agricultural terms of trade to follow an increase in agricultural labor productivity. Theorem 2 shows that when labor is abundant and there is significant technological dualism between agriculture and industry, then income effects cause demand to increase faster than supply. The terms of trade for agriculture therefore improve with labor productivity, because of domestic demand responses. Finally, Theorem 3 links changes in agricultural prices to real wages and employment.

Theorem 1

In the North-South economy, assume that labor productivity increases in the agricultural sector of the South. This leads to better terms of trade for agriculture if and only if the following inequality is satisfied in the South:

$$X_B^S > \frac{1}{D^2}\,(\beta a_1 a_2 + \alpha\,\frac{c_1^2}{p_B^2}).$$

In particular, if exports X_B^S are high, technologies dual, (D large) and capital use in basics (c_1) small, higher labor productivity in agriculture always improves the terms of trade of agriculture vis-a-vis industry.

The conditions of this theorem are likely to be met by a developing country with high level of exports as a proportion of GDP.

The strategy of the proof (contained in Appendix A) is to define an implicit function linking the productivity of labor in the basic sector, a_1, and the price p_B, a function which is always equal to zero in equilibrium. From this implicit function, we then derive the derivative of p_B with respect to a_1 across equilibria. The effect of a change in p_B on all other endogenous variables is then explored.

Corollary 2

Assume that labor productivity in the agricultural sector of the South increases. Then a necessary and sufficient conditions for the price of agricultural goods to drop is that

$$\frac{1}{D^2}(a_1 a_2 \beta + \frac{\alpha c_1^2}{p_B^2}) > \bar{X}_B^S$$

In particular, when initial productivity is high (a low a_1), technologies are homogeneous (D is small), and agricultural exports are relatively low ($\bar{X}_B^S$ small), further increases in agricultural productivity decrease agricultural prices (but the effect is likely to be proportionately small).

The conditions of this Corollary are similar to those of an industrial country such as the U.S..

Proof

The proof of Theorem 1 implies this corollary, since it shows that the sign of $\frac{dp_B}{da_1}$ is always that of $\frac{\partial \phi}{\partial p_B}$. ∎

The next theorem shows that increasing labor productivity always leads to higher food prices when the economy has abundant labor (α large) and technologies are dual (D large):

Theorem 2

Consider a North-South economy as above. In the South labor is abundant (α large) and technologies dual ($\frac{c_2}{D} < \frac{2w}{p_B}$). Then higher labor productivity in agriculture of the South leads always to better terms of trade for agricultural goods.

Under the same conditions for the South increasing agricultural exports without improving labor productivity, will always lead to lower terms of trade and to lower export revenues. Therefore, the South only gains from increasing exports if its labor productivity in agriculture increases as well.

The proof of this theorem is in Appendix A.

Remark: This theorem highlights the role of income effects in producing an increase in p_B as productivity rises. This is because the term $2w/p_B$ is in fact a measure of the strength of the income effect, while the term c_2/D measures instead the supply response. When $2w/p_B$ is larger than c_2/D, demand from wage income increases faster than supply so that p_B increases. The income effect leads to a stronger rise in demand than in supply.

Having studied the impact of changes in productivity on agricultural prices, we analyze next the impacts of such changes on real wages and on employment.

Theorem 3

Consider a North-South economy where the South's technologies are dualistic (D large). As labor productivity in agriculture increases, the terms of trade of agriculture vs. industry may either improve (Theorem 1) or worsen (Corollary 2). If terms of trade for agriculture improve, real wages and total employment increase. If agriculture's terms of trade fall, real wages and employment may either increase or decrease.

The proof of this theorem is in Appendix A.

In all of the above, the volume of exports of the South remain fixed at $\overline{X_B^S}$. The next section studies comparative statics experiments where productivity and the volume of exports vary simultaneously.

5. Export Policies and Agricultural Productivity

Up to now we have examined the impact of productivity increases on two types of regions: one displaying the structural characteristics of a "Southern" economy, while the other exhibits those of an industrial economy. In both cases, the experiment was to increase labor productivity in agriculture (to reduce a_1) while the level of exports X_B^S stayed constant, and observing the impact this has on prices, consumption and employment of the exporting region.

In this section we shall enlarge the scope of the experiment, to allow the volume of exports to change following an increase in labor productivity. Figures 1 and 2 of Section 3 illustrate this experiment.

The model is now modified as follows: as before, industrial demand in the North is exogenously given $I^D(N) = \bar{I}^D$. However, exports of the South X_B^S are now not exogenous: they are instead endogenously determined. The crucial difference is introduced by dropping the equation (18) $X_B^S = \overline{X_B^S}$. We introduce in its place another equation for demand for basics in the South B^D (denoted (18a) in section 1):

$$wL = p_B B^D \qquad (18a)$$

i.e., in the South wage income is spent on basics. By Walras Law (W), (18a) is equivalent to:

$$rK = I^D$$

i.e., in the South, capital income is spent on industrial goods. This new equation allows us to "close" the model without requiring to fix exogenously the level of exports X_B^S. Therefore the level of exports X_B^S now changes as industrial demand in the North $I^D(N)$ varies. Furthermore, even if $I_B^D(N)$ is fixed, X^S varies with changes in a_1. This means that changes in agricultural productivity lead to changes in the volume of exports. We call this new version a type II North-South model.

The next result studies changes in prices and exports volumes, following an increase in agricultural productivity in the South:

Theorem 4

Consider a type II North-South economy. The South has the characteristics of Theorem 2 and its basic sector uses few capital inputs (c_1 small). The initial rates of profit are relatively high: $2r > \frac{a_1}{D}$ in both regions. Then if agricultural labor productivity increases in the South:

(1) The terms of trade of agriculture vis-a-vis industry improve. Real wages in the South increase;

(2) In the South domestic consumption of basics increase and exports X_B^S drop;

(3) Export revenues of the South $p_B X_B^S$ increase so that industrial imports X_I^D increase.

