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# PRODUCTIVITY AND EXTERNALITIES: MODELS OF EXPORT-LED GROWTH

by

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## PRODUCTIVITY AND EXTERNALITIES:

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### Abstract

In developing countries, successful export-led growth (ELG) industrialization has been associated with rapid structural change and productivity growth. There are major difficulties in explaining this performance using a standard neoclassical growth model. To develop a more satisfactory framework, we start from empirical and theoretical work with models incorporating externalities. We develop a simple analytical model with an export externality that captures the large increase in both total factor productivity and trade share associated with export-led growth. A second model is developed to decompose growth into various components: (1) factor accumulation, (2) a factor reallocation effect from moving factors from low to high productivity sectors, (3) an export externality effect arising from exporting light and heavy manufactures, and (4) an import externality effect arising from importing capital goods (heavy manufactures). The second model is implemented with data for an archetype semi-industrial country. In addition to accounting for the higher total factor productivity (TFP) growth observed in countries pursuing ELG strategies, the model captures the patterns of structural change experienced by such countries better than simpler neoclassical models without disequilibrium features or externalities.

## I. Introduction

The relationship between exports and growth is at the heart of much of the debate on the selection of a country's industrialization strategy. A central task in the area of trade policy is to identify the linkages through which trade policy promotes growth. Though seldom rigorously formulated, the export-led growth (ELG) strategy, contrasted with the import-substitution industrialization (ISI) strategy, has often been cited as the main reason for observed differences in development patterns and performance among developing countries.

Even assuming the superior performance of ELG, there is still active debate about what exactly is the difference between ISI and ELG and about the mechanisms through which policies followed under ELG strategies translate into higher growth. For some, it is the "visible hand" involving an interventionist strategy of successfully "picking winners" which is at the heart of ELG [Westphal (1978); Westphal, Kim, and Dahlman (1985)]. For others, it is the "invisible hand" operating in markets with little government participation which explains the success of ELG [Balassa and Associates (1982), Balassa (1985), Bhagwati (1988), Krueger (1985), Little (1982)]. For the former, a judicious combination of selective infant-industry protection, export promotion, and intervention accounts for much of the success of ELG. For the latter, a relatively neutral set of incentives across activities, which promotes allocative efficiency, accounts for the superior performance of ELG.

These differences of interpretation aside, when pushed to provide an underlying theoretical model to explain the superiority of an ELG strategy, both camps invoke the loss of growth from the static distortionary costs due to excessive market interventions. These are the efficiency losses arising from distorted incentives in a neoclassical general equilibrium model. To these triangle losses, some would add the less-easily conceptualized losses due to x-inefficiency and rent seeking or directly unproductive profit-seeking (DUP) activities. Pushed further, both camps, with varying enthusiasm, cite the still-less-easily conceptualized losses due to lower total factor productivity (TFP) growth over time and limited exploitation of economies of scale because of small markets. At this point, we have moved some distance from the static efficiency arguments in the neoclassical model. The interventionist school argues further that dynamic effects include mechanisms of "technology transfer" from developed countries involving externalities that are missed in the static neoclassical model.

As argued in Section III, the evidence suggests that these dynamic effects are crucial and must be an important part of any explanation of the relative performance of ELG and ISI. In Section IV, we propose a simple model incorporating externalities which captures one possible way of formalizing the link between exporting and higher growth. In Section V, we go a step further and develop a more complete model in which externalities arise not only from exporting but also from the acquisition of technology embodied in imported capital equipment. In Section VI, we calibrate the model to a Korea-like, middle income, semi-industrial economy. Comparative numerical exercises indicate that this model with externalities captures the pattern of industrialization and TFP change in Korea and other countries following an ELG strategy much better than the standard neoclassical model.

## II. Export-Led Growth: The Evidence

The superior performance of countries pursuing an ELG strategy is well documented in many comparative studies sponsored by the OECD, NBER, and World Bank.[1] From this literature, a number of suggestive "stylized facts" have emerged.

First, countries undergoing ELG have industrialized by achieving high growth rates, increasing trade shares in GDP, and dramatic structural change. As documented in Chenery, Robinson, and Syrquin (1986), countries pursuing ELG strategies had rapid structural changes characterized by: (1) rapid increases in the use of intermediate inputs ("deepening" of their input-output structure) and (2) unbalanced growth led by increased demand for tradable goods. Typically, the early phase of ELG industrialization is led by light manufacturing, followed by development of the intermediate and capital goods sectors.[2]

Second, there is an acceleration in the rate of economic growth during the transformation associated with industrialization.[3] There is a positive correlation (at the economywide level) between aggregate growth and TFP growth. One common explanation for these observations is that there is continuing dynamic disequilibrium adjustment in the

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[1]See comparative case studies by Little, Scitovsky, and Scott (1970), Balassa and Associates (1971, 1982), Bhagwati (1978), and Chenery, Robinson, and Syrquin (1986). Cross-country correlations between export growth and aggregate growth are presented in Michaely (1977), Heller and Porter (1978), Balassa (1978), Feder (1983), and Jung and Marshall (1985).

[2]See Chenery, Robinson, and Syrquin (1986), chapters 3, 6, and 7. Balassa (1979) describes these phases in terms of "stages" of comparative advantage. See also de Melo (1985), who compares Korea and Taiwan.

[3]Evidence in support of the acceleration hypothesis during the industrialization of today's developed countries is given in Kuznets (1971). Evidence for today's developing countries is reviewed in Syrquin (1986).

factor markets as the expanding industrial sectors pull resources from the agricultural and "traditional" sectors.[4]

Third, supply-side sources of growth decompositions for countries that have followed an ELG strategy resemble more the pattern of developed countries than the pattern of other developing countries. For ELG countries, the contributions of capital accumulation and TFP growth to total output growth are higher than for other developing countries (indeed, than for developed countries).[5] By itself, these TFP results do not help "explain" differences between ISI and ELG patterns of development. Since the contribution to growth of TFP is calculated residually, the observed difference really amounts to a restatement of the problem.

Fourth, limited cross-country evidence using data for manufacturing sectors indicates a positive correlation between the role of export expansion and TFP growth at the sectoral level.[6] These results are consistent with the hypothesis that export expansion leads to higher TFP growth through exploiting economies of scale, technology transfer, or increasing competitive incentives. There is also evidence that import substitution is correlated with low TFP growth rates at the sectoral level. These results are consistent with the hypothesis that import substitution (liberalization) leads to lower (higher) TFP growth by reducing

[4]The classic two-sector development model is Lewis (1954). Bruno (1968), Robinson (1971), and Feder (1986) present two-sector models in which they econometrically estimate the contribution of disequilibrium adjustment in the factor markets to growth. Syrquin (1986) presents some computations for archetype economies.

[5]The evidence is detailed in Chenery (1986).

[6]The evidence is from Nishimizu and Robinson (1984). The countries are Japan (1955-1970), Korea (1965-1973), Turkey (1953-1973), and Yugoslavia (1962-1972). The data cover 16 manufacturing sectors.

(increasing) cost-reduction incentives.[7] However, cross-country variations in TFP growth rates are larger than within-country variations across sectors. This result indicates that the contribution to structural change of intersectoral variations in TFP growth rates do not suffice to explain the large differences in the structure of final demand between countries following ISI and ELG strategies.

These results have motivated a number of growth-accounting simulation exercises with neoclassical multisector models. One strand of work has sought to model the observed structural changes accompanying ELG. Chenery and Syrquin (1986) and Kubo, Robinson, and Urata (1986) trace the impact of ELG and ISI strategies on the structure of production in open input-output models by imposing exogenously the changes in final demand and aggregate trade. Another strand of work with long-run computable general equilibrium (CGE) models relates changes in aggregate growth and in trade structure to policy regimes characteristic of ISI and ELG strategies. For example, Chenery et al. (1986) characterize an ELG strategy in a Korea-like economy by specifying neutral incentives (i.e., no anti-export bias) and an ISI strategy by pervasive import rationing resulting in premia of over 100 percent on all imported goods (largely intermediate and capital goods). Simulations representing a 20-year period show a relatively small difference in growth rates between the two strategies. Even when exogenous differences in TFP growth rates between the two strategies are introduced, the model still does not adequately capture the differences in terminal year sectoral output and demand structure typical of ELG and ISI strategies.[8]

[7]An alternative, but not exclusive, hypothesis is that export expansion and import liberalization increase TFP growth by relaxing the foreign exchange constraint, facilitating imports of nonsubstitutable intermediate and capital goods.

