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HYMER-RESNICK AND EAST ASIAN INDUSTRIES IN OPEN RURAL ECONOMIES: DELINEATION BY SEASONAL RESPONSES

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We model the differential responses of rural industries in a Dutch Disease framework. The farm sector, F, subject to seasonal undulation, is exportable; the Z-goods sector is importable and G is either nontraded or exportable. Labor is quasi-surplus. We show that exogenous or season-induced expansion in F expands G if nontraded (East Asian response) and shrinks Z unambiguously (Hymer-Resnick response). When G is exportable, expansion in F leaves G output unchanged (season neutral), shrinks Z, while the export of G falls (Dutch Disease).

1. Introduction

Rural industrialization has been the subject of growing interest since the 1970s (Oshima, 1971; Kada, 1977; Ho, 1977; Chuta and Liedholm, 1979; Leiserson and Anderson, 1980). Several conference volumes on the impacts of rural industries in Asia have come out in the recent past (Chee and Mukhopadhyay, 1985 and 1985a; Choe, 1986; Shand, 1986; Islam, 1987). Its resurgence is due partly to some disappointment with the growth poles framework and its now obvious corollary of massive urban problems and, perhaps unintended, rural neglect, poverty and social unrest (Shand, 1986a). The original promise of a rapidly modernizing center with adequate trickle-down disguised potentials of frequent short circuits that resulted in dismal growth performance.

Neglect of the rural nonfarm sector was reinforced by two influential theoretical paradigms. The first is the Lewis-Fei-Ranis dualistic view of development where the modern dynamic sector has largely (though not necessarily correctly) been identified with the urban sector while the farm sector provides the surplus that fuels the modern sector (Lewis, 1954; Ranis and Fei, 1961). On the other hand, the concept of Z-goods introduced by Hymer and Resnick (1969) has cast a dark shadow over rural industries. The agrarian economy was viewed as producing

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an exportable (food) and a non-traded manufacture called *Z*-goods and importing a commodity *M*. As the price of food in terms of *M* rises, the *Z*-goods sector tends to shrink if the *Z*-goods is inferior. Resnick (1971) observed a pattern of continuous shrinkage by the *Z*-goods sector in the Philippines, Burma and Thailand. Extinction seemed the logical long-term prospect of this sector. This is what we term "Hymer-Resnick experience."

It is interesting that the idea of rural industrialization was given impetus from the empirical side of the economics profession. Oshima (op. cit.), Kada (op. cit.) and Ho (op. cit.) pioneered the work of detailing the rural industry growth experience of Japan, Korea and Taiwan. This phenomenon is now known among the growing circle of students of rural industry economics as the "East Asian experience" (Shand, 1987a). Nonfarm incomes of farming households reached 80 percent of total income in Japan and 63 percent in Taiwan by 1980 (Oshima, 1983). Instead of expiring, rural industry, perhaps transformed but rural nonetheless, forged ahead and became an important cog in the rural and national economies.

Theory, in this case, lagged behind observation. Hymer and Resnick (op. cit.), though no longer fully workable, have not been transcended — a fact which leaves a lingering residue of unease. The sentiment is expressed by Anderson and Leiserson (op. cit.) as a hope that theory will once again be reconciled with reality. Bautista (1971) appended the idea of *Z*-goods to a small, open agrarian economy model and found that the shrinkage of the *Z*-goods sector is not contingent on the inferiority of *Z*-goods. Being just a two-sector model, this cannot handle both the Hymer-Resnick experience and the East Asian experience. Barnum and Squire (1979), among others, have argued that there is no reason to believe in the inferiority of *Z*-goods. And yet it is undeniable as Resnick (op. cit.) observed that certain activities, say textile weaving, have diminished or disappeared from the landscape in the course of development.