The proof of this theorem is in Appendix A.

Conclusions

This paper examines the impact of labor productivity in agriculture on prices, real wages and employment in an agricultural exporting economy. The results are obtained in a simple 2 × 2 × 2 North-South trade model, and illustrated in a simulation of the same model using data for Argentina and the United States circa 1970.

A main result of the paper is that the terms of trade for agriculture may improve with increases in the productivity of agricultural labor. This belies the conventional wisdom that increases in productivity lower prices. At the same time, it confirms the intuition of W. Arthur Lewis (1978) and others regarding the role of agricultural productivity growth in developing economies. We show that in economies with dualistic technologies, a higher output/labor ratio in agriculture leads to higher real wages, to higher domestic consumption, and to higher domestic employment levels. This occurs even when the level of industrial demand and exports are held fixed, so that higher wage income need not dampen growth nor reduce the volume of goods exported. As a matter of fact, since export revenues increase with higher labor productivity in agriculture, more industrial goods can be imported.

A second result shows that if the structural characteristics of an industrial economy are introduced into the same model, a very different productivity-output price relation emerges. That is, in an economy with homogeneous technologies, and a relatively low level of agricultural exports, the price of agricultural goods decreases as labor productivity increases. The results reveal, therefore, a non-monotonic response of agricultural prices to labor productivity: in the North labor productivity growth in agriculture leads to lower food prices, while in the South it is associated with higher food prices. When agriculture productivity increases in the North but not in the South, the South's terms of trade worsen and its real wages and employment decrease. By contrast, increases in labor productivity in agricultural of the South, increase agricultural prices. This latter result suggests that investment aimed at increasing agricultural labor productivity of the South, may be a good price-support policy for agricultural products world-wide. This appears to be at least as good a policy, and possibly much less distortionary, than the agricultural subsidies currently in use within most OECD countries.

These results also have implications for export policies: better results are achieved from agricultural export promotion when labor productivity is high in these sectors. In order to prevent a deterioration in the South's terms of trade, labor productivity in agriculture should increase in step with the expansion of agricultural exports.

Appendix A

Proof of Theorem 1

Consider the balance of payments condition (equation (11)):

$$X_I^D(S) = p_B^D X_B(N)$$

Since equilibrium imports of the South X_I^D is the difference between domestic demand and supply for industrial goods, we may rewrite (11) as

$$\frac{\overline{I}^D(S) - I^S(S)}{p_B} = X_B^D(N) \tag{19}$$

Note that $\overline{I}^D(S)$ and $X_B^D(N)$ are exogenously determined by (17) and (18) respectively (since $X_B^D(N) = X_B^S(S) = \overline{X_B^S}$).

Our next task is to derive $\frac{\partial p_B}{\partial a_1}$ by rewriting (19) as a function of the exogenous variables and of p_B only. We do this in several steps. Inverting equations (7) and (8) we obtain the equilibrium volume of output of industrial goods as functions of total labor and capital employed.

$$I^S = \frac{(a_1 K - c_1 L)}{D} . \tag{20}$$

Therefore (19) is

$$\overline{I}^D(S) - \frac{a_1}{D} K - \frac{c_1}{D} L - p_B \overline{X}_B^S = 0 \tag{21}$$

Now capital supply K and labor supply L are functions of factor prices: $L = \alpha \frac{w}{p_B} + \bar{L}$ and $K = \beta r + \bar{K}$, from (3) and (4). Factor prices are, in turn, functions of commodity prices: inverting the price equations (1) and (2) one obtains the Stolper-Samuelson relations:

(22) $$w = \frac{p_B c_2 - c_1}{D}$$

and

(23) $$r = \frac{a_1 - p_B a_2}{D} .$$

We may therefore express (21) as a function of only one variable, p_B:

(24) $$p_B^2(A - \bar{X}_B^S) + p_B(C + \bar{I}^D) - V = 0$$

where $A = \frac{\beta a_1 a_2}{D^2}$, $C = \frac{c_1 \bar{L} - a_1 \bar{K}}{D} + \frac{\alpha c_1 c_2 - \beta a_1^2}{D^2}$ and $V = \frac{\alpha c_1^2}{D^2}$.

Note that (24) depends only on p_B and exogenous parameters of the South. Solving equation (24) gives a unique price equilibrium p_B^* as a function of the $\bar{I}^D$, $\bar{X}_B^S$ and the eight exogenous parameters of the technologies and factor endowments of the South: a_1, a_2, c_1, c_2, α, β $\bar{L}$ and $\bar{K}$.

Equation (24) is always satisfied at an equilibrium, and gives an implicit function of p_B and a_1 when all other parameters remain constant. We denote this $\phi(p_B, a_1) = 0$. By the implicit function theorem, we obtain the total derivative of p_B with respect to a_1 across equilibria:[3]

$$\frac{dp_B}{da_1} = - \frac{\frac{\partial\phi}{\partial a_1}}{\frac{\partial\phi}{\partial p_B}} .$$

The partial derivative $\partial\phi/\partial a_1$ is now computed:

Let ϕ be $I^D(S) - I^S(S) - p_B X_B^S = 0$ (equation (19)).

We consider the case where X_B^S and $I^D(S)$ are both constant. Then the partial derivative of ϕ with respect to a_1 is $\frac{\partial\phi}{\partial a_1} = - \frac{\partial I^S}{\partial a_1}$.