[8]See also Lewis, de Melo, and Robinson (1987) who compare different models of Korea's ELG period.

## III. Externalities and Growth

The discussion above suggests that empirical work based on the neoclassical model only partially captures the stylized facts of ELG industrialization. Such models indicate that there are efficiency gains from introducing a policy regime of neutral incentives, but the gains are much too small to explain the observed differences in economic performance. The policy recommendation may be correct, but it cannot be justified using standard neoclassical models. The neoclassical framework must be expanded. One plausible way is to introduce externalities. Empirical case studies of countries pursuing ELG, and recent theoretical work, both support this approach.

Case studies indicate that ELG strategies have taken place with active government participation, well beyond simply preventing the development of an anti-export bias through dismantling policies to limit imports. On the export side, governments used large direct subsidies and, in addition, employed non-price policies, including the extensive use of export targeting and the establishment of "trade-promoting organizations" (TPOs). In Korea, for example, the Korea Trade Promotion Corporation (KOTRA) was established as early as 1962 with government funds. During the early period of ELG industrialization in Korea, indicative export targets were set jointly by the government and various exporters' associations (with the government exerting leverage through its control of credit and other regulatory instruments).[9]

TPOs have played an important role in successful ELG strategies by providing trade information and inquiry services, trade promotion such as trade fairs, market development

[9] See Westphal (1978).

advice, and assistance to firms in specialized areas such as product design and packaging.[10] Keesing and Singer (1989) argue that TPOs (when efficiently designed and operated) promote exports of manufactured goods which, in turn, generate huge potential external benefits. These externalities cannot be internalized in earnings of an individual exporting firm (e.g., technology acquisition, learning, and training; buyer's learning; economies of agglomeration; and general product quality improvement).[11] They are analogous to the role of infrastructure in big-push models (discussed briefly below).

On the import side, case studies indicate that countries pursuing ELG strategies have concentrated their imports more heavily in capital goods and selected intermediates compared to countries pursuing ISI strategies. Furthermore, ELG countries like Korea and Taiwan experienced very rapid increases in the import content of exports, a reflection not only of policies which have provided direct and indirect exporters with unrestricted access (and tariff exemptions) on imported inputs but also of exporting itself which gives exporters access to a tremendous range of technological improvements through the activities of the buyers of their exports.[12] In several papers, Westphal and his associates [Westphal (1982), Westphal, Kim, and Dahlman (1985)] have argued that the infant-industry exporting activity in Korea hastened the process of assimilating and mastering foreign technologies, thereby offsetting the static distortionary costs of the selective infant-industry protection pursued by the Korean government. They argue that the promotion of infant-industry

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[10]For a description of the activities of TPOs in four countries pursuing ELG policies, see Keesing (1988).

[11]This evidence suggests that the benefit of the externality is achieved through government investment. In the models presented below, we do not incorporate this link explicitly, though it could be handled along the lines suggested by Barro (1988).

[12]See de Melo (1985), who shows that Korea and Taiwan doubled the import content of exports within a decade.

exporting has enforced the mastering of foreign technology, since exporting of manufactures requires the ability to meet world market standards in specifications and quality, as well as distribution and marketing.[13]

Recent contributions to the growth theory literature also emphasize externalities. Though couched in terms of steady-state dynamic models, these contributions have generated suggestive results for understanding ELG in developing countries (an inherently unbalanced process). Three approaches are especially interesting. First, some models introduce Marshallian externalities, either in the form of human capital accumulation [Lucas (1988)], or complementarity between disembodied knowledge and physical capital [Romer (1986)]. These models, in effect, introduce increasing returns to scale at the economywide level, while maintaining constant returns to scale at the level of the firm. In addition to allowing for differences in growth rates over long periods of time, these models show that a decentralized equilibrium can exist despite the existence of a form of aggregate increasing returns in production [Romer (1988a)].

Second, some models include a mechanism whereby an externality generates an acceleration in the rate of growth. Such mechanisms occur in recent growth models with imperfect competition, either Schumpeterian [Helpman (1988)] or monopolistic competition [Romer (1988b)]. In these models, disembodied knowledge is obtained by investment in research and development (R&D). This representation of how knowledge is created is really more appropriate for explaining the creation of new technology in developed countries than for explaining TFP growth in developing countries. However, the mechanism by which

[13] This argument is different from learning by doing [Arrow (1962)], where labor productivity increases with the level of cumulative gross investment or output, although both arguments are largely consistent with the data. Westphal argues, however, that the successful assimilation of imported technology (the learning) is itself dependent on the policy environment.

the rate of growth is a positive function of the number of products through investment in R&D is broadly compatible with some descriptions in the development literature on adopting and mastering foreign technology.

Third, some models incorporate pecuniary externalities that enter via demand spillovers between sectors (for example, models of a "big push" in Murphy, Shleifer, and Vishny [1989a,b]). In these models, a low level equilibrium growth path might arise in an uncoordinated market economy which generates an inefficiently low level of investment.[14] In such an environment, firms capture in their profits only a small fraction of the total contribution of their investment to aggregate income. Subsidies and grants to investment are essential. In the case of infrastructure, adequate investment may not be built without government assistance. Models with demand spillover effects are also consistent with the evidence from countries pursuing ELG strategies where infant-industry exporters acquired a wide range of foreign technologies. When mastered and assimilated by the firms engaged in exporting activities, these technologies spill over to other activities.

From these recent theoretical contributions, we take on the notions of pecuniary externalities, spillovers, and the need for government participation either in the form of coordination of activities or in the form of subsidies to activities which take place at suboptimal levels. The importance of government participation will be apparent in the stylized model of an ELG-productivity link of Section IV. In the more complete representation of an ELG strategy in the model described in Section V, there will be spillover benefits to non-industrial sectors from the improvement of capital equipment through the increase in the volume of imported capital goods.

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[14]There is an early literature on similar "low level traps" in economic development; see, for example, Nelson (1956).

From the case studies, we retain a stages approach to ELG industrialization. Export growth first takes place in light manufacturing, followed by successful import substitution (and exports) in heavy industries. In our models, we emphasize the role of externalities as an engine of growth and industrialization during the first stage when light manufacturing is the leading sector. We will consider a single 10-20 year transition period rather than attempt to compare different long-run, steady-state growth paths.

## IV. A Model with an Export Externality

A simple ELG model with an externality linked to exporting is presented in Table 1. To help the transition to the more elaborate model with factor markets and intermediate inputs used in Sections V and VI, we introduce most of the functional forms to be used later. The model starts from de Melo and Robinson (1989).

There is a domestically produced good, D, which is an imperfect substitute in demand with an imported good, M. There is a second domestically produced good, E, which is sold on the export market and is not demanded domestically. The economy can produce combinations of D and E according to a production possibility frontier, or "transformation" function. In equations 1 and 2, the substitution and transformation possibilities are given by CES and CET functions, respectively. Foreign trade takes place at fixed world prices, i.e., we make the small-country assumption (equations 3 and 4). For now, aggregate production, $\bar{X}$, is fixed. The balance of trade constraint, equation 10, precludes any free lunch, and equations 6 to 9 specify profit maximization by producers and cost minimization by demanders. Equation 11 is the market-clearing condition.

