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NONTRADABLE GOODS AND THE TIMMER-FALCON EFFECT

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I. INTRODUCTION

In their well-known study, Timmer and Falcon [13] demonstrated empirically that a positive relationship exists between rice yields and the rice-fertilizer price ratio. As these authors showed, an increase in the rice-fertilizer price ratio leads to increased fertilizer applications which, in turn, increase rice yields. In this paper, we consider the role of the rice-fertilizer price ratio in a general-equilibrium model of an agrarian economy. One distinguishing feature of this model is that it accounts for the large place that nontradable goods occupy in the GDP of countries at all levels of development.[1] We show below that when we account for the role of nontradable goods in the economy, the impact of a fall in the rice-fertilizer price ratio on rice yields is less straightforward than is implied by the Timmer-Falcon analysis.

II. THE STRUCTURE OF THE AGRARIAN ECONOMY

We begin our analysis by specifying the production structure of the agrarian economy produces rice, manufactured goods, and nontradable goods. Rice, or good 1, is the only export good. Rice production requires inputs of labor, the specific factor (land), and an intermediate good (fertilizer). Rice production is characterized by flexible input coefficients for each of these three inputs. Manufactures, or good 2, compose the import-competing sector and include fertilizer.[2] Manufactures production requires inputs of labor and the specific factor industrial capital and is characterized by flexible input coefficients. The third and last sector of the economy consists of nontradable production or good N. Nontradable pro-

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[1] Kravis, Heston, and Summers [9, Tables 6–10] show that, for a sample of thirty-four countries at all levels of development, the portion of GDP attributable to nontradables ranges from 26 to 57 per cent. The role of nontradable goods in general-equilibrium models was first addressed by Komiya [8].

[2] UNCTAD [14] provides data that show domestic fertilizer consumption exceeding domestic fertilizer production for developing Africa, developing America, and developing Asia. Fertilizer production in agrarian economies is therefore import-competing.

duction consists of services and construction [9, p. 193]. By far, the larger component of nontradables is services. As Kravis, Heston, and Summers [10, Table 12] show, service production tends to be more labor intensive than commodity production. Therefore, we assume that nontradable production requires labor inputs only.

Since our focus here is on the role of the nontradable sector, it is appropriate to briefly consider the place of this sector in developing economies. In particular, we should consider the service sector. Katouzian [7] provides a useful, functional breakdown of the service sector into three categories. The category that will dominate very-low-income, agrarian economies contains what he calls "the older services." This category includes domestic servants, stable hands, etc., and tends to diminish very quickly with industrial development and the accompanying social changes. The second category he calls "complementary services." This category is most relevant to our focus here. It includes those services which are associated with industrial production and urbanization. These include banking, finance, transportation, and wholesale and retail trade. As an agrarian economy begins to develop, this category of services grows quickly.[3] The final category Katouzian calls "the new services." This category tends to grow with per capita income and leisure, and it includes education, entertainment, modern health services, etc. The new services are less relevant than complementary services to the types of economies we are considering here.

We can indicate more precisely the structure of the agrarian economy with the following set of production functions:

$$Y_1 = F_1(L_1, T, X_{21}) \quad \text{(rice)},$$
$$Y_2 = F_2(L_2, K) \quad \text{(manufactures)},$$
$$Y_N = L_N \quad \text{(nontradables)}.$$

Y_j is the gross output of sector j, and L_j is the labor input into sector j production. $\sum_j L_j = L$, where L is the exogenously given labor force. T is the available amount of agricultural land, and K is the stock of industrial capital. X_{21} is the intermediate input of good 2 (fertilizer) into rice production. We choose units so that $Y_N = L_N$.

In order to formulate a complete, general-equilibrium model, we need to introduce additional variables. w, r_T, and r_K are the wage rate, the rental rate on land, and the rental rate on capital, respectively. p_j is the price of good j. a_{ij} is the conditional input coefficient representing the input of factor or intermediate good i into the production of a unit of good j. We have chosen units so that $a_{LN} = 1$. D_j is the domestic consumption of good j. I represents national income, and t_1 is an export tax on rice. The symbol "*" over a price indicates that it is a world price.