Since $I^S = (\frac{a_1 K - c_1 L}{D})$ by (20),

$$\frac{\partial I}{\partial a_1} = K(\frac{\partial(\frac{a_1}{D})}{\partial a_1}) - L(\frac{\partial(\frac{c_1}{D})}{\partial a_1}) + \frac{a_1}{D}(\frac{\partial K}{\partial a_1}) - \frac{c_1}{D}(\frac{\partial L}{\partial a_1})$$

Now

$$K = \beta r + \bar{K} = \beta\frac{a_1}{D} - \frac{p_B a_2 \beta}{D} + \bar{K} \text{ (from (4) and (23)), so that}$$

$$\frac{\partial K}{\partial a_1} = \frac{\beta}{D^2}(D - c_2 a_1) + \frac{\beta a_2 c_2 p_B}{D^2} = - \frac{\beta c_1 a_2}{D^2} + \frac{\beta c_2 a_2 p_B}{D^2} = \frac{\beta a_2}{D}(p_B\frac{c_2}{D} - \frac{c_1}{D})$$

$$= \frac{\beta a_2 w}{D} .$$

also

$$L = \alpha\frac{w}{p_B} = + \bar{L} = \frac{\alpha c_1}{D} - \frac{\alpha c_2}{p_B D} + \bar{L} \text{ (from (3) and (22)). Thus}$$

$$\frac{\partial L}{\partial a_1} = - \frac{\alpha c_2^2}{D^2} + \frac{\alpha c_1 c_2 p_B}{p_B^2 D^2} = - \frac{c_2 \alpha}{D p_B}(\frac{c_2 p_B}{D} - \frac{c_1}{D}) = - \frac{c_2 \alpha w}{p_B D} .$$

Therefore,

$$\frac{\partial I^S}{\partial a_1} = K\left(\frac{1}{D} - \frac{a_1c_2}{D^2}\right) + \frac{a_1}{D}\left(\frac{\beta a_2 w}{D}\right) - \frac{c_1}{D}\left(-\frac{c_2\alpha w}{p_B D}\right) - L\left(\frac{-c_2c_1}{D^2}\right)$$

$$= \frac{K}{D} - \frac{c_2}{D}\left(\frac{a_1K}{D} - \frac{c_1K}{D}\right) + \frac{\beta a_1a_2w}{D^2} + \frac{\alpha c_1c_2w}{p_BD^2} = \frac{K}{D} - \frac{c_2}{D}I^S + \frac{w}{D^2}(\beta a_1a_2 + \alpha c_1c_2)$$

Since $K = K^B + K^I = c_1B^S + c_2I^S$, this implies

$$\frac{\partial I^S}{\partial a_1} = \frac{1}{D}\left(K^B + \frac{w}{D}(\beta a_1a_2 + \alpha c_1c_2)\right), \text{ so that}$$

(25) $$\frac{\partial \phi}{\partial a_1} = -\frac{1}{D}\left(K^B + \frac{w}{D}(a_1a_2\beta + c_1c_2\alpha)\right),$$

where K^B is the capital stock used in the basics sector of the South. Since $K^B > 0$, $\partial\phi/\partial a_1$ is always negative.

Thus the sign of dp_B/da_1 will always be equal to that of the denominator, which we now show can be either positive or negative. From (21), since $\bar{I}^D(N)$ and $\bar{X}_B^S$ are constant:

(26) $$\frac{\partial \phi}{\partial p_B} = -\frac{\partial I^S}{\partial p_B} - \bar{X}_B^S = \frac{1}{D^2}\left(\beta a_1a_2 + \frac{\alpha c_1^2}{p_B^2}\right) - \bar{X}_B^S .$$

The full expression for dp_B/da_1 is thus,

(27) $$\frac{dp_B}{da_1} = \frac{\frac{1}{D}\left(K^B + \frac{w}{D}(a_1a_2\beta + c_1c_2\alpha)\right)}{\frac{1}{D^2}\left(a_1a_2\beta + \frac{\alpha c_1^2}{p_B^2}\right) - \bar{X}_B^S} .$$

Therefore, if in the South:

(i) the level of exports is high, $\bar{X}_B^S$ large;

(ii) capital intensity in the basic sector is low, c_1 small; and

(iii) there is significant duality in technology, D large;

then by (27) p_B will <u>rise</u> as productivity increases and a_1 falls. This completes the proof of theorem 1. ■

Proof of Theorem 2

Consider the resolving equation (24). As shown in Theorem 1, the impact of increases in labor productivity on the price of basics is determined by the sign of

$$\frac{dp_B}{da_1} = - \frac{\frac{\partial\phi}{\partial a_1}}{\frac{\partial\phi}{\partial p_B}}, \text{ where } \phi \text{ is equation (24).}$$

We showed in theorem 1 that $-\partial\phi/\partial a_1$ is always positive. We now show that $\partial\phi/\partial p_B$ is negative when α is large and $c_2/D_B < 2w/p$. This will imply that as a_1 drops (i.e. labor productivity in agriculture increases) p_B <u>increases</u>, what we wish to prove.

Consider then the partial derivative $\partial\phi/\partial p_B$. From (24):

$$\frac{\partial\phi}{\partial p_B} = 2p_B(A - \bar{X}_B^S) + C + I^D(S) \tag{28}$$

Since α is large, the sign of (28) is determined by those terms containing α. In A there are no terms in α; in C the term is $\alpha c_1(c_2/D^2) > 0$; therefore (28) is negative when

$$2p_B X_B^S > \frac{\alpha c_1 c_2}{D^2} . \tag{29}$$

We analyze this expression next. From Chichilnisky (1981), pp. 175 and 176 we obtain an expression for $\overline{X}_B^S$ in terms of p_B:

$$(30) \qquad \overline{X}_B^S = \frac{\alpha c_1}{D^2 p_B}(c_2 - \frac{c_1}{p_B}) + \frac{\beta a_1}{D^2}(a_2 - \frac{a_1}{p_B}) + \frac{c_1\overline{L} - a_1\overline{K}}{Dp_B} + \frac{\overline{I}^D(S)}{p_B} .$$