Table 1: AN EXPORT-EXTERNALITY MODEL

| | | |
|---|---|---|
| (1) | $Q = F(M, D^D; \sigma)$ | CES aggregation function |
| (2) | $\bar{X} = A \cdot G(E, D^S; \Omega)$ | CET transformation function |
| (3) | $P^m = R \cdot \pi^m \cdot (1 + tm)$ | Import price |
| (4) | $P^e = R \cdot \pi^e \cdot (1 + te)$ | Export price |
| (5) | $P^t = P^d \cdot (1 + td)$ | Tax-ridden domestic price |
| (6) | $P^q = f_1(P^m, P^t; \sigma)$ | Consumer price |
| (7) | $P^x = g_1(P^e, P^d; \Omega)$ | Producer price |
| (8) | $M/D^D = f_2(P^m, P^t; \sigma)$ | Import demand equation |
| (9) | $E/D^S = g_2(P^e, P^d; \Omega)$ | Export supply equation |
| (10) | $A = \bar{A} \cdot (E/E_0)^{-\eta}$ | Export externality ($E > E_0$, $\eta > 0$, $A = \bar{A}$ if $E < E_0$) |
| (11) | $\pi^m \cdot M = \pi^e \cdot E$ | Balance of trade constraint |
| (12) | $D^D - D^S = 0$ | Domestic demand = supply |

Variables

| | |
|---|---|
| $M, E$ | = Imports, exports |
| $D^D, D^S$ | = Demand and supply of the domestic good |
| $Q$ | = Composite consumer good |
| $\bar{X}$ | = Fixed aggregate composite production |
| $\pi^m, \pi^e$ | = Fixed world prices of imports and exports |
| $R$ | = Conversion factor or "nominal" exchange rate |
| $P^m, P^e$ | = Domestic prices of imports and exports |
| $P^d, P^t$ | = Domestic prices of domestic sales, D, exclusive and inclusive of sales tax |
| $P^q, P^x$ | = Domestic prices of composite consumer good, Q, and composite output, X |

Parameters

| | |
|---|---|
| $\sigma, \Omega$ | = Elasticity of substitution (CES), elasticity of transformation (CET) |
| $\eta, E_0$ | = Externality parameters |

The export externality is introduced in equation 10, which states that the amount of (composite) domestic production is an increasing function of exports beyond some base level volume of exports, $E_0$. This is a true externality since the first-order condition, equation 9, does not take equation 10 into account. Producers do not see the benefits of exporting beyond the competitively determined level and, hence, do not internalize the presence of equation 10.[15]

In equation 2, ignoring A, the transformation function is homogeneous of degree 1 in E and D. Just as in the recent growth models with externalities, where A represents disembodied technological knowledge that receives no compensation, here the function for A is also treated as purely external. In Arrow (1962) and Romer (1986), the choices concerning the rate of accumulation of capital make the evolution of productivity endogenous. In equation 10, there are assumed to be productivity-enhancing effects that are associated with exporting and so affect the A parameter.

Figure 1 illustrates both the competitive equilibrium in the stylized model of Table 1 and the optimum solution that takes into account the externality in equation 10. Quadrant I depicts the external balance of trade constraint, which is the 45 degree line since, by choice of units, we set $\pi^m = \pi^e = 1$ (and $R \equiv 1$ by choice of numeraire). Quadrant IV depicts the production possibility curve perceived by producers and the production possibility curve, taking into account the externality. The corresponding consumption possibility frontiers are shown in quadrant II. Finally, quadrant III is the 45 degree line which specifies equilibrium in the market for domestic sales. The competitive solution is at points P and C, but the

[15]This specification is similar to that in other trade theory models analyzing arguments for "infant export industry" protection; see Bhagwati (1978) and the dynamic model by Mayer (1984).

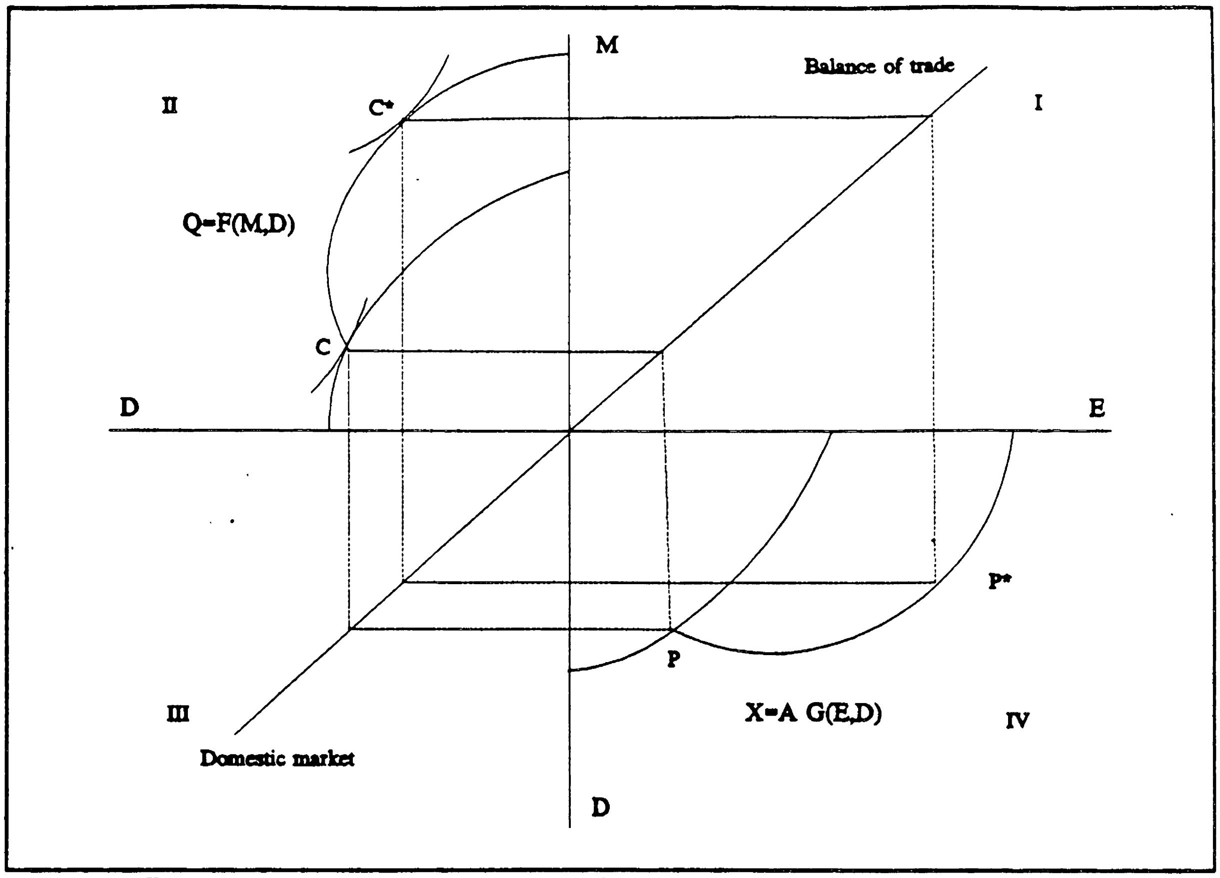

**Figure 1**: Diagram of the Export-Externality Model

optimal solution is at P* and C*.[16] The optimal solution will obtain either as a result of government intervention, as discussed below, or as a result of producers internalizing the externality, in which case equation (9) would be replaced by a first order condition that includes $\eta$, yielding a full-information competitive model.