The model we construct has many aspects in common with accepted models in Dutch Disease economics (Corden, 1981, 1982, 1984; Corden and Neary, 1982; Forsyth and Kay, 1980.) It has three sectors; capital is sector-specific while labor is mobile; no distortions mar the products and labor markets and market clearing is a rule; it is a purely real model ignoring monetary considerations. Trade is always balanced. All commodities produced are final consumption goods. It, however, differs on several aspects proper to a rural economy: it assumes the existence of quasi-labor surplus; the technology of the importable sector assumes only the use of labor and has a marginal product curve with a linear segment; and when seasonality is the main source of movement, the lead sector goes through a succession of boom and bust. We will see that the conclusions are slightly different especially in the case of the nontraded goods sector.

In Section 2, we present the small open rural economy model with nonfood nontraded sector G and show that when the rain comes, G expands (East Asian response) while the importable Z shrinks (Hymer-Resnick). In Section 3, G is an exportable and G is shown to be neutral towards seasonal variation in F. However, the export of G falls (Dutch Disease) and G may even become an importable good. Z, however, continues to exhibit a Hymer-Resnick response.

It appears therefore that rural industries at any given time consist on the one hand of activities that have competitive and dynamic nature that get sharpened with the opening of trade with the outside world and, on the other, of activities that survive only under protective isolation. In this view, it is Ricardian specialization rather than inferiority that fuels structural change. The problem of delineating the dynamic rural industries from the "distress adaptation" varieties (Islam, 1986) is an important policy issue in this area. The result is a framework which, together with empirical implementation, can be used to design policies affecting rural industries such as credit and other initiatives.

2. Seasonality in a Small Open Rural Economy: *G* Nontraded

Seasonality is an important concern in the economics of agriculture specially in monsoon Asia (Oshima, 1971, 1983). Agriculture by its very nature is more subject to the vagaries of the elements than other endeavours and has a profound impact on resource allocation in the rural economy. The succession of wet and dry seasons dictates the allocation pattern of rural labor across the different sectors. The purpose of this section is to introduce formally the idea of "seasonality" into a model of an open rural economy.

Consider an economy subject to a succession of wet and dry seasons. The economy is dominated by the farm sector F producing, food, X_F, requiring a fair amount of water. Farm output is a composite of many agricultural products, some commercial and some subsistence. Rainfed agriculture dominates the scene. It is natural to expect the wet season agricultural production to dwarf that of the dry season. Farm production never really ceases during the dry spell. Watermelon and cantaloupe, for example, are dry season crops. The well-behaved farm production function of food is defined to be

(1) $X_F = A(\theta) F(K_F, L_F), F_L, F_K > 0, F_{LL}, F_{KK} < 0,$

where $F_i = \partial F / \partial i, F_{ii} = \partial F_i / \partial i, \ i = L, K.$

K_F and L_F are capital and labor (in hours) complements in farm production. Capital is considered sector-specific and is immobile across sectors. $A(\theta)$ is the Oshima seasonality function and we define it as

(2) $A(\theta) = d + \sin \theta, \qquad d \geq 1,$

$\theta > 0.$

θ is the seasonality parameter.The following correspondences are assumed to apply:

(3)	$0 < \theta \leq \tau/2$	wet season,
	$\tau/2 < \theta \leq \tau$	onset of dry season,
	$\tau < \theta \leq (3/2)\tau$	dry season,
	$(3/2)\tau < \theta \leq 2\tau$	onset of wet season.

The marginal product of a resource, say labor, tends therefore to undulate with the total product. This is the simplest possible characterization of $A(\theta)$. The period and amplitude can easily be altered by introducing appropriate constants.

Definition 1: A rural industry is pro-cyclical if its labor absorption strictly rises during the peak agricultural season (rainy season) and strictly falls during the slack (dry) season. It is counter-cyclical when the reverse is true. It is neutral if no change is registered.

The idea of cyclical behavior of rural industries deserves some comment. The two most important linkages between farm and the nonfarm rural sectors are the factor market linkage, notably the labor market in this case, and the product market linkage through income.