When α is large, the term that dominates the expression for $\overline{X}_B^S$ is

$$\frac{\alpha c_1 (c_2 - \frac{c_1}{p_B})}{D^2 p_B}$$

Therefore, from (29) $\frac{\partial \phi}{\partial p} < 0$ when $2p_B X_B^S \sim \frac{2\alpha c_1 (c_2 - \frac{c_1}{p_B})}{D^2} > \frac{\alpha c_1 c_2}{D^2}$ i.e., when

$$(31) \qquad c_2 > \frac{2c_1}{p_B} .$$

From Chichilnisky (1981), p. 177, $c_2 > 2c_1/p_B$ is equivalent to

$$(32) \qquad \frac{c_2}{D} < \frac{2w}{p_B} .$$

Therefore, $\frac{\partial \phi}{\partial p_B} < 0$ and $\frac{dp_B}{da_1} < 0$, when $\frac{c_2}{D} < \frac{2w}{p_B}$ and α is large.

This completes the first part of the proof. The last statement in the theorem is proved in Proposition 1, Chichilnisky (1981). There it is shown that

Since (36) is identically satisfied across equilibrium, we obtain:

$$\frac{dp_B}{da_1} = -\frac{\frac{\partial\psi}{\partial a_1}}{\frac{\partial\psi}{\partial p_B}}. \tag{37}$$

Now,

$$\frac{\partial\psi}{\partial a_1} = \frac{\partial rK}{\partial a_1} - \frac{\partial}{\partial a_1}\left(\frac{a_1K - c_1L}{D}\right). \tag{38}$$

From the Appendix (equation A.3) $\frac{\partial K}{\partial a_1} = \beta a_2 \frac{w}{D}$. Since $K = \beta r + \bar{K}$, $r = \frac{K - \bar{K}}{\beta}$, so that

$$\frac{\partial r}{\partial a_1} = \frac{a_2 w}{D}. \tag{39}$$ Therefore,

$$\frac{\partial rK}{\partial a_1} = r\left(\beta \frac{a_2 w}{D}\right) + K\left(\frac{a_2 w}{D}\right) > 0 \tag{40}$$

Furthermore, from the Appendix (A.7), since $K^B = B^S c_1$,

$$\frac{\partial}{\partial a_1}(I^S) = \frac{\partial}{\partial a_1}\left(\frac{a_1K - c_1L}{D}\right) = \frac{1}{D}\left(c_1B^S + \frac{w}{D}(a_1a_2\beta + c_1c_2\alpha)\right) > 0, \tag{41}$$

so that from (38), (40) and (41):

$$\frac{\partial\psi}{\partial a_1} = \frac{a_2 w}{D}(2\beta r + \bar{K}) - \frac{1}{D}\left(c_1B^S + \frac{w}{D}(a_1a_2\beta + c_1c_2\alpha)\right) = \frac{a_2 w\beta}{D}\left(2r - \frac{a_1}{D}\right) \tag{42}$$

$$+ \frac{a_2 w}{D}\bar{K} + \frac{a_1a_2K}{D^2} - \frac{c_1c_2}{D^2}(L + \alpha w)$$

which is negative when α is large and β small.

Now consider $\partial\psi/\partial p_B$:

(43) $$\frac{\partial\psi}{\partial p_B} = \frac{\partial rK}{\partial p_B} - \frac{\partial I^S}{\partial p_B} + \frac{\partial}{\partial p_B}(r(N)K(N)) - \frac{\partial}{\partial p_B}(I^S(N))$$

which equals

(44) $$\frac{a_2\beta}{D}(\frac{a_1}{D} - 2r) - \frac{\bar{K}a_2}{D} + \frac{c_1^2\alpha}{D^2p_B^2} + \frac{a_2(N)\beta(N)}{D(N)}(\frac{a_1(N)}{D(N)} - 2r(N))$$
$$- \frac{\bar{K}(N)a_2(N)}{D(N)} + \frac{(c_1(N))^2\alpha(N)}{(D(N))^2p_B{}^2} .$$

By the assumptions that r and r(N) are high, the first and fourth terms are negative. The last term is small since $\alpha(N)$ is small. In the South, the term $\frac{c_1^2\alpha}{D^2p_B^2}$ is small because c_1 is small and even though α is large, p_B^2 has a second order term in α by (24). Therefore, (44) < 0. Since (44) and (42) are negative, it follows from (37) that $\frac{dp_B}{da_1}$ is negative. This means that when a_1 drops, p_B increases. It also follows that exports of basics decrease when a_1 drops, as we show next. Since

$$X_B^S = B^S - B^D = \frac{c_2L - a_2K}{D} - \frac{wL}{p_B} = \alpha(\frac{c_2}{D}\frac{w}{p_B} - (\frac{w^2}{p_B})) - \frac{a_2K}{D}$$

and

$$\frac{dX_B^S}{da_1} = \frac{dX_B^S}{d(\frac{w}{p_B})} \frac{d(\frac{w}{p_B})}{da_1} ,$$

we obtain

$$\frac{dX_B^S}{da_1} = [\alpha(\frac{c_2}{D} - \frac{2w}{p_B}) - \frac{a_2}{D} \frac{dK}{d(\frac{w}{p_B})}] \frac{d(\frac{w}{p_B})}{da_1} .$$