It should be obvious that, for a given initial structure, the welfare gain from an ELG strategy will be increasing in $\eta$. The gain will also depend on the values of $\sigma$ and $\Omega$, the (income compensated) price elasticities of demand for imports and supply of exports, respectively. As a typical case, consider an industrializing economy with 10 percent trade shares in GDP (assume X = 100 and E = M = 10). Sensitivity calculations for this

[16] An interesting question is whether the competitive solution is always stable. In our empirical applications, it is stable, but it is easy to pick parameter values where it is not.

hypothetical economy are shown in Table 2, which reports the full-information optimum solution values for absorption, Q, which is the appropriate welfare indicator.[17] For given values of $\eta$, the welfare gain is increasing in $\sigma$ and $\Omega$. For example, for the first set of runs, with $\eta = 0.1$, the trade share in expenditure increases from 13.1 percent to 20.0 percent as the values of $\sigma$ and $\Omega$ are raised from 0.75 to 3.0. For high values of both $\eta$ and $\Omega$, the transformation function becomes very flat. For values $\eta = 0.3$, $\sigma = 3.0$, and $\Omega = 3.0$, the model was infeasible.

What combination of parameter values best represents a typical country following an ELG strategy? If one takes the Korean experience between 1965 and 1975, the combination of parameters in Run 12 ($\eta = 0.2$, $\sigma = 3.0$, $\eta = 1.5$) seems plausible. That combination gives a productivity-ELG link of 1.27 percentage points per year (12.7% increase in output divided by 10 years) and an increase in export share in GDP from 10 percent to 25 percent under the assumption that the externality is fully exploited. Korea's performance was spectacular, and one would expect other more typical countries to achieve a similar transformation over, say, 20 rather than 10 years.

Since, by definition, the externality is not perceived by the agents, it can be exploited only through policy intervention. The model in Table 1 includes three price-wedge instruments: (1) an export subsidy, te; (2) a tariff, tm; and (3) an indirect tax on the domestic good, td. Any net taxes or subsidies are financed by nondistorting, lump-sum transfers from or to the single household. The government does not demand goods. Given these instruments, we analyze three policy scenarios: an export subsidy alone; an export

[17] We also choose Q as the numeraire good, setting $P^q = 1$.

Table 2: SENSITIVITY EXPERIMENTS

| Run | Parameter Values: ETA ($\eta$) | SIGMA ($\sigma$) | OMEGA ($\Omega$) | Solution Values: Q = Y | M = E | $D^D = D^S$ |
|---|---|---|---|---|---|---|
| 1 | 0.1 | 0.75 | 0.75 | 101.6 | 13.3 | 88.8 |
| 2 | 0.1 | 1.50 | 0.75 | 101.9 | 13.9 | 88.4 |
| 3 | 0.1 | 0.75 | 1.50 | 102.2 | 14.7 | 88.5 |
| 4 | 0.1 | 1.50 | 1.50 | 102.8 | 16.1 | 87.6 |
| 5 | 0.1 | 3.00 | 1.50 | 103.3 | 17.2 | 86.7 |
| 6 | 0.1 | 1.50 | 3.00 | 103.7 | 18.4 | 86.8 |
| 7 | 0.1 | 3.00 | 3.00 | 104.6 | 20.9 | 85.1 |
| 8 | 0.2 | 0.75 | 0.75 | 106.6 | 16.9 | 91.5 |
| 9 | 0.2 | 1.50 | 0.75 | 107.5 | 17.4 | 91.0 |
| 10 | 0.2 | 0.75 | 1.50 | 109.2 | 20.7 | 92.2 |
| 11 | 0.2 | 1.50 | 1.50 | 111.1 | 22.9 | 91.2 |
| 12 | 0.2 | 3.00 | 1.50 | 112.7 | 24.8 | 90.0 |
| 13 | 0.2 | 1.50 | 3.00 | 114.5 | 28.7 | 91.2 |
| 14 | 0.2 | 3.00 | 3.00 | 117.4 | 33.2 | 88.6 |
| 15 | 0.3 | 0.75 | 0.75 | 116.4 | 21.7 | 98.4 |
| 16 | 0.3 | 1.50 | 0.75 | 118.2 | 22.9 | 97.8 |
| 17 | 0.3 | 0.75 | 1.50 | 123.2 | 29.4 | 102.1 |
| 18 | 0.3 | 1.50 | 1.50 | 127.1 | 32.1 | 100.9 |
| 19 | 0.3 | 3.00 | 1.50 | 130.2 | 35.3 | 99.2 |
| 20 | 0.3 | 1.50 | 3.00 | 135.8 | 44.6 | 103.4 |
| 21 | 0.3 | 3.00 | 3.00 | NS | NS | NS |

NS: No solution (infeasible).

Variables and parameters are defined in Table 1.

subsidy financed by an indirect tax, given a government revenue constraint; and export targeting.

We use the model to solve for optimal policy combinations. The problem is treated as a nonlinear program, maximizing absorption Q subject to the equations in Table 1 as constraints.[18] The tax rates are instrumental variables. In some experiments, it is possible to achieve the full-information optimum. In others, given additional constraints on government revenue or export targets, we consider the costs of not being able to attain the full-information solution.

The results of these scenarios, which all start from run 12 in Table 2, are reported in Table 3. Consider the tax and subsidy experiments. Using export subsidies alone would achieve the optimum and would require an export subsidy rate of 150 percent at a fiscal cost representing 25 percent of GDP. GATT surveillance notwithstanding, this approach would raise the eyebrows of even the most outward-looking finance minister! In an economy with a well-established and efficient tax collection system, the full benefit of the externality could be achieved at no net cost to the treasury by combining a 25 percent production tax with a 98 percent export subsidy (experiment 4). Alternatively, by Lerner symmetry, the same production tax could be combined with a 50 percent subsidy to imports (experiment 5).[19]

It is unlikely that the full benefits of an externality are achievable by policy intervention if only because of ignorance about the exact nature of the externality and thus

[18] The model is solved using the GAMS software; see Brooke, Kendrick, and Meeraus (1988).

[19] Accounting for the numeraire, the product of the exchange rate and export subsidy in row 4 of Table 3 equals the exchange rate times the import tariff in row 5.

Table 3: POLICY EXPERIMENTS

| | | Variables and parameters: | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Experiment | Q=Y | E=M | D | $P^x$ | $P^e$ | $P^m$ | $P^d$ | ER | te | td | tm | GR |
| 1 | BASE RUN | 100.0 | 10.0 | 90.0 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2 | FULL INFO | 112.7 | 24.8 | 90.0 | 1.13 | 0.77 | 0.77 | 1.04 | 0.74 | 0.0 | 0.0 | 0.0 | 0.0 |
| Tax and subsidy experiments: | | | | | | | | | | | | | |
| 3 | te | 112.7 | 24.8 | 90.0 | 1.41 | 1.91 | 0.77 | 1.04 | 0.74 | 1.50 | 0.0 | 0.0 | -28.2 |
| 4 | te & td | 112.7 | 24.8 | 90.0 | 1.13 | 1.53 | 0.77 | 1.04 | 0.74 | 0.98 | 0.25 | 0.0 | 0.0 |
| 5 | td & tm | 112.7 | 24.8 | 90.0 | 1.13 | 1.53 | 0.77 | 1.04 | 1.47 | 0.0 | 0.25 | -.50 | 0.0 |
| Government Revenue Constraint experiments: | | | | | | | | | | | | | |
| 6 | GR = -5 | 106.7 | 14.3 | 92.7 | 1.12 | 1.26 | 0.91 | 1.01 | 0.90 | 0.39 | 0.0 | 0.0 | -5.0 |
| 7 | GR = -10 | 109.8 | 17.3 | 93.0 | 1.20 | 1.44 | 0.86 | 1.02 | 0.84 | 0.67 | 0.0 | 0.0 | -10.0 |
| 8 | GR = -15 | 111.4 | 19.7 | 92.6 | 1.26 | 1.59 | 0.83 | 1.03 | 0.80 | 0.92 | 0.0 | 0.0 | -15.0 |
| 9 | GR = -20 | 112.3 | 21.9 | 91.8 | 1.32 | 1.72 | 0.80 | 1.03 | 0.78 | 1.14 | 0.0 | 0.0 | -20.0 |
| 10 | GR = -28.2 | 112.7 | 24.8 | 90.0 | 1.41 | 1.91 | 0.77 | 1.04 | 0.74 | 1.50 | 0.0 | 0.0 | -28.2 |
| Export target experiments: | | | | | | | | | | | | | |
| 11 | E = 15 | 107.6 | 15.0 | 92.9 | 1.08 | 0.90 | 0.90 | 1.01 | 0.88 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12 | E = 20 | 111.5 | 20.0 | 92.5 | 1.12 | 0.82 | 0.82 | 1.03 | 0.80 | 0.0 | 0.0 | 0.0 | 0.0 |
| 13 | E = 30 | 111.4 | 30.0 | 85.0 | 1.11 | 0.72 | 0.72 | 1.06 | 0.68 | 0.0 | 0.0 | 0.0 | 0.0 |

For all these experiments $X = 100$, $P^q = 1$, $\sigma = 3.0$, $\Omega = 1.5$, $\eta = 0.2$. The Base Run solution assumes no actor sees externalities. The Full Information solution is the optimum.