When the rain comes, productivity in agriculture rises and so does income. The first linkage reallocates rural labor in favor of agriculture, while the other raises demand for nonfarm goods and thus tends to pull labor the other way. Those rural nonfarm endeavours where labor rises as farm income rises (pro-cyclical) are those with high income elasticity and thus have clear growth potential. Those whose link with agricultural income is weak and, instead, thrive when agricultural demand for labor is low (counter-cyclical) are conceivably less promising as potential long-term employment providers. In other words, dynamic advantage seems to lie in those activities with strong positive link to rural income. It is, thus, of some policy importance to delineate those activities that have growth potential. Seasonality is one way to do that.

The production function in Z reflects its primitiveness, the low level of capital use and the relatively high labor intensity. Other characteristics more or less common are production primarily for own use and within the household, part-timeness and low skill requirement (cf., e.g., Islam, 1986). The latter can be particularly controversial since some handicrafts require great skill. But the most important feature may be the use of "backward technology" which reverses the factor proportions obtaining in the outside world. These considerations suggest a rather simple structure for Z-goods production:

$$(4) \quad X_Z = aL_Z + h(L_Z), \qquad a > 0,$$

$$h' > 0, h'' < 0, h'(\infty) = 0$$

where X_Z is the amount of Z-goods produced and L_Z is the number of labor hours dedicated to Z-goods production. Note first that the marginal product of labor hours is constant for large enough L_Z. Why? Z-goods production at the lower end of the productivity spectrum may be construed as an infinite vector of activities and the constancy of marginal productivity is attained by shifting L_Z from one activity to another. In other words, L_Z need not slide down the marginal product curve of one activity. Because of the structure of the production function, the sector becomes the rural employer of last resort. Unemployment, strictly speaking, does not exist.

Definition 2: In the agrarian economy labor is quasi-surplus when $h' = h'' = 0$, i.e., the marginal product of labor is constant.

It is quasi-surplus in that the real wage rate does not change as long as the horizontal segment is used. Since the Z-goods is importable, the outside economy must be producing the goods at a lower cost than the agrarian economy. If the marginal product of labor in the Z-sector is allowed to push towards zero, the cost of production with abundant labor will be zero and the Z-goods will cease to be importable. This assumption is therefore crucial.

But a labor-abundant economy importing a labor-intensive commodity and exporting a more capital-intensive commodity seems to go against the grain of the Heckscher-Ohlin theorem, unless the importable good Z is produced with a different (more capital-intensive) technology outside. This precisely is the tack taken here. Thus, in comparison to the world production technology of the importable good, exportable food is actually more labor-intensive. But protective isolation has resulted in the reversal of factor proportions in the Z-goods sector.

The other rural nonfarm sector, G, is nontraded and is distinguished from the Z-sector by the use of capital. Its production function which is assumed well-behaved, is

$$(5) \quad X_G = G(L_G, K_G), \qquad G_L, G_K > 0, \qquad G_{LL}, G_{KK} < 0.$$

where $G_i = \partial G / \partial i$ and $G_{ii} = \partial G_i / \partial i, \quad i = L, K.$

Although capital is used, capital in this model is sector-specific. If L is the total labor hours in the rural economy, full employment implies that

$$(6) \quad L = L_Z + L_F + L_G.$$

The market equilibrium for labor with perfectly mobile labor is given by the equality of the value of marginal products across the 3 sectors:

$$(7) \quad \text{(a) } P_G G_L = (a+h')P_Z$$

$$\text{(b) } A(\theta) F_L = (a+h')P_Z$$

P_G and P_Z are prices of G and Z in terms of food. $A(\theta) F_L$ and G_L are marginal products of labor in the F and G sectors, respectively. We assume that the labor market is perfectly competitive and thus returns to homogeneous labor equalize, although this may do violence to the observation that returns to labor do not usually equalize across sectors. The rural income in terms of X_F is

(8) $Y = X_F + P_G X_G + P_Z X_Z$.