Now, $\frac{c_2}{D} < \frac{2w}{p_B}$ by assumption, and $\frac{d(\frac{w}{p_B})}{da_1} < 0$ by proof of theorem 3 (34). When α is large this implies $\frac{dX_B^S}{da_1} > 0$, i.e. exports X_B^S drop as labor productivity increases. Domestic consumption of basics $B^D(S)$ increases when a_1 drops, because $B^D = \frac{wL}{p_B} = \alpha(\frac{w}{p_B})^2 + \frac{w}{p_B} \bar{L}$, and $\frac{d(\frac{w}{p_B})}{da_1} < 0$. Finally, imports of industrial goods in the South are

$$X_I^D = I^D(S) - I^S(S) = rK - (\frac{a_1K - c_1L}{D}) = \beta r^2 + r\bar{K} - \beta\frac{a_1 r}{D} - \frac{\bar{K}a_1}{D} + \frac{c_1 L}{D}$$

so that

$$\frac{dX_I^D}{dr} = \beta(2r - \frac{a_1}{D}) + \bar{K} + \frac{c_1}{D} \frac{dL}{dr}$$

which is positive since c_1 is small in the South, and $2r > \frac{a_1}{D}$. Since r decreases with a drop in a_1 by the proof of theorem 3, this completes the proof. ∎

APPENDIX B

Parameter Estimates for Argentina and the United States: Data Sources and Estimation Methods

This appendix documents the data sources and methods used to derive the 1970 parameter estimates for Argentina and the United States. Section 1 reviews data sources and estimation methods for each region's factor supply equations (including α, β, $\bar{L}$, $\bar{K}$). Section 2 discusses the derivation of the remaining parameters, including the regional capital and labor input coefficients, trade shares, final demand structures, etc.

B.1 Factor Supply Equations

The North-South model set forth in section 2 of the text determines the general equilibrium of a complete two region "world" economy. The most appropriate method for empirically testing the structure of this model would be to estimate all the equations of the system simultaneously using available nonlinear regression techniques. This was recently done for Sri Lanka and the United Kingdom by Chichilnisky, Podivinsky and Heal (1982). However, our primary objective here is not to test the structure of the model but to provide a practical and reproducible procedure for obtaining a set of parameter estimates that accurately reflect the basic structure of the economies under study and which allow us to simulate alternative trade policies in these regions. To make the procedure reproducible, many parameters were derived directly from readily available national accounts and input-output tables. Factor supply equations were estimated using time series data from each region. In obtaining these estimates, an effort was made to stay as close as possible to the original specification of the model and to use similar structural forms and data series for both countries.

B.1.1 Real Wages and Employment:

If real wages increase, especially in urban industries, the supply of labor available to these sectors is also likely to increase. Higher returns to organized employment may draw workers from alternative, less renumerative, self-employed occupations in agriculture and services. In other situations, new entrants may be attracted from population groups which have traditionally low labor force participation rates or from outside the country. Alternatively, those already employed may simply work longer hours. This relation between labor supplied and real wages can be written

$$L = \alpha(w/p_B) + \bar{L} \quad (1)$$

where L is the total labor supplied measured in person-years or hours, w/p_B is a measure of real wages in industry and $\bar{L}$ and α are exogenous parameters. To capture the lagged response of labor to a change in wages and to smooth contractual and legislated jumps in the wage, w/p_B was measured as a moving average and equation (1) was estimated over a suitable historical interval. Given estimates of α and $\bar{L}$, average responsiveness of labor supplied to changes in the real wage can be approximated by the "mean point elasticity" (MPE)

$$\varepsilon = (L' - \bar{L})/L' \quad (2)$$

where L′ is the mean of the dependent variable over the estimation period. A plausible range of elasticity estimates can then be computed by taking one standard error around the constant term $\bar{L}$.

Table 1 reports estimates of equation (1) for Argentina between 1964 and 1977. Total employment and total labor force statistics for the Buenos Aires region were regressed on a composite real wage series (see Table 4). These coefficient estimates indicate a significant positive relation between real wages and labor force participation in Buenos Aires, i.e. a positive α. Since the Buenos Aires region accounts for only 40% of the employment in Argentina, these equations may overstate the responsiveness of the labor supply to changes in the real wage (due to the fact that labor migration between regions is generally greater than between nations).

Table 1: Argentina Labor Supply Equation
(t statistics in parentheses)

Eq.	Dependent Variable	R^2 (adj)	D.W.	ρ	α[1]	$\bar{L}$
(1A)	Labor force	.46	2.07	.92 (8.97)	574 (2.44)	2410 (4.53)
(1B)	Total Employment	.42	1.93	.93 (9.75)	663 (2.7)	2139 (3.72)

[1] In both equations the dependent variable is a two year moving average of the real wage series reported in Table 4.

The R^2s of .42 to .46 indicate that only a fraction of the change in labor supply may be attributed to real wage movements. Initially, all three equations displayed high levels of autocorrelation, so the maximum likelihood iterative technique was used to estimate the autocorrelation coefficients ρ shown. Point elasticity estimates for labor supply response range from .11 to .5, and appear to predict labor force and employment changes with about equal accuracy. Again, if anything, these estimates may be high since they reflect employment changes in one subregion of the country.

Table 2: Point Elasticities for Labor Supply in Argentina

Equation	Period	Mean Dep. Variable	Point Elasticities[1] High	Estimated	Low
(1A)	1964-77	3316	.43	.24	.11
(1B)	1964-76	3156	.50	.32	.24

[1]Based on one standard error around the constant term.

Table 3 provides the data on employment and labor supply for Buenos Aires. Since there is no readily available labor supply series for Argentina, the Buenos Aires region was used as a proxy for the country as a whole. The ILO provides a series on the rate of unemployment and number of unemployed persons in Buenos Aires. These statistics were converted into total employment and labor supply as shown in Table 2.

The ILO also reports nominal wage rates for manufacturing, transportation and agricultural sectors over approximately the same period. These three series were used to compute a composite nominal wage using sectoral employment weights derived from World Development Report Tables (see Table 4). When deflated by the World Bank's consumer price index, this series provided the real wage variable for both equations.