Variables and parameters are defined in Tables 1 and 2. ER is the real exchange rate, which equals $R/P^d$. The solution values for the nominal exchange rate, R, are the same as the solution values of $P^m$. GR is net government revenue from tax collection and subsidy disbursement.

about the optimal mix of policies.[20] Experiments imposing a government revenue constraint and export targeting give an idea of the cost of departing from the full-information optimum. The government revenue constraint experiments indicate that half of the benefits of the externality can be obtained with an export subsidy of 39 percent. Likewise, setting the volume of exports at 15 (about a third of the way between the competitive and full-information solutions) achieves over half of the externality benefits. The implication is that, if our representation of the externality is a reasonable approximation of how ELG works, the cost of policy errors is not large.[21]

## V. A Model with Import and Export Externalities

The small model with an export externality illustrates the implications of capturing the potential role of export promotion in a development strategy. If such externalities are present, they are well worth exploiting. However, this model only captures some of the stylized facts characteristic of ELG discussed above. Also, while the stylized model is suggestive, it is highly aggregated and cannot capture the changes in sectoral structure that are typical of countries undergoing industrialization. In this section, we expand the model to incorporate a bit more sectoral structure and include an additional externality mechanism through which expanded trade is thought to affect economic performance.

[20]In a different context, authors such as Harberger (1988) have argued that uniform tariffs should be pursued even granted the theoretical argument that they are not optimal because of ignorance of the parameters needed to compute optimal tariffs.

[21]Of course, this result depends crucially on the particular functional form chosen for the externality linkage.

In extending the neoclassical growth model to include externalities, the idea is to capture the major observed differences in the pattern of industrialization between ISI and ELG development strategies. A model of the transformation requires, at a minimum, four sectors: agriculture, light manufacturing, heavy manufacturing, and services. We start from archetype models of developing countries at different stages of development described in Chenery, Robinson, and Syrquin (1986).

We extend the model presented in Table 1 in a number of ways. Detailed equations are presented in the Appendix. The product differentiation assumptions with regard to both exports and imports are carried over to each of the four sectors.[22] We add interindustry linkages, assuming a Leontief technology for demands for intermediate inputs. We include primary inputs, labor and capital, with sectoral Cobb-Douglas production functions for real value added.

On the demand side, we specify a single representative consumer with an extended Stone-Geary utility function that includes savings.[23] Final demand thus includes both consumer goods and capital goods, yielding the extended linear expenditure system (ELES). We choose as the numeraire price the cost function corresponding to the ELES utility function, so that maximizing supernumerary expenditure is equivalent to maximizing the indirect utility function.

As in the previous model, government collects indirect taxes and tariffs, pays subsidies, and finances any difference through lump-sum transfers. We also retain the small-country assumption, with fixed international prices of sectoral exports and imports. The

[22]There is a two-way trade in every sector except services in which there are no imports.

[23]The expenditure system is the ELES or extended linear expenditure system; see Lluch, Powell, and Williams (1977).

balance of trade is also fixed exogenously, with the real exchange rate serving as the equilibrating variable.

Export externalities enter exactly as in the small model but now appear in two sectors: light and heavy manufacturing. Exports of agriculture and services are assumed to generate no externalities. We also add an additional externality that works through imports. We assume that imported capital goods are more productive than domestic capital goods. Since the model is static, with a fixed aggregate capital stock, current imports cannot affect the current capital stock. However, we are doing comparative statics experiments designed to represent roughly a decade of rapid growth. We postulate a link between the import ratio in heavy manufacturing and the productivity of the capital stock in the comparative statics experiments. The functional form is analogous to that for the export externality:

$$B = (M/\bar{M})^{\eta};\ \eta > 0$$

$$K^e = B \cdot \bar{K}$$

where $K^e$ is the economywide effective capital stock.

The effect of this formulation is to specify a link between the import ratio in heavy manufacturing and the size of the "effective" capital stock. In the static model, this link is treated as an import externality that affects the aggregate capital stock. At the sectoral level, we assume either that producers do not see that raising the import ratio will increase the effective capital stock for their sector or that the productivity increase is not achieved unless it is widespread.

As in the small model, the existence of export and import externalities will lead to potential welfare gains from policy intervention. We include three price wedge instruments: an export subsidy in light and heavy manufacturing and an import subsidy in heavy manufacturing. In simulating alternative development strategies, we again solve the model as a nonlinear program, maximizing the utility of the representative consumer subject to all the model equations and solving for the optimum levels of the three subsidy instruments. The three policy instruments are not independent and, as in the small model, one could choose alternative instruments that would achieve the same optimum (e.g., domestic production taxes or subsidies).

In modelling both import and export externalities, we are postulating a link but are not specifying the mechanism by which the externality works. For example, the acquisition of technological mastery through imports of capital goods involves learning, requiring both time and resources. Likewise, on the export side, developing efficient institutional support for exporting involves investment. In the model, these links are costless and, in comparative statics experiments, timeless as well. The elasticities in the various externality equations should be interpreted as implicitly incorporating these costs.

Table 4 reports the structure of the model economy in the base year. The data are drawn from Chenery, Robinson, and Syrquin (1986) and represent an archetype semi-industrial country with per capita income of $600 (in 1970 dollars). This economy is in the early to middle phase of the industrial transformation described by Chenery and Syrquin (1986). We seek to capture the transition to the next stage, which involves roughly doubling per capita income and lowering agriculture's share of GDP from 20 percent to about 15 percent.

During this transition, resources move out of agriculture, mostly into light manufacturing. Vernon (1989) describes technical change in the production of such goods as characterized by process rather than product innovation. In Vernon's view, the

Table 4: STRUCTURE OF THE ECONOMY IN THE BASE YEAR

| | Agriculture | Light mfg | Heavy mfg | Services | Total or average |
|---|---|---|---|---|---|
| Composition (%) | | | | | |
| Output | 18.7 | 32.4 | 15.7 | 33.2 | 100.0 |
| Value added | 20.5 | 22.0 | 12.5 | 45.0 | 100.0 |
| Employment | 38.3 | 19.2 | 6.5 | 36.0 | 100.0 |
| Capital stock | 20.4 | 13.9 | 9.0 | 56.7 | 100.0 |
| Exports | 38.3 | 21.1 | 16.5 | 24.1 | 100.0 |
| Imports | 16.7 | 17.9 | 65.4 | 0.0 | 100.0 |
| Ratios (%) | | | | | |
| Exports/output | 22.8 | 7.2 | 11.7 | 8.1 | 11.1 |
| Imports/output | 12.1 | 7.5 | 56.4 | 0.0 | 13.5 |
| Price elasticities | | | | | |
| Import demand[a] | 4.0 | 1.1 | 0.8 | 4.0 | |
| Export supply[b] | 4.0 | 3.0 | 0.5 | 4.0 | |
| Consumer demand[c] | -0.7 | -0.8 | -1.0 | -1.0 | |
| Income elasticity | 0.8 | 0.8 | 1.3 | 1.3 | |
| Productivity ratios (%)[d] | | | | | |
| Labor | 61.5 | 124.7 | 122.2 | 123.8 | 100.0 |
| Capital | 84.1 | 143.7 | 193.9 | 80.1 | 100.0 |

Notes:

[a]Compensated price elasticity ($= \sigma$).