Now part of X_F is exported to, say the urban sector or abroad and, in return, the rural sector imports Z-goods substitutes (textiles, porcelain, etc.). Let M be the amount of X_Z imported. Then, the trade balance equation is

(9) $M = e_F X_F / P_Z, \quad 0 < e_F < 1,$

where e_F is the proportion of X_F exported. We thus have an extremely simple trade balance relation. Farm export pays for Z-goods imports. We focus here only on the static version of the model. The goods market balance equations for G and Z, respectively, are:

(10) $D^G(Y, P_Z, P_G) = X_G$

where D^G is the market demand for X_G as a function of Y, P_Z and P_G, and

(11) $D^Z(Y, P_Z, P_G) = (X_Z + M)$

where D^Z is the market demand for X_Z and (X_Z+M) is the total domestic supply of Z. The excess demand equation for food is residual and given (10) and (11) would automatically equal zero in a Walrasian system. We therefore have effectively 10 equations [(1), (4), (5), (6), (7a), (7b), (8), (9), (10), (11)] and 10 unknowns, namely, $X_Z, X_G, X_F, L_F, L_G, L_Z, e_F, Y, M, P_G$. We have an identified system. We assume that capital in this model is sector-specific so that it is treated exogenously. The reduced system of equation, assuming labor to be quasi-surplus, is

(12) (i) $D^G((X_F+P_G X_G+P_Z X_Z), P_Z, P_G) = X_G$

(ii) $D^Z((X_F+P_G X_G+P_Z X_Z), P_G, P_Z) = X_Z + (e_F / P_Z) X_F$

(iii) $A(\theta) F_L = a P_Z$

(iv) $P_G G_L = a P_Z$

The set $(L_G^*, L_Z^*, P_G^*, e_F^*)$ that solves (i), (ii), (iii) and (iv) simultaneously is the equilibrium solution of the model. It is easy to see that given $(L_G^*, L_Z^*, P_G^*, e_F^*)$, the other endogenous variables in the model are determined readily. We assign 1, 2, 3 and 4 to variables L_G, L_Z, P_G and e_F, respectively.

The Jacobian matrix, J, of (12i)–(12iv) has the following elements:

(13)
$$
\begin{aligned}
J_{11} &= -G_L < 0 \\
J_{12} &= 0 \\
J_{13} &= D_y{}^G X_G + Dp_G^G < 0 \\
J_{14} &= 0 \\
J_{21} &= e_F A(\theta) F_L / P_Z > 0 \\
J_{22} &= (e_F A(\theta) F_L - aP_Z)/P_Z < 0 \\
J_{23} &= D_Y^Z X_G + Dp_G^Z > 0 \\
J_{24} &= -X_F / P_Z < 0 \\
J_{31} &= -A(\theta) F_{LL} > 0 \\
J_{32} &= -A(\theta) F_{LL} > 0 \\
J_{33} &= 0 \\
J_{34} &= 0 \\
J_{41} &= P_G G_{LL} < 0 \\
J_{42} &= 0 \\
J_{43} &= G_L > 0 \\
J_{44} &= 0
\end{aligned}
$$

where $D_y{}^i = \partial D^i / \partial Y$, $D^i_{PG} = \partial D^i / \partial P_G$, $i = G, Z$, and where in J_{ij}, i refers to the ith equation in (12) and j refers to the jth variable. All the signs are normally expected. $J_{23} > 0$ is satisfied if Z is normal ($D^z_y > 0$) and Z and G are substitutes ($Dp_G^Z > 0$). $J_{13} < 0$ means that the negative price effect on demand exceeds the positive income effect of an increase in P_G. Totally differentiating (12i)–(12iv) with respect to θ and transferring to the right-hand side gives