Table 3: Employment Data for Buenos Aires 1964-79
(in thousands)

Year	Unemployment Number	Unemployment Rate	Labor Force	Total Employment
1964	177.6	5.7	3116	2938
1965	167.4	5.3	3158	2991
1966	172.7	5.6	3084	2911
1967	198.7	6.4	3105	2906
1968	153.3	5	3066	2913
1969	140.3	4.3	3263	3122
1970	158	4.8	3292	3134
1971	196.5	6	3275	3079
1972	221.5	6.6	3356	3135
1973	173	5.6	3089	2916
1974	121.6	3.4	3576	3455
1975	97.0	2.3	3678	3593
1976	159.1	4.5	3536	3376
1977	103.3	2.8	3689	3586
1978	101.6	2.8	3629	3527
1979	69.5	2	3475	3406

Sources: ILO Yearbook, various issues, 1970-77. World Bank Tables, Central Bank of Argentina.

Table 4: Real Wages in Argentina 1964-80
(pesos per hour)

	Nominal Wage Rates[1]			Sectoral Emp. Weights[2]			CPI (1970 = 100)	Composite Real Wage
	Manuf.	Services	Agric.	Manuf.	Services	Agric.		
1965		.69	.49	.342	.477	.181	42.1	1.569
1966		.94	.63	.339	.484	.177	54.2	1.581
1967	1.22	1.15	.74	.335	.491	.174	71.1	1.547
1968	1.27	1.29	.84	.332	.498	.17	81.9	1.469
1969	1.40	1.42	.94	.329	.504	.167	87.9	1.513
1970	1.65	1.67	1.14	.326	.511	.163	100	1.582
1971	2.27	2.27	1.75	.322	.518	.16	134	1.619
1972	4.00	3.32	2.50	.319	.525	.156	214.4	-1.588
1973	6.00	5.75	4.49	.316	.53	.154	345.8	-1.629
1974	8.00	7.32	6.41	.313	.536	.151	426.5	-1.73
1975	23.00	22.97	16.83	.31	.542	.148	1204.8	-1.826
1976	70.00	66.65	50.29	.306	.549	.145	6542.2	- .996
1977	154.00	270.82	106.32	.303	.555	.142	18072.2	-1.172

[1]ILO Yearbook, Table 22, Various Issues.

[2]World Development Report, 1977, 1980.

Table 5 reports the results estimates of equation (1) using data for the United States. When estimated in the linear form of equation (a), the U.S. regression exhibited significant autocorrelation. Efforts to correct for this using conventional methods were not successful so a first-difference formulation was adopted (annual log percent change). As reported in Table 5, this form resulted in acceptable Durbin-Watson coefficients. The wage rate used was a two year moving average of CPI deflated hourly compensation in nonagricultural sectors. The dependent variable is the percent change in nonagricultural employment (see Table 6).

Table 5: U.S. Labor Supply Equations

Dependent Variable	Ind. Variable	Sample Mean	R^2 (adj)	D.W.	α	L	Point Elasticity Est	High	Low
Total Employ-ment*	Hourly Real Wage*	2.12% (1955-75)	.43	1.48	.59 (3.64)	1.3 (4.18)	.59	.75	.43

* Annual log percent change.

Estimated over a time period similar to that used for Argentina equation, the U.S. elasticity appears to be in the slightly higher range of .43 to .75. Note that these estimates may also overstate the responsiveness of labor supply to real wages since the movement of labor from agriculture to industry is also being captured.[4]

Table 6: U.S. Wage and Employment Data 1953-81

Year	Average Hourly Earnings	CPI	Real Hourly Earnings	Total Nonagricultural Employment
1953	1.61	80.1	2.13	54.90
1954	1.65	80.5	2.13	53.90
1955	1.71	80.2	2.13	55.70
1956	1.80	81.4	2.21	57.50
1957	1.89	84.3	2.24	58.12
1958	1.95	86.6	2.25	57.45
1959	2.02	87.3	2.31	59.07
1960	2.09	88.7	2.36	60.32
1961	2.14	89.6	2.39	60.55
1962	2.22	90.6	2.45	61.76
1963	2.28	91.7	2.49	63.08
1964	2.36	92.9	2.54	64.78
1965	2.46	94.5	2.60	66.73
1966	2.56	97.2	2.63	68.92
1967	2.68	100	2.68	70.53
1968	2.85	104.2	2.74	72.10
1969	3.04	109.6	2.77	74.30
1970	3.23	116.3	2.78	75.20
1971	3.45	121.3	2.84	75.97
1972	3.70	125.3	2.95	78.70
1973	3.94	133.1	2.96	81.60
1974	4.24	147.7	2.87	83.30
1975	4.53	161.2	2.81	82.44
1976	4.86	170.5	2.85	85.42
1977	5.25	181.5	2.89	88.73
1978	5.69	195.4	2.91	92.66
1979	6.16	217.4	2.83	95.48

Sources: Tables B-29, B-38 and B-52, Economic Report of the President, 1982.

B.1.2 Capital Utilization and Profitability

A change in the [illegible] rental rate for capital may have two effects on the capital stock. First, the existing stock of plant and equipment may be used more intensively. The magnitude of this "vintage" effect depends on, among other things, the quality of older capital goods available for extended use and renovation. Under plausible assumptions, higher profits increase the share of older capital goods which can profitably be utilized. Second, new capital goods may be purchased or imported. The magnitude of this second influence depends on the outcome of two conflicting forces: a higher rate of profit making investment more attractive countered by the demand dampening effect of the higher cost of capital. In addition, this new investment effect may be subject to lags as the lead times needed to order, fabricate and install new equipment and structures slow the adjustment of the actual stock toward the desired level.