Given this notation and the assumption of constant returns to scale in production

[3] UNCTAD reports that while the trade and finance sector "has remained relatively constant throughout the 1970s, at 38–39 per cent of total services in developed market-economy countries, it has grown in developing countries from 38.8 per cent to 42.5 per cent. For non-oil exporting developing countries the share has risen from 39.4 per cent in 1970 to 46.3 per cent in 1979" [15, p. 4].

and perfect competition in all markets, we can formulate the following general-equilibrium system:

$$a_{L1}Y_1 + a_{L2}Y_2 + Y_N = L, \tag{1}$$
$$a_{T1}Y_1 = T, \tag{2}$$
$$a_{K2}Y_2 = K, \tag{3}$$
$$wa_{L1} + r_T a_{T1} + p_2 a_{21} = p_1, \tag{4}$$
$$wa_{L2} + r_K a_{K2} = p_2, \tag{5}$$
$$w = p_N, \tag{6}$$
$$a_{L1} = a_{L1}(w, r_T, p_2), \tag{7}$$
$$a_{T1} = a_{T1}(w, r_T, p_2), \tag{8}$$
$$a_{21} = a_{21}(w, r_T, p_2), \tag{9}$$
$$a_{L2} = a_{L2}(w, r_K), \tag{10}$$
$$a_{K2} = a_{K2}(w, r_K), \tag{11}$$
$$Y_N = D_N(p_1, p_2, p_N, I), \tag{12}$$
$$I = p_1Y_1 + p_2Y_2 + P_NY_N - p_2a_{21}Y_1 + t_1ep^*{}_1(Y_1 - D_1), \tag{13}$$
$$p_1 = (1 - t_1)ep^*{}_1, \tag{14}$$
$$p_2 = ep^*{}_2. \tag{15}$$

Equations (1)–(3) are full-employment conditions, and equations (4)–(6) are the zero-profit conditions. Equations (7)–(11) are the conditional input coefficient functions. Equation (12) is the equilibrium condition for the nontradable good market, and equation (13) defines national income in terms of the local currency. Finally, equations (14) and (15) define the domestic prices of rice and manufactures. This system of equations determines fifteen endogenous variables. These are Y_1, Y_2, Y_N, w, r_T, r_K, a_{L1}, a_{T1}, a_{21}, a_{L2}, a_{K2}, p_1, p_2, P_N, and I. All other variables are exogenous.

Our analysis will be simplified if we rewrite equations (1)–(15) in terms of the equations of change introduced by Jones [5]. This requires some additional notation. We will use the circumflex, "^", to denote proportional change. μ_{Li} denotes the proportion of the labor endowment used in sector j. θ_{ij} denotes the share of factor or intermediate input i in the output of sector j. σ^j denotes the Allen partial elasticity of substitution [1, Chapter 19] between inputs in sector j production.[4] s is the common, Allen partial elasticity of substitution in consumption and ν_j is the share of good j in total consumption. η_j is the income elasticity of sector j demand.

[4] Using a common Allen elasticity for rice production involves the assumption that $\sigma_{LT}{}^1 = \sigma_{L2}{}^1 = \sigma_{T2}{}^1$. This implies that the production function for the agricultural sector is a three-factor, constant-elasticity-of-substitution (CES) production function over the incremental range considered by the analysis. It is possible that this assumption may not hold in a given economy. Indeed, with three inputs into rice production, it is theoretically possible for one of these three Allen elasticities to be negative [12]. However, empirical evidence is not sufficient to allow us to assume a particular pattern of substitution. While Kako [6] estimates that labor and fertilizer are p-complements for Japanese rice production, Kuroda [11] estimates that land and fertilizer are p-complements for Japanese agriculture as a whole. In the absence of clear empirical evidence as to the signs of $\sigma_{LT}{}^1$, $\sigma_{L2}{}^1$, $\sigma_{T2}{}^1$, we assume that they are all positive and equal to σ_1.