(14)
$$
\begin{aligned}
E_1 &= -D_y^G F \cos\theta = E_1{}' \cos\theta. \\
E_2 &= (-D_y^Z F + e_F F/P_Z)\cos\theta = E_2{}' \cos\theta, \\
E_3 &= -F_L \cos\theta = E_3{}' \cos\theta, \\
E_4 &= 0.
\end{aligned}
$$

Note that $E_j' < 0$, all $j = 1, 2, 3$, if Z and G are normal and $D_y^Z > e_F / P_Z$. Now, $\cos\theta = (dA(\theta)/d\theta)$ given (2). Note that

(15) (i) $\cos\theta > 0$, $0 < \theta < \tau/2$ and $(3/2)\tau < \theta \le 2\tau$,

(ii) $\cos\theta < 0$, $\tau/2 < \theta \le (3/2)\tau$.

Thus, $\cos\theta > 0$ during the rainy season and $\cos\theta < 0$ during the dry season. We now have the following:

Proposition 1: [Nontraded G is pro-cyclical]. $(dL_G^*/d\theta) \gtrless \theta$ if $\cos\theta \gtrless 0$

Proof: Appendix A.1.

Proposition 2: [Z is counter-cyclical]. $(dL_Z^*/d\theta) \lessgtr 0$ if $\cos\theta \gtrless 0$

Proof: Appendix A.2.

Proposition 3: The price of G rises (falls) with wet (dry) season. [$(dP_G^*/d\theta) \gtrless 0$ if $\cos\theta \gtrless 0$].

Proof: Appendix A.3.

Proposition 4: Exports of F rise (fall) with the wet (dry) season. [$(de_F^*/d\theta) \gtrless 0$ if $\cos\theta \gtrless 0$].

Proof: Appendix A.4.

Although $\cos\theta$ is associated with rain or lack of it, we can interpret $\cos\theta > 0$ as just a Hicks-neutral technical change that raises agricultural productivity. Viewed in this way, we see that the "East Asian experience" is reflected in the response of the G and the Hymer-Resnick experience is reflected by the response of the Z to progress in the farm sector. Increased farm income raises Z-goods demand but this is made up for by raising imports paid for by rising farm exports (e_F^* rises: Ricardian effect). Meanwhile, labor is being lured away from the Z-sector towards the farm sector where the wage is tending to rise (direct de-industrialization). Likewise G absorbs more labor since G wage has also a tendency to rise as P_G^* rises. Thus labor moves from Z to G as well (indirect de-industrialization). In contrast to Hymer and Resnick (op. cit.), the nontraded G sector is not the lagging sector. No inferiority is assumed.

Associating $\cos\theta$ with seasonality, however, gives us now a way to delineate the promising activities, which, as pointed out, is a crucial policy issue. Those nontraded endeavours that raise labor absorption in peak rainy season when farming is also absorbing labor are clear candidates. This is important because seasonal labor absorption data for different industries are many times available!

3. Exportable G

Suppose now that G is exportable and its price, P_G, is exogenous by the small country assumption. We now assume that the technology utilized in this sector is up-to-date and does not reverse the prevailing factor proportions obtaining in the rest of the world. G is labor-intensive relative to Z in the rest of the world. Relative to Z, however, in this agrarian economy, G is capital intensive. This is because, as we observed, Z sports a backward technology that reverses the factor proportions outside. Equation (9) now becomes

$$(16) \quad M = (e_F X_F / P_Z) + (e_G P_G X_G / P_Z), \quad 0 < e_G < 1,$$

where e_G is the proportion of X_G exported. Equation (10) becomes

$$(17) \quad D^G(Y, P_Z, P_G) = X_G(1 - e_G).$$

We still have 10 equations in 10 unknowns with e_G replacing P_G. The reduced system of equation is now

$$(18) \quad \text{(i)} \quad D^Z(X_F + P_G X_G + P_Z X_Z, P_Z, P_G) = X_G(1 - e_G)$$