[b]Compensated price elasticity ($= \Omega$).

[c]Marshallian (uncompensated) own-price elasticity.

[d]Ratio to the economywide average.

acquisition of technology in these sectors relies on machinery suppliers and in-house production engineers rather than on in-house R&D. This view of technological change in light manufacturing is also consistent with Westphal's interpretation of Korea's experience with export-led growth. Thus, we do not try to capture the next stage of industrialization during which growth shifts towards heavy industry with performance-sensitive products for which technical change requires substantial amounts of R&D expenditures.[24]

The elasticities of import demand and export supply specified for light and heavy manufacturing in Table 4 reflect this view. It is technically relatively easy to produce light manufactures for exporting and relatively difficult for heavy manufacturing. It is also assumed to be difficult to produce a domestic substitute for imported heavy manufacturing goods.

Note that in Table 4, in line with the empirical evidence reviewed earlier, we assume that the marginal products of labor and capital are lower in agriculture than in industry. The model includes distortion parameters which specify a fixed ratio of sectoral marginal products for labor and capital relative to the economywide averages (a complete equation listing is given in the Appendix). Capturing the productivity gains from moving resources out of agriculture is achieved in the model by simply setting all these parameters to one and resolving.[25]

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[24]Korea has recently increased its share of R&D expenditures in GNP from 0.57 percent in 1980 to 3.0 percent in 1986. This current trend is more consistent with the recent theoretical literature on R&D externalities discussed earlier and is indicative of Korea's maturation.

[25]The Appendix describes the equations and data sources.

## VI. Illustrative Simulations of ELG Industrialization

We now see if the extension of the neoclassical model to include an export externality and an import externality captures the observed differences in growth and industrialization patterns between ISI and ELG strategies. As mentioned above, our simulations are intended to portray the transition to an industrial economy with a sizable "light industry" sector.

The focus of the simulations is to see how far the trade externalities go toward endogenizing the contribution of TFP growth to overall growth and the pattern of structural change typical of ELG industrialization strategies. With the static model, the simulations consist of factor accumulation and exogenous technological change (in agriculture only) augmented by the presence of the externalities described in Section V. The results are presented in Tables 5 and 6.

To isolate the contribution of the trade externalities, we report four experiments (see the bottom of Table 5). The first three experiments are cumulative. In the first experiment, E1, growth and structural change are entirely through factor accumulation and exogenous technological change in agriculture that combines deepening of interindustry linkages and exogenous TFP growth (see the Appendix). The net effect is a residual contribution of TFP to total growth of less than 1 percent. Experiment E1 reflects the growth and structural change that would be generated by the neoclassical growth model. The second experiment, E2, recognizes that a productivity gain is realized by moving factors out of low-productivity agriculture. As can be seen from the top of Table 5, the contribution of the "residual" to

Table 5: EXPERIMENT RESULTS, AGGREGATE VARIABLES

| Experiments: | Base solution | E1 Factor growth | E2 Factor reallocation | E3 Externality 1 | E4 Externality 2 |
|---|---|---|---|---|---|
| GDP change (%) | 0.0 | 54.9 | 59.6 | 77.8 | 109.0 |
| Growth contributions (%) | | | | | |
| Labor | 0.0 | 30.5 | 28.1 | 21.5 | 15.3 |
| Capital | 0.0 | 68.5 | 63.2 | 48.5 | 34.8 |
| Residual | 0.0 | 1.0 | 8.7 | 30.0 | 49.9 |
| Ratios (%) | | | | | |
| Exports/GDP | 22.2 | 26.6 | 25.0 | 33.5 | 44.6 |
| Imports/GDP | 27.0 | 31.3 | 29.6 | 37.6 | 48.1 |
| Foreign savings/GDP | 4.8 | 4.2 | 4.6 | 3.5 | 2.7 |
| Real exchange rate index | 100.0 | 111.5 | 98.5 | 106.5 | 124.0 |
| Agricultural terms of trade | 100.0 | 82.6 | 103.9 | 106.8 | 109.7 |
| Export subsidy (%) | | | | | |
| Light mfg | 0.0 | 0.0 | 0.0 | 42.3 | 44.3 |
| Heavy mfg | 0.0 | 0.0 | 0.0 | 51.4 | 79.5 |
| Import subsidy (%) | | | | | |
| Heavy mfg | 0.0 | 0.0 | 0.0 | 24.6 | 49.7 |
| Externality indices: | | | | | |
| Effective production | | | | | |
| Light mfg | 100.0 | 100.0 | 100.0 | 118.6 | 143.3 |
| Heavy mfg | 100.0 | 100.0 | 100.0 | 103.0 | 106.3 |
| Effective capital stock | 100.0 | 100.0 | 100.0 | 102.5 | 112.8 |

Description of experiments:

E1 = Factor accumulation + exogenous technological change in agriculture (see text and appendix).
E2 = E1 + removal of factor productivity differentials.
E3 = E2 + low externality parameters (see text).
E4 = E2 + high externality parameters (see text).

Table 6: EXPERIMENT RESULTS, SECTORAL VARIABLES

| Experiments: | Base solution | E1 Factor growth | E2 Factor reallocation | E3 Externality 1 | E4 Externality 2 |
|---|---|---|---|---|---|
| Agriculture | | | | | |
| Output index | 100.0 | 233.1 | 195.2 | 161.6 | 138.5 |
| Producer price index | 100.0 | 85.2 | 102.3 | 114.1 | 127.9 |
| Consumer price index | 100.0 | 84.2 | 102.4 | 113.3 | 121.8 |
| Exports/output (%) | 22.8 | 29.2 | 21.8 | 10.6 | 5.4 |
| Imports/output (%) | 12.1 | 7.8 | 12.9 | 33.8 | 72.5 |
| Light manufacturing | | | | | |
| Output index | 100.0 | 145.1 | 161.1 | 215.6 | 267.8 |
| Producer price index | 100.0 | 109.7 | 103.8 | 107.7 | 113.7 |
| Consumer price index | 100.0 | 109.2 | 103.8 | 84.0 | 69.4 |
| Exports/output (%) | 7.2 | 4.1 | 6.7 | 27.6 | 44.0 |
| Imports/output (%) | 7.5 | 9.6 | 7.8 | 6.0 | 5.0 |
| Heavy manufacturing | | | | | |
| Output index | 100.0 | 172.0 | 208.1 | 226.0 | 230.8 |
| Producer price index | 100.0 | 97.8 | 81.9 | 82.8 | 85.1 |
| Consumer price index | 100.0 | 95.5 | 87.2 | 70.6 | 57.3 |
| Exports/output (%) | 11.7 | 11.3 | 13.0 | 16.1 | 17.6 |
| Imports/output (%) | 56.4 | 60.6 | 45.6 | 53.9 | 75.0 |
| Services | | | | | |
| Output index | 100.0 | 166.4 | 174.4 | 167.8 | 172.0 |
| Producer price index | 100.0 | 100.4 | 103.0 | 121.1 | 141.0 |
| Consumer price index | 100.0 | 101.1 | 103.1 | 122.6 | 143.1 |
| Exports/output (%) | 8.1 | 5.4 | 7.5 | 3.0 | 1.3 |
| Imports/output (%) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Composition of real GDP (%) | | | | | |
| Agriculture | 20.5 | 27.1 | 22.2 | 18.0 | 14.7 |
| Light manufacturing | 22.0 | 18.1 | 19.7 | 25.7 | 30.4 |
| Heavy manufacturing | 12.5 | 12.2 | 14.5 | 15.3 | 14.9 |
| Services | 45.0 | 42.6 | 43.6 | 41.0 | 40.0 |

growth is now almost 9 percent. In terms of GDP growth, this factor relocation effect raises GDP by 5 percentage points.