In an effort to account for each of these effects, two estimating procedures were used to relate capital stocks and the rate of return. The first is a vintage formulation in which the amount of capital in use depends on the available stock and the profit rate,

$$KU_t = \beta_0 + \beta_1 r_t + \beta_2 (r_t {*} K_{t-1}) \quad (3)$$

where KU_t is the utilized capital stock in period t, r_t is the after tax rate of return in period t and K_{t-1} is the total amount of capital (net of depreciation) available at the beginning of the period. This formulation separates the vintage effect, which depends positively on the amount of capital available and on the current profit rate, from investment related additions to stocks. Both effects are assumed to depend only on the current rate of return. Gathering terms in (3), the total effect of profits on capital utilized (supplied) can be written as

$$KU_t = \beta r_t + K_t \quad (4)$$

where $\beta = \beta_1 + \beta_2 {*} K_{t-1}$ and $K_t = \beta_0$.

The second structural form posits a lagged partial adjustment equation designed to incorporate a lag between the increase in investment expenditures and the actual installation or upgrading of capital structures and equipment. First differencing (4) yields,

(5) $$KU_t - KU_{t-1} = \beta(r_t - r_{t-1}) + (K_t - K_{t-1})$$

Note that the left side of (4) is simply net investment (I_t) at time t.

We have called KU_t the capital stock utilized at time t. In contrast to most published measures of aggregate capital stocks which simply sum up all past investment net of some exogenously determined depreciation rate, this particular stock measure is an economic one: that is, it refers to the quantity of capital actually being utilized in a given period rather than the amount which is physically available. To get closer to this latter concept, published capital stock estimates were multiplied by capacity utilization rates for manufacturing. While these capacity measures are readily available for the U.S., a utilization series had to be estimated for Argentina. Regressing net capital stock on real GDP yielded a capital/output trend. Deviations around this trend were considered deviations from "full capacity," which was defined as 85% utilization of the total stock.

For Argentina, both stock adjustment equations yielded remarkably similar measures of capital responsiveness (despite the differences in structural form and data series). For the United States, the partial adjustment equation (5) exhibited strong autocorrelation. Measures taken to correct for serially correlated errors yielded an unstable adjustment process. As a result, only estimates from the vintage formulation (3) are reported for both countries.

Table 7 reports the results of estimating equation (4) using Argentine data. In all cases the vintage effect is strongly positive, while current investment response seems to move inversely to the profit rate. This negative investment response may be due to the effect of higher capital costs on current investment, or simply to the fact that investment responds with a lag so that the vintage term (β_2) is picking up both influences of the profit rate. Equations 3A to 3C test several combinations of utilized and total net nonresidential capital stock.

Table 7: Argentine Capital Utilization Equation

Equation	Dependent Variable	Independent Variables β_0	β_1	β_2	R^2	D.W.
(3A)	KU_t	190.9 (3.71)	-10.9 (-2.8)	.97[1] (13.6)	.95	2.05
(3B)	KU_t	208.1 (4.4)	-15.0 (-6.1)	1.07 (14.8)	.96	1.56
(3C)	K_t	213.7 (17.0)	-13.2 (-20)	1.04 (53.6)	.99	1.64

[1] In equation 3A the lagged capital stock term is $r_t{*}KU_{t-1}$.

Table 8 summarizes the range of total β estimates (see eq. 4) for these three equations. In all cases, the net response of capital utilization to changes in profitability appears to be relatively small. Similarly, the partial adjustment specification yielded a point elasticity of .05 using the same data set and estimation period.

Table 9 provides the data and computational procedures used to develop the utilized capital stock and profit series for Argentina. Note that both of the profit weighted series ($r_t{*}K_t$ and $r_t{*}KU_t$) were rescaled to have the same mean as the original series. The utilized capital stock was predicted by simple regression of K_t on real GDP.

Table 8: Argentina Capital Responsiveness
Sample Period: 1961-75

Equation	Sample Mean	Point Elasticities High	Estimate	Low
(3A)	205.6	.32	.07	-.17
(3B)	205.6	.22	-.01	-.24
(3C)	234.8	.15	.10	.04

Table 9: U.S. Capital Utilization Equation

Eq.	Dependent Variable	Independent Variables β_0	β_1	β_2	R^2	D.W.	h statistic
(3D)	KU_t	480 (11.0)	-62.4 (-13.1)	.109 (20.44)	.95	1.54	1.15

Table 10 reports the results of the vintage equation using data from the United States over the period 1955 to 1980. We again find that the overall response of capital use to a change in the profit rate is significantly positive with the vintage term dominating this effect. Whereas the new investment term is again negatively related to the profit rate, the magnitude of the vintage effect appears to be larger in the U.S. than in Argentina. As a result, the range of point elasticities for capital utilization is higher for the U.S. (on the order of .21 to .34), as reported in Table 10.

Table 10: U.S. Capital Utilization and Profitability Responsiveness
Sample Period: 1955-80

Equation	Sample Mean	Point Elasticities High	Estimate	Low
(3D)	664.7	.34	.28	.21

Assuming that this data accurately reflects stock and profitability movements, there are several possible explanations for the low profit responsiveness in Argentina as compared to that in the United States. Part of the explanation is that the U.S. begins the period with a larger, more diversified capital stock. In addition, foreign exchange constraints may have limited the growth of Argentina's industrial capital stock during this period. Alternatively, investor confidence, political stability and other government economic policies may also have influenced capital utilization varies between the two countries. In any case, it appears that the Argentine industrial sector is less responsive to favorable movements in its own terms of trade (i.e. higher profitability) than is its counterpart in the United States.

B.2 Technological Coefficients

The principal source of technology data was sector level value added data obtained from national accounts and from published input-output tables. Total value added by industry was first adjusted to remove indirect taxes and imputed land rents. This left only payments to labor and capital, the two factors considered by the model. Given labor's share of value added in each sector, dividing by a reported average wage rate yielded estimates of labor input per unit (dollar) of output in each industry. When combined with observed output levels for each of the two sectors, these preliminary labor/output estimates also provided total factor demand estimates (i.e. labor hours demanded). If these estimates deviated significantly from reported labor supply totals, the average wage rate was adjusted to remove this discrepancy.