$$\text{(ii)} \quad D^G(X_F + P_G X_G + P_Z X_Z, P_Z, P_G) = X_Z + (e_F X_F + e_G P_G X_G) / P_Z$$

$$\text{(iii)} \quad A(\theta) F_L = aP_Z$$

$$\text{(iv)} \quad P_G G_L = aP_Z.$$

Let the set $(L_G'^*, L_Z'^*, e_G'^*, e_F'^*)$ solve (18.i)–(18.iv) simultaneously. The endogenous variable correspondence is now the following: L_G(1), L_Z(2), e_G(3), and e_F(4). The Jacobian matrix, J', of the system (18), has elements identical to J except for the following:

$$(19) \quad \begin{aligned} J_{11}' &= -G_L(1-e_G) < 0 \\ J_{13}' &= X_G > 0 \\ J_{21}' &= (F_L/P_Z)(e_F - e_G) \gtreqless \text{ as } e_F \gtreqless e_G. \\ J_{23}' &= -P_G X_G / P_Z < 0 \\ J_{43}' &= 0. \end{aligned}$$

These now substitute for correspondingly numbered elements in (13). We now have the following:

Proposition 5: [Exportable G is season-neutral.] $[(dL_G'^* / d\theta) = 0]$.

Proof: Appendix A.5.

Proposition 6: [Z is counter-cyclical.] [$(dL_Z{}' */d\theta) \lesseqgtr 0$ if $\cos\theta \gtreqless 0$].

Proof: Appendix A.6.

Proposition 7: G exports fall with the rise in F exports. [$(de_G{}' */d\theta) \lesseqgtr 0$ if $\cos\theta \gtreqless 0$ (Dutch Disease effect)].

Proof: Appendix A.7.

Proposition 8: F exports rise with the rain. [$(de_F{}' */d\theta) \gtreqless 0$ if $\cos\theta \gtreqless 0$].

Proof: Appendix A.8.

When G is exportable and normal, an expansion in F raises domestic demand for G. This is made up for by decreasing the proportion, $e_G{}' *$, exported. This is a Dutch disease effect without de-industrialization. The domestic production level of G remains the same. Z will shrink for the same reason as in the previous case. Increased domestic demand for Z-goods results in increased imports as labor is reallocated to the more productive farm sector. In the extreme case, G which started as an exportable could end up as an importable ($e_G{}' * < 0$). Note that in this case no indirect de-industrialization in Z is occurring since the relative prices are all fixed. In contrast with ordinary Dutch Disease expectations, exportable G is not strictly a shrinking sector.

Conclusion

We set out to account for the East Asian and the Hymer-Resnick responses of rural industries, both of which are robust empirical observations. We construct a three-sector model with the farm sector, F, as exportable, Z-goods as importable and G as either nontraded or exportable. The production function in Z is characterized by a marginal product curve with a horizontal segment for very large labor absorbed. The motivation is that at the lower segment, Z activity is construed as an infinite vector of sub-activities and the Z marginal product need not slide down the curve of one sub-activity. Labor is defined as quasi-surplus when its absorption forces labor into this horizontal segment. The "small country" assumption is maintained. The vehicle for analysis is the seasonality characterizing the farm sector. We define an industry to be pro-cyclical if its demand for labor rises with the increase in production (and income) in the farm sector. Pro-cyclical industries tend to link strongly with rural incomes. Counter-cyclical ones tend to link strongly with the existence of quasi-surplus labor. The former are more dynamic while the latter are just fallback distress-coping responses. We showed (Propositions 1 and 2) that nontraded G is pro-cyclical (East Asian response) while Z is counter-cyclical (Hymer-Resnick response). The price of G rises causing the expansion while increased demand for Z increases imports due to larger exports of farm output (Propositions 3 and 4). Nontraded G is a growth sector in contrast to Hymer and Resnick (op. cit.). When G is treated as an exportable, it becomes season-neutral but Z remains counter-cyclical (Propositions 5 and 6). Increased demand for G forces a domestic decline in G exports (Dutch Disease) but has no effect on output (Proposition 7) while increased imports of Z are financed through larger exports of farm output (Proposition 8). thus, farm sector poverty fuels Z's prominence by producing a protective wall of isolation. No inferiority is assumed anywhere.