In the next two experiments, the externalities in exporting of light and heavy manufactures and in importing of heavy manufactures are introduced. In E3, the values of all externality parameters are set at 0.1; in E4, the export externality parameters are set at 0.15 and the import externality parameters at 0.20. The contribution of the two externalities to effective production and to the economywide effective capital stock are reported at the bottom of Table 5. The empirical result is a contribution of TFP growth to total growth of 30 to 50 percent, which is consistent with empirical evidence.

Experiment E1 represents an "equilibrium" neoclassical description of an ELG strategy. Adding the "disequilibrium" assumption of differential factor productivity growth during the transformation stabilizes the agricultural terms of trade index, a widely observed stylized fact of development over relatively long time periods. For an economy following a manufacturing ELG strategy, the factor reallocation effect also has some effect toward stabilizing the value of the relative price of tradables because tradables (which are concentrated in manufacturing) benefit from cheaper capital and labor through the reallocation effect. Note, however, that the factor reallocation effect has little effect on the openness of the economy as the aggregate ratios of exports and imports to GDP are very similar for E1 and E2. As a first approximation, E2 corroborates numerically the acceleration hypothesis during the transition but does not contribute toward an explanation of structural change.

In E3, where externality effects are small, there is some change in the real exchange rate and terms-of-trade indices compared to E2 but nothing dramatic. Openness is increased by about a third, with exports and imports reaching 35 percent of GDP.[26] The factor accumulation rates in the experiments approximate those realized by Korea during 1975-1985. Assuming the experiments represent a decade, the implied compound growth rate is 5.2 percent per annum under E3, which is much less than the 7.7 percent rate achieved by Korea during that period. The externality effects assumed in E4 result in an annual compound growth rate of 7.7 percent, matching historical performance. However, E4 overestimates structural change (in terms of openness) during that period, whereas E3 yields an increase in openness very close to the one achieved by Korea during 1975-1985.

Table 5 indicates the implications for structural change of incorporating "disequilibrium" in factor markets and externalities into the basic neoclassical CGE model. The factor reallocation effect (experiment E2) prevents the agricultural sector from increasing its share in GDP, but it misses entirely the change in the sectoral structure of foreign trade that takes place during a manufacturing ELG industrialization strategy. In experiment E2, import and export shares in gross output are too high for agriculture and too low for industry, particularly for heavy manufacturing. By contrast, with externalities, the CGE model captures much better the surge in light manufacturing exports (e.g., textiles and other consumer goods) and heavy manufacturing (e.g., capital goods) imports as well as the declining share of agricultural exports and rising share of agricultural imports. The patterns of structural change in output and foreign trade under E3 and E4 replicate fairly closely those observed during the early to middle phase of ELG in countries such as Korea and Taiwan when growth was greatest in light manufacturing sectors.

[26]Because foreign savings is maintained to a fixed value currency units in E3 and E4, its share in GDP declines with increasing externalities.

One last stylized feature of ELG growth is nicely captured by the modified model with trade externalities. Williamson (1979), citing the Kim and Roemer (1979) study of Korea's industrialization, notes that, in contrast with most other developing countries, Korea's relative (to GDP) price index of investment goods declined by approximately 40 percent during the period 1962-1975. Table 6 shows that with the subsidy to imports of heavy manufacturing necessary to induce the acquisition of heavy manufacturing imports, there is a dramatic decline in the domestic purchaser's price index of heavy manufacturing products. The producer price index of heavy manufacturing increases between E3 and E4 because of the more than doubling of the export subsidy to heavy manufacturing in E4 compared to E3. It is also interesting to note that the subsidy rates in experiments E3 and E4 are in line with the subsidies to infant industry exports described by Westphal (1982). The patterns of structural change in Table 6 are, of course, only suggestive, but they do capture the salient differences in structural change observed between ISI and ELG strategies.

In these experiments, the policy mix involves only subsidies to exporting manufactures and importing heavy manufactures. As with the small model, the total expense of the program is large. In the high elasticity externality experiment (E4), the cost of all subsidies equals 12 percent of gross sales and 27 percent of GDP. We did an additional experiment that started from E4, but added a uniform indirect tax rate (td) of 15 percent. The result is a similar pattern of subsidies, but essentially no net tax on households. It is certainly feasible to design a mix of indirect taxes and subsidies that exploit the externalities, with little impact on total net tax revenue. The implied sectoral tax and subsidy rates are also within observed ranges for semi-industrial countries.

## VII. Conclusion

In spite of their extreme simplicity, there are a couple of lessons to be learned from the stylized models incorporating export and import externalities. First, from a theoretical perspective, the approach appears to be fruitful. The models capture well the major stylized facts of growth and structural change in countries undergoing ELG. They also overcome a major shortcoming of the neoclassical model. In the neoclassical model, TFP growth appears by magic, with no link to changes in economic structure or policy choices. These trade-externality models provide a first step toward endogenizing major driving forces generating measured total factor productivity growth in ELG countries. They also provide a better framework for analyzing the links between aggregate economic performance, structural change, and policy choices.

Second, there is a lesson for policy analysts. In the presence of externalities, many of the simple policy rules emanating from the neoclassical general equilibrium model are no longer valid. Policy rules aimed toward minimizing static efficiency losses may miss potential gains arising from policy links to externalities. As is common in economics, there appear to be some trade-offs—in this case, between static efficiency costs and dynamic gains from exploiting externalities linked to export performance and import structure. The empirical results with the small export-externality model and the second model adding an import externality, support this view and suggest a change in policy perspective. If there are externalities to be exploited, policymakers should pursue them aggressively and not worry overmuch about getting the instruments just right. The simulations indicate that, when there are rectangles to be gained, an economy can easily afford to lose some triangles along the way.

The simple stylized models of ELG presented here are based on the empirical experience of countries that have pursued successful ELG strategies. Yet, they are only skeletal models that emphasize one possible explanation of TFP growth: Marshallian externalities. In this environment, the empirical results support the view that policymakers should pursue an interventionist policy regime to coordinate private sector activities. Further work is needed to explore the channels through which the externalities operate and interact with the structural changes that accompany industrialization. The models developed here are only a first step in that direction.

## Appendix

This appendix completes the description of the model presented in Section V. The following notation is adopted throughout. If double subscripts are employed, the first subscript denotes the sector of origin, the second the sector of destination. Upper case letters are reserved for endogenous variables, unless they have a bar, in which case they are exogenous variables or normalizing constants. Parameters and policy variables are denoted by Greek or lower case latin letters. Variables with a tilde over them represent nominal magnitudes. There are four sectors indexed over i or j: Agriculture, Light Manufacturing, Heavy Manufacturing, and Services (A, H, L, and S respectively).

We use CES and CET functions to describe substitution possibilities in trade. To save on notation, note that CES and CET functions can be written symmetrically, using the same share parameter $\alpha$ and exponent $\rho$: $X = \mathrm{CES}(F_1, F_2; \alpha, \rho, \bar{A})$ where the CES substitution elasticity $\sigma$ and CET transformation elasticity $\Omega$ are given by $\sigma = 1/(1-\rho)$; $-\infty < \rho < +1$ in the CES case and $\Omega = 1/(\rho - 1)$; $1 < \rho < +\infty$ in the CET case. In both cases, the function is written:

$$X = \bar{A}\,[\alpha\, F_1^{\rho} + (1-\alpha)\, F_2^{\rho}\,]^{1/\rho}$$

Table A1 lists the equations describing the model underlying the simulations reported in Section VI. The model includes the export externality, the import externality, and an assumption of differential factor productivities for capital and labor across sectors. The export externality is the same as the one introduced for the simple model in Section IV, except that it now applies to exports of light and heavy manufacturing (see equation A8).