We assume that t_1 and p^*_1 are the only exogenous variables that change and that t_1 is initially zero. The result is the following system of equations of change:[5]

$$\mu_{L1}\hat{Y}_1+\mu_{L2}\hat{Y}_2+\mu_{LN}\hat{Y}_N+\mu_{L1}\hat{a}_{L1}+\mu_{L2}\hat{a}_{L2}=0, \tag{1b}$$
$$\hat{Y}_1+\hat{a}_{T1}=0, \tag{2b}$$
$$\hat{Y}_2+\hat{a}_{K2}=0, \tag{3b}$$
$$\theta_{L1}\hat{w}+\theta_{T1}\hat{r}_T=\hat{p}_1, \tag{4b}$$
$$\theta_{L2}\hat{w}+\theta_{K2}\hat{r}_K=0, \tag{5b}$$
$$\hat{w}-\hat{p}_N=0, \tag{6b}$$
$$\hat{a}_{L1}=[-(\theta_{T1}+\theta_{21})\hat{w}+\theta_{T1}\hat{r}_T]\sigma^1, \tag{7b}$$
$$\hat{a}_{T1}=[\theta_{L1}\hat{w}-(\theta_{L1}+\theta_{21})\hat{r}_T]\sigma^1, \tag{8b}$$
$$\hat{a}_{21}=(\theta_{L1}\hat{w}+\theta_{T1}\hat{r}_T)\sigma^1, \tag{9b}$$
$$\hat{a}_{L2}=\theta_{K2}(\hat{r}_K-\hat{w})\sigma^2, \tag{10b}$$
$$\hat{a}_{K2}=\theta_{L2}(\hat{w}-\hat{r}_K)\sigma^2, \tag{11b}$$
$$\hat{Y}_N=v_1s\hat{p}_1-(1-v_N)s\hat{p}+\eta_N(\hat{I}-v_1\hat{p}_1-v_N\hat{p}_N), \tag{12b}$$
$$\hat{p}_1=\hat{p}^*_1-dt_1. \tag{14b}$$

Missing from these equations is an expression for $\hat{I}$, equation (13b). In the Appendix, we derive expressions for the proportional change in *real* income, $\hat{I}-v_1\hat{p}_1-v_N\hat{p}_N$, for each of the two exogenous changes we consider in Sections III and IV.

III. AN EXPORT TAX ON RICE

For a number of reasons, we expect that there will be a tendency for the agricultural sector of a less-developed, agrarian economy to be taxed.[6] We therefore consider the implications of an export tax on rice. In this case, the proportional change in real income is zero (see Appendix), and the system reduces to:

$$[-\mu_{L1}\sigma^1-\mu_{L2}\sigma^2-(1-v_N)\mu_{LN}s]\hat{w}+\mu_{L1}\sigma^1\hat{r}_T+\mu_{L2}\sigma^2\hat{r}_K=v_1\mu_{LN}sdt_1 \tag{1c}$$
$$\theta_{L1}\hat{w}+\theta_{T1}\hat{r}_T=-dt_1, \tag{4c}$$
$$\theta_{L2}\hat{w}+\theta_{K2}\hat{r}_K=0. \tag{5c}$$

This is a system of three equations in the three unknowns $\hat{w}, \hat{r}_T$, and $\hat{r}_K$. Our interest is in the impact of the export tax on rice yields and output. Accordingly, we solve (1c), (4c), and (5c) for $\hat{w}$, $\hat{r}_T$, and $\hat{r}_K$. We substitute the expressions for $\hat{w}$ and $\hat{r}_T$ into equation (8b) and then substitute the resulting expression for $\hat{a}_{T1}$ into equation (2b). We thereby obtain:

[5] Equations (7b) and (8b) incorporate the condition $\sigma_{LL}{}^1\theta_{L1}+\sigma^1\theta_{T1}+\sigma^1\theta_{21}=0$. See [12].

[6] See [2] on the political economy of agricultural protection.

$$\hat{Y}_1 = \{\theta_{21}\theta_{K2}\mu_{L1}\sigma^1 + (\theta_{21} + \theta_{L1})\mu_{L2}\sigma^2 + \theta_{K2}[\theta_{21}(1 - v_N) + \theta_{L1}v_2]\mu_{LN}s\}\sigma^1 dt_1/Det,$$

where $Det = [-\theta_{K2}(1 - \theta_{21})\mu_{L1}\sigma^1 - \theta_{T1}\mu_{L2}\sigma^2 - (1 - v_N)\theta_{T1}\theta_{K2}\mu_{LN}s]$ and is unambiguously negative.

Rice yields and, therefore, rice output unambiguously fall. As in the Timmer-Falcon analysis, the fall in the rice-fertilizer price ratio causes stagnation in rice production. The fertilizer intensity of rice production, θ_{21}, is important. As θ_{21} increases, the numerator of the above expression becomes more positive and the denominator less negative. The size of the fall in yields and output is directly related to the fertilizer intensity of rice production.

