A REVIEW OF FOUR DEMOECONOMIC GENERAL EQUILIBRIUM MODELS

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April 1981
WP-81-43

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FOREWORD

Roughly 1.6 billion people, 40 percent of the world's population, live in urban areas today. At the beginning of the last century, the urban population of the world totaled only 25 million. According to recent United Nations estimates about 3.1 billion people, twice today's urban population, will be living in urban areas by the year 2000.

Scholars and policy makers often disagree when it comes to evaluating the desirability of current rapid rates of urban growth and urbanization in many parts of the globe. Some see this trend as fostering national processes of socioeconomic development, particularly in the poorer and rapidly urbanizing countries of the Third World; whereas others believe the consequences to be largely undesirable and argue that such urban growth should be slowed down.

As part of a search for convincing evidence for or against rapid rates of urban growth in developing countries, scholars in the Population, Resources, and Growth Task have been constructing general equilibrium models for Mexico, Sweden, Hungary, and Japan. The purpose of these models is to describe the fundamental aspects of the process of demoeconomic development and structural change both in historical and contemporary settings. This paper summarizes and reviews these models and offers suggestions for future research.

A list of the papers in the Population, Resources, and Growth Series appears at the end of this report.

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ACKNOWLEDGMENTS

I would like to thank Andrei Rogers, Chairman of the Human Settlements and Services Area for his warm encouragement. Susie Riley typed and Maria Rogers edited the paper. Their efficiency and patience are worth a special mention with appreciation.

ABSTRACT

General equilibrium simulation modeling has become one of the standard tools of analyzing various economic forces within and among nations. Several models of this type have been built in the Human Settlements and Services (HSS) Area to study economic forces and their interactions with demographic forces.

This paper summarizes these models and reviews the advantages and disadvantages of general equilibrium modeling and of the specific specifications chosen by the authors. The models reviewed here include a prototype model and three case-study models (Mexico, Sweden, and Hungary). A brief description of an earlier dualistic prototype model and a fourth case study (Japan) are given in the Appendices.

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A REVIEW OF FOUR DEMOECONOMIC GENERAL EQUILIBRIUM MODELS

1. INTRODUCTION

Urbanization—a measure of the proportion of population residing in urban areas—is increasing rapidly in most developing countries.* Analysts and policy makers, however, are sharply divided in their evaluation of the desirability of this rapid increase. Proponents of urbanization, on the one hand, consider growth of urban activities as a necessary condition for the development of the total economy and, as a result, the raising of living standards. Without a rapid growth of urban activities, it is argued, productivity would remain lagged and further growth would diminish. Opponents, on the other hand, hold the view that undesirable consequences of rapid urbanization far outweigh the desirable ones, regarding most governments as incapable of coping with the rapid change satisfactorily. They argue that the rate of urbanization should be slowed down or at least urban activities should be more dispersed.

In these sharply divided arguments, both parties have depended heavily on the results of partial and static analyses. For example, some studies look only at efficiences in physical production in single time periods, while others look only at the

*See, for example, Rogers (1977, 1980).

detrimental aspects of urban life. Seldom has the urbanization phenomenon been studied as a unit encompassing all interacting forces of an economy: urban, rural, consumption, and production forces. It is also rare that urbanization is studied as a part of the dynamic changes of an economy even though urbanization itself is caused by and causes these changes.

Clearly a more holistic approach is what we need: an approach that allows an anlysis of a dynamic system, a developing economy in its entirety.

The models reviewed here were built within the Human Settlements and Services (HSS) Area* with this as a goal. It was intended that the analyses using these models would identify various *direct and indirect* forces that determine the pattern of urbanization and would clarify the consequences of certain policy options in the perspective of the economy in general. In order to achieve this, the models were built to enable one to examine various direct and indirect responses of a developing economy to demographic, economic, and other exogenous changes. They, therefore, are able to describe the past, assess the future, and display relevant policy options for the whole economy. At the same time, however, they remain small enough to maintain their analytical tractability and not become simply "black boxes."

All the models are in a dualistic general equilibrium framework characterized by the work of Kelley, Williamson, and Cheetham (1972). The term "dualistic" used here refers to the technological dualism described in Eckaus (1955) as well as consumption dualism. [For reviews of theories of dualistic economic development, see Dixit (1973) and Lluch (1977).] Accordingly, in these models