The import externality (equation A7) increases aggregate effective capital and hence has economywide implications. Finally, the assumption of differential factor productivity across sectors is reflected by fixed distortion parameters in the first-order conditions for factor demands (see equations A6 and A5).

Since there is only one consumer who maximizes utility given by the equations of the ELES, we have chosen as numeraire the cost function corresponding to the ELES so that, given our choice of numeraire, maximizing supernumerary expenditures (see equation A1) is equivalent to maximizing utility. Also note that exogenous foreign transfers, $\bar{B}$, expressed in foreign currency units, are given to the representative household and that the government's activity is restricted to collecting and disbursing tax revenues.

The values for the externality parameters are discussed in the main text. The factor productivity differentials, or distortion parameters, are drawn from evidence reported in Chenery, Robinson, and Syrquin (1986), particularly chapters 3, 5, and 8. The assumed values for the base solution are:

$$\lambda_1^K = 0.84\ ; \qquad \lambda_2^K = 1.44\ ; \qquad \lambda_3^K = 1.94\ ; \qquad \lambda_4^K = 0.80$$

$$\lambda_1^L = 0.62\ ; \qquad \lambda_2^L = 1.25\ ; \qquad \lambda_3^L = 1.25\ ; \qquad \lambda_4^L = 1.24$$

The assumed values for sectoral technology and the structure of the base solution sectoral outputs are given in Table A2, and the social accounting matrix (or SAM) for the base data is given in Table A3. The elasticities for the CET, CES, and ELES functions describing export supply, import demand, and consumer demand are described in Table 5 in the main text.

In all experiments, the following assumptions are made about factor accumulation and exogenous technological progress in agriculture. The labor force is augmented by 32 percent and the capital stock (net of depreciation) by 79 percent. These figures, representative of Korea during 1975-85, imply annual compound growth rates of 2.8 percent and 6 percent respectively. In agriculture, exogenous technological progress (on real value added) of 79 percent is combined with increasing intermediate-input requirements. The input-output coefficients for intermediate inputs into agriculture from the non-agricultural sectors are increased by 40 percent. The elements of column 1 in Table A2 become: 0.170, 0.100, 0.169, and 0.125. In addition, the entry from agriculture to light manufacturing is doubled. As can be seen from the contribution of the residual to growth in Table 5, this combination of technological progress and deepening intermediate input structure yields a contribution of the residual to value-added growth in agriculture of 4.3 percent.

**Table A1**: A Multisector Model with Trade Externalities

*Welfare Indicator*

(A1) $$W = \tilde{Y} - \tilde{S} - \sum_{i} PQ_i \cdot \gamma_i$$

*Technology*

(A2) $$X_i = \overline{AX} \cdot K_i^{\alpha_i} \cdot L_i^{(1-\alpha_i)}$$

(A3) $$V_i = \sum_{j} a_{ij} \cdot X_j$$

(A4) $$Q_i = \mathrm{CES}(D_i, M_i;\ \beta_i, \sigma_i, \overline{AQ_i})$$

(A5) $$X_i = \mathrm{CET}(D_i, E_i;\ \delta_i, \Omega_i, AT_i)$$

*Factor Markets*

(A6) $$K_i^{D} = \frac{\alpha_i \cdot PN_i \cdot X_i}{\lambda_i^{K} \cdot W_K}$$

(A7) $$L_i^{D} = \frac{(1 - \alpha_i) \cdot PN_i \cdot X}{\lambda_i^{L} \cdot W_L}$$

*Externalities*

(A8)

$$AT_k = \overline{AT_k} \left[\frac{E_k}{\overline{E}_k}\right]^{-\eta_k} \qquad k \in \cdot L,\ H \text{ and } E_k \geq \overline{E}_k$$

$$AT_k = \overline{AT_k} \qquad k \in A,\ S \text{ or } E_k < \overline{E}_k$$

(A9)

$$B = \left[\frac{M_H}{\overline{M}_H}\right]^{\psi} \qquad M_H \geq \overline{M}_H$$

$$B = 1 \qquad M_H < \overline{M}_H$$

*Resource Constraints and Effective Capital Stock*

(A10)

$$\sum_i L_i^D = \overline{L}$$

(A11)

$$\sum_i K_i^D = K^e$$

(A12)

$$K^e = B \cdot \overline{K}$$

*Export Supply and Import Demand*

(A13)

$$\frac{D_i}{E_i} = \left[\frac{\delta_i \cdot PD_i}{(1 - \delta_i) \cdot PE_i}\right]^{\Omega_i}$$

(A14)

$$\frac{D_i}{M_i} = \left[\frac{\beta_i \cdot PD_i}{(1 - \beta_i) \cdot PM_i}\right]^{-\sigma_i}$$

*Prices*

(A15)

$$PQ_i = (PM_i \cdot M_i + PD_i \cdot D_i)/Q_i$$

(A16)

$$PN_i = PX_i - \sum_j a_{ji} \cdot PQ_j$$

(A17)

$$PK = \sum_j PQ_j \cdot b_j$$

(A18)

$$PX_i = (PE_i \cdot E_i + PD_i \cdot D_i)/X_i$$

(A19)

$$PM_i = \overline{PWM_i} \cdot R \cdot (1 + tm_i)$$

(A20)

$$PE_i = \overline{PWE_i} \cdot R \cdot (1 + te_i)$$

*Demand*

(A21)
$$\tilde{S} = \beta_0 \cdot \tilde{Y}$$

(A22)
$$Z_i = b_i \cdot \tilde{S}/PK$$

(A23)
$$PQ_i \cdot C_i = PQ_i \cdot \gamma_i + \frac{\beta_i}{\sum_j \beta_j} (\tilde{Y} - \tilde{S} - \sum_j PQ_j \cdot \gamma_j)$$

*Balance of Trade Constraint*

(A24)
$$\sum_i (\overline{PWM}_i \cdot M_i - \overline{PWE}_i \cdot E_i) = \overline{B}$$

*Income and Government Revenue*

(A25)
$$\tilde{Y} = W_L \cdot \overline{L} + W_K \cdot \overline{K} + \tilde{G} + \overline{B} \cdot R$$

(A26)
$$\tilde{G} = \sum_i (tm_i \cdot M_i \cdot \overline{PWM}_i - te_i \cdot E_i \cdot \overline{PWE}_i) \cdot R$$

*Market Equilibrium*

(A27)
$$Q_i = V_i + Z_i + C_i$$

*Numeraire*

(A28)
$$\overline{P} = PK^{\beta_0} \prod_i (PQ_i)^{\beta_i}$$

Table A2: Input-Output Coefficients and Factor Ratios

| Sector | Input-Output Coefficients: | | | | Ratios: | | Output: |
|---|---|---|---|---|---|---|---|
| | Agric | Light mfg | Heavy mfg | Services | K/XD | K/L | XD |
| Agriculture | 0.170 | 0.111 | 0.080 | 0.048 | 1.44 | 1.61 | 224 |
| Light mfg | 0.071 | 0.250 | 0.191 | 0.108 | 0.65 | 2.20 | 388 |
| Heavy mfg | 0.121 | 0.180 | 0.239 | 0.050 | 0.76 | 4.21 | 188 |
| Services | 0.089 | 0.119 | 0.090 | 0.113 | 2.27 | 4.79 | 397 |

Table A3: Social Accounting Matrix

| Receipts | Expenditures | | | | | | |
|---|---|---|---|---|---|---|---|
| | Commodity | Activity | Value added | House-holds | Capital account | Rest of world | Total |
| Commodity | | 597 | | 509 | 120 | | 1,226 |
| Activity | 1,064 | | | | | 133 | 1,197 |
| Value added | | 600 | | | | | 600 |
| Households | | | 600 | | | | 600 |
| Capital account | | | | 120 | | | 120 |
| Rest of world | 162 | | | -29 | | | 133 |
| Total | 1,226 | 1,197 | 600 | 600 | 120 | 133 | |

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