Given an estimate of the profit share of value added by sector, an average profit rate and the total stock of capital, an exactly analogous procedure was used to obtain capital coefficients.

Table 13 reports value added compositions for nine sectors of the Argentine economy during 1970. For the investment goods sector, a wage share of .39 was used in all of the simulations. Because of the importance of agricultural exports, additional data was compiled for Argentine agricultural production technologies.

Table 13: Value Added Composition by Sector for Argentina 1970 (billions of 1970 pesos)

Sector	Total Value Added	Rents & Indirect Taxes	Employee Compensation	Wage Share
Agriculture	11.12	3.78	5.0	.68
Mining	1.79	.22	.50	.32
Manufactures	26.8	1.22	9.9	.39
Utilities	1.84	.02	.89	.49
Construction	4.84	0	3.92	.81
Trade	11.39	.82	3.49	.33
Transp/Comm.	8.58	.64	3.9	.49
Finance	3.83	.37	1.66	.48
Services	15.65	0	10.0	.64
Total	85.8	6.98	35.36	.41

Source: Central Bank of Argentina, 1977.

Table 14 presents capital-labor ratios based on surveys of grain farms in two regions of Argentina during 1965 and 1968. Note that the wage share of total valued added less rents ranges between .42 and .87 with an average of .68 for these producers. Adjusting for proprietor's income, a value added share of .71 was used for the simulations described in Section 3.

Table 14: Capital-Labor Ratio in Two Argentina Grain Producing Regions

	County of 25 de Mayo (1965)			Pergamino Area (1968)			
	Small	Medium	Large	Small	Medium	Large	Total
Fixed Capital:							
Machinery and Working	3.69	5.83	16.02	5.77	13.56	21.31	66.18
Land and Buildings[1]	7.90	15.47	49.80	16.09	54.90	102.57	246.73
Buildings (est.)[1]	1.98	3.87	12.45	4.02	13.73	25.64	61.68
Rate of Return (%)	4.40	3.90	5.40	2.70	3.10	4.30	4.13
Total Revenue to:							
Invested Capital	.25	.38	1.54	.26	.85	2.02	5.29
Land	.26	.45	2.02	.33	1.28	3.31	7.64
Labor (person-years)[2]	1.80	2.60	4.60	6.60	11.60	14.90	42.10
Agricultural Wage Rate (pesos/hour--ILO)	82.00	82.00	82.00	91.00	91.00	91.00	91.00
Total Wage Bill	.44	.64	1.13	1.80	3.17	4.07	11.25
Total Value Added	.95	1.47	4.69	2.39	5.29	9.39	24.18
Wage share	.46	.44	.24	.75	.60	.43	.47
Profit share	.26	.26	.33	.11	.16	.21	.22
Rents	.27	.31	.41	.14	.24	.35	.32
Value Added Less Rents	.69	1.02	2.67	2.07	4.01	6.09	16.54
Wage Share	.64	.63	.42	.87	.79	.67	.68
Profit Share	.36	.37	.58	.13	.21	.33	.32
Value labor/capital	1.78	1.69	.74	6.81	3.74	2.01	2.13

Source: USDA (1972), page 110.

[1]Millions of Pesos.

[2]Person-years per farm.

[3]ILO Yearbook, various issues.

Finally, Table 15 provides value added decompositions of nine sectors of the U.S. economy plus government. Agriculture's wage share of value added share of .71 was used for the basic sectors, while the average for other sectors (.58) was used for the investment goods sector.

Table 15: The Value Added Content of U.S. Exports, 1970[1]

Sector	Exports	Imports	GDP[2]	Persons Employed[3]	Total Hours	Employ Comp.	Wage Share
Agriculture	9.43	7.95	25	4.52	6.78	17.52	.71
Mining	3.70	10.80	13	.62	1.24	4.96	.39
Construction	1.60	.02	49	4.30	6.45	33.86	.69
Manuf. Durables	21.46	18.90	136	11.20	22.40	106.40	.78
Manuf. Nondurables	12.33	9.40	102	8.50	17.00	63.75	.63
Trade	7.90	6.82	167	20.50	41.00	127.10	.76
Transportation	4.20	3.41	86	4.80	9.60	42.24	.49
Finance	1.30	1.10	62	3.95	7.90	29.63	.47
Services	3.20	.50	114	13.60	27.20	84.32	.74
Government	.03	.02	131	12.55	25.10	107.93	.83
Total	65.16	58.92	883	84.54	139.57	509.78	.58

Summary:
Export Wage Share: .69
Import Wage Share: .59
Overall Wage Share: .58

[1]Source: National Accounts, 1970, Economic Report of the President, 1982.

[2]GDP net of rents and indirect taxes.

[3]Billions of person hours.

FOOTNOTES

[1]Lewis (1978) divides agriculture into traded and nontraded sub-sectors, and then describes the effect of productivity improvements in the nontraded agricultural sector. In the model developed below there is only one agricultural sector supplying both domestic needs and export demand. However, even in this simplified framework, results in the spirit of Lewis's are obtained.

[2]In view of the Walras Law and of its homogeneity properties, an equilibrium of this model is consistent with a standard Arrow-Debreu competitive general equilibrium model for some set of individual preferences.

[3]Total derivatives are denoted with d, e.g. $\frac{dp_B}{da_1}$. Partial derivatives are denoted with ∂, e.g. $\frac{\partial \phi}{\partial a_1}$.

[4]Labor supply equations were also estimated for both countries using both population and real wages as explanatory variables. The resulting MDE's were within the range reported here for both countries.

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