The use of seasonality as an analytic vehicle is interesting because it gives us a direct way of delineating the dynamic from the distress-coping activities. The reason is that seasonal labor absorption and output data for different rural endeavours are often available from official sources. It is just a matter of comparing labor absorption movements from slack to peak agricultural periods. Thus a crucial policy issue is immediately addressed.

Appendix

We first evaluate the determinant of the Jacobian matrix J. We have

$$|J| = \begin{vmatrix} J_{11}(-) & 0 & J_{12}(-) & 0 \\ J_{21}(+) & J_{22}(-) & J_{23}(+) & J_{24}(-) \\ J_{31}(+) & J_{32}(+) & 0 & 0 \\ J_{41}(+) & 0 & J_{43}(+) & 0 \end{vmatrix}$$

The parenthesized sign after each element is the sign given in (13). Using the last column for evaluation, we have

$$|J| = J_{24}\,[J_{11}J_{32}J_{43} - J_{41}J_{32}J_{13}] > 0.$$

A.1. We find $(dL_G^*/d\theta)$. Substituting (13) for the first column in $|J|$, and again using the last column $(dL_G^*/d\theta)$ is

$$\begin{vmatrix} E_1'(-) & 0 & J_{13} & 0 \\ E_2'(-) & J_{22} & J_{23} & J_{24} \\ E_3'(-) & J_{32} & 0 & 0 \\ 0 & 0 & J_{42} & 0 \end{vmatrix} (\cos\theta)/|J| = J_4[E_1'J_{32}J_{43}]\cos\theta/|J|$$

Now $J_{24}[E_1'J_{32}J_{43}]/|J| > 0$. Thus $dL_G^*/d\theta \gtrless 0$ as $\cos\theta \gtrless 0$ which is Proposition 1.

A.2. We find $(dL_Z^*/d\theta)$. Substituting (13) for the second column in $|J|$, $(dL_Z^*/d\theta)$ is

$$\begin{vmatrix} J_{11} & E_1' & J_{13} & 0 \\ J_{21} & E_2' & J_{23} & J_{24} \\ J_{31} & E_3' & 0 & 0 \\ J_{41} & 0 & J_3 & 0 \end{vmatrix} (\cos\theta)/|J| = J_{24}[J_{11}E_3'J_{43} + E_1'J_{32}J_{41} - J_{41}E_3'J_{13} - J_{43}J_{31}E_1']\cos\theta/|J|.$$

Now $J_{24}[-\cdot-]/|J| < 0$. Thus $(dL_Z^*/d\theta) < 0$ as $\cos\theta > 0$ which is Proposition 2.

A.3. We find $(dP_G^*/d\theta)$. This is

$$\begin{vmatrix} J_{11} & 0 & E_1 & 0 \\ J_{21} & J_{22} & E_2' & J_{24} \\ J_{31} & J_{32} & E_3' & 0 \\ J_{41} & 0 & 0 & 0 \end{vmatrix} (\cos\theta)/|J| = J_{24}[-J_{41}J_{32}E_1']\cos\theta/|J|.$$

Now $J_{24}[-\cdot-]/|J| > 0$. Thus $(dP_G^*/d\theta) > 0$ which is Proposition 3.