IV. A FALL IN THE WORLD PRICE OF RICE

In this section, we analyze the impact of a fall in the domestic price of rice which is not due to a policy of the government but rather is due to a fall in the exogenous *world* price of rice. We consider a negative $\hat{p}^*_1$, setting dt_1 equal to zero. In contrast to the case of the export tax, the fall in p_1 reduces real income. As we show in the Appendix, $\hat{I} - v_1\hat{p}_1 - v_N\hat{p}_N = \phi_1\hat{p}^*_1$, where ϕ_1 is the share of rice exports in national income. Substituting this into equation (12b), the system reduces to:

$$[-\mu_{L1}\sigma^1 - \mu_{L2}\sigma^2 - (1 - v_N)\mu_{LN}s]\hat{w} + \mu_{L1}\sigma^1\hat{r}_T + \mu_L{}^2\sigma^2\hat{r}_K = -\mu_{LN}(v_1 s + \eta_N\phi_1)\hat{p}^*_1, \tag{1d}$$

$$\theta_{L1}\hat{w} + \theta_{T1}\hat{r}_T = \hat{p}^*_1, \tag{4d}$$

$$\theta_{L2}\hat{w} + \theta_{K2}\hat{r}_K = 0. \tag{5d}$$

As in the case of the export tax, we solve this system for $\hat{w}$, $\hat{r}_T$, and $\hat{r}_K$. We substitute the expressions for $\hat{w}$ and $\hat{r}_T$ into equations (8b) and then substitute the resulting expression for $\hat{a}_{T1}$ into equation (2b), obtaining:

$$\hat{Y}_1 = \{-\theta_{21}\theta_{K2}\mu_{L1}\sigma^1 - (\theta_{L1} + \theta_{21})\mu_{L2}\sigma^2 - \theta_{K2}[\theta_{21}(1 - v_N) + \theta_{L1}v_2]\mu_{L1}s + \theta_{L1}\theta_{K2}\mu_{LN}\phi_1\eta_N\}\sigma^1\hat{p}^*_1/Det.$$

Both $\hat{p}^*_1$ and Det are negative. Therefore, the first three terms within the curly brackets, which are identical to those appearing in the case of the export tax, contribute to a potential fall in rice yields and output. However, the last term within the curly brackets contributes to a potential *rise* in rice yields and output. In the general case, then, the sign of $\hat{Y}^1$ is ambiguous.

The meaning of the last term, $\theta_{L1}\theta_{K2}\mu_{LN}\phi_1\eta_N$, is as follows. The fall in the world price of rice reduces the real income of the economy. This tends to shift the demand schedule for nontradable goods to the left. Since nontradable production is labor intensive, this potential shift of the demand schedule places downward pressure on the wage (and upward pressure on land rents). Rice output responds positively to a lowered price for labor inputs.

As in the case of the export tax, rice output will be more likely to fall the greater is the fertilizer intensity of agricultural production. Rice output is less

likely to fall or will fall by a smaller amount the greater is the income elasticity of nontradable demand. For a long time, conventional wisdom held that the income elasticity of demand for nontradables or, more specifically, for services is greater than unity. This view was based on the observation that the share of services in GDP grows with the per capita GDP of countries. Kravis, Heston, and Summers [9, Chapters 6 and 10] have shown, however, that in *real* terms the share of services in GDP remains more or less constant with per capita GDP. The increasing nominal share is due to the fact that "services are much cheaper in the relative price structure of a typical poor country than in that of a rich country" [10, p. 191]. In the same article [10], these authors control for both income and price effects and estimate an income elasticity of demand for services of approximately unity.[7] Their data indicate that countries at all income levels expend about one-third of their income on services in real terms. With η_N being unity, the wage effect could be of a non-trivial size. The effect will be greater the larger the amount of rice exported relative to national income (ϕ_1).

We have found that the income elasticity of nontradable demand and the rice-export share in national income, as well as the fertilizer intensity of agricultural production, are important in determining the response of rice yields and output to a change in the world price of rice.