A.4. We find $(de_F^*/d\theta)$. Substituting (13) for column 4 in $|J|$, and using column 4 for evaluation, $(de_F^*/d\theta)$ is

$$J_{22}\begin{vmatrix} J_{11} & J_{13} & E_1' \\ J_{31} & 0 & E_3' \\ J_{41} & J_{43} & 0 \end{vmatrix} (\cos\theta)/|J| - J_{32}\begin{vmatrix} J_{11} & J_{13} & E_1' \\ J_{21} & J_{23} & E_2' \\ J_{41} & J_{43} & 0 \end{vmatrix} (\cos\theta)/|J| =$$

$J_{22}\,[J_{13}E_3{}'J_{41} + E_1{}'J_{31}J_{43} - J_{43}E_3{}'J_{11}]\,(\cos\theta)/\,|J|$

$-J_{32}\,[J_{13}E_2{}'J_{41} + E_1{}'J_{21}J_{43} - J_{41}J_{23}E_1{}' - J_{43}E_2{}'J_{11}]\,(\cos\theta)/\,|J|.$

Now $J_{22}\,[- \cdot -]\,/\,|J| > 0$ and $-J_{32}\,[- \cdot -]\,/\,|J| > 0$ so that $(de_F{}^*/d\theta) \gtrless 0$ if $\cos\theta \lessgtr 0$ or Proposition 4.

We now evaluate $|J'|$ whose elements are in (19) and those elements in (13) not substituted for by elements in (19).

$$|J'| = \begin{vmatrix} J_{11}{}'(-) & 0 & J_{13}{}'(+) & 0 \\ J_{21}{}'(+) & J_{22}(-) & J_{23}{}'(-) & J_{24}(-) \\ J_{31}(+) & J_{32}(+) & 0 & 0 \\ J_{41}(-) & 0 & 0 & 0 \end{vmatrix} = J_{24}\,[-J_{41}J_{32}J_{13}{}'] < 0.$$

A.5. We find $(dL_G{}'{}^*/d\theta)$. Substituting (13) for the first column of $|J'|$ and evaluating via the 4th column, $(dL_G{}'{}^*/d\theta)$ is

$$J_{24} \begin{vmatrix} E_1{}' & 0 & J_{13} \\ E_3{}' & J_{32} & 0 \\ 0 & 0 & 0 \end{vmatrix} (\cos\theta)/|J'| = 0.$$

This is Proposition 5.

A.6. We find $(dL_Z{}'{}^*/d\theta)$. Substituting (13) for the second column in $|J'|$ and evaluating via the Cramer's Rule using the 4th column, $(dL_Z{}'{}^*/d\theta)$ is

$$J_{24}\,[-J_{41}E_3{}'J_{13}]\,(\cos\theta)\,/\,|J'|.$$

Now $J_{24}\,[- \cdot -]\,/\,|J'| < 0$ so that $dL_Z{}'{}^*/d\theta \lesseqgtr 0$ if $\cos\theta \gtrless 0$ or Proposition 6.

A.7. We find $(de_G{}'{}^*/d\theta)$. Substituting (13) for the 3rd column in $|J'|$ and evaluating via the 4th column, we have

$$J_{24}\,[-J_{41}J_{32}E_1{}']\,(\cos\theta)\,/\,|J'|.$$

Now $J_{24}\,[- \cdot -]\,/\,|J'| < 0$, so that $(de_G{}'{}^*/d\theta) \gtrless 0$ if $\cos\theta \lessgtr 0$, which is Proposition 7.

A.8. We find $(de_F{}'^{*}/d\theta)$. Substituting (13) for the 4th column in $|J'|$ and evaluating via the 4th row, $(de_F{}'^{*}/d\theta)$ is

$$-J_{41}\,[J_{13}E_2{}'J_{32} - J_{32}J_{23}E_1{}' - E_3{}'J_{22}J_{13}]\,(\cos\theta)\,/\,|J'|.$$

Now $-J_{41}\,[-\cdot-]\,/\,|J'| > 0$. Thus $(de_F{}'^{*}/d\theta) \gtreqless 0$ if $\cos\theta \gtreqless 0$ which is Proposition 8.

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