V. CONCLUSION

The ambiguity of output effects in the presence of nontradable goods has been noted in an "even" model of international trade by Ethier [4]. This ambiguity also is present in the "odd" model considered here.[8] Given the large share of nontradable goods in the GDPs of both rich and poor countries, it is important to consider the role of this sector in transmitting the general-equilibrium effects of changes in agricultural prices. We have shown here that when a change in the rice-fertilizer price ratio involves a change in real income, there is an income effect which acts opposite to the Timmer-Falcon effect. This income effect is due to the labor intensity of nontradable production. The degree to which the income effect counteracts the Timmer-Falcon effect is an empirical matter. However, our theoretical analysis shows that the income effect will be greater the larger are the income share of rice exports and the income elasticity of nontradable demand.

[7] The subsample of countries in the Kravis, Heston, and Summers study with real, per capita GDP levels of less than 45 per cent of U.S. real, per capita GDP are: Malawi, Kenya, India, Pakistan, Sri Lanka, Zambia, Thailand, Philippines, Korea, Malaysia, Colombia, Jamaica, Syria, Brazil, Romania, Mexico, Yugoslavia, Iran, Uruguay, and Ireland.

[8] In an "even" model, the number of primary factors equals the number of tradable goods, whereas in an "odd" model, the number of primary factors (labor, land, and capital here) exceeds the number of traded goods (rice and manufactures here).

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APPENDIX

In this Appendix, we derive expressions for the proportional change in real income $(I - v_1\hat{p}_1 - v_N\hat{p}_N)$ for the case of an export tax on rice and for the case of a fall in the world price of rice. We assume in both cases that t_1 is initially equal to zero. Before we consider the two exogenous changes, we prove the following condition:

$$p_1 dY_1 + p_2 dY_2 + p_N dY_N - p_2 a_{21} Y_1 = 0. \tag{A.1}$$

Proof: Net output must equal the sum of factor payments:

$$p_1Y_1 + p_2Y_2 + p_NY_N - p_2a_{21}Y_1 = wL + r_TT + r_KK.$$

We totally differentiate this equation with $dL = dT = dK = 0$ to obtain:

$$p_1dY_1 + p_2dY_2 + p_NdY_N - p_2dX_{21} + Y_1dp_1 + Y_2dp_2 + Y_Ndp_N - X_{21}dp_2 = Ldw + Tdr_T + Kdr_K, \tag{A.2}$$

where $X_{21} = a_{21}Y_1$.

It is the case that:

$$Ldw + Tdr_T + Kdr_K = (a_{L1}dw + a_{T1}dr_T)Y_1 + (a_{L2}dw + a_{K2}dr_K)Y_2 + Y_Ndw.$$

By the envelope theorem [3, Mathematical Appendix]:

$$dp_1 = a_{L1}dw + a_{T1}dr_T + a_{21}dp_2,$$
$$dp_2 = a_{L2}dw + a_{K2}dr_K.$$

Therefore,

$$Ldw + Tdr_T + Kdr_K = Y_1dp_1 - X_{21}dp_2 + Y_2dp_2 + Y_Ndp_N. \tag{A.3}$$

Substituting equation (A.3) into equation (A.2), we obtain condition (A.1).

Proposition: In the case of an export tax on rice, the change in real income is zero.

Proof: The change in income is:

$$dI = p_1dY_1 + p_2dY_2 + p_NdY_N - p_2dX_{21} + Y_1dp_1 + Y_Ndp_N + (D_1 - Y_1)dp_1,$$

where $(D_1 - Y_1)dp_1$ is the increment in government revenues. Imposing condition (A.1), we have:

$$dI = D_1dp_1 + Y_Ndp_N.$$

The expression for the proportional change in real income can be written as:

$$D_1dp_1/I + Y_Ndp_N/I + (p_1D_1/I)dt_1 - (p_NY_N/I)(dp_N/p_N) = 0.$$

The export tax has no impact on real income.

Proposition: In the case of a fall in the world price of rice, the proportional change in real income is $\phi_1\hat{p}^*_1$, where ϕ_1 is the share of rice exports in nominal income.

Proof: The change in income is:

$$dI = p_1dY_1 + p_2dY_2 + p_NdY_N - p_2dY_{21} + Y_1dp_1 + Y_Ndp_N.$$

Imposing condition (A.1), we have:

$$dI = Y_1dp_1 + Y_Ndp_N.$$

The expression for the proportional change in real income can be written as:

$$Y_1dp_1/I + Y_Ndp_N/I - (p_1D_1/I)(dp^*_1/p^*_1) - (p_NY_N/I)(dw/w) = \phi_1\hat{p}^*_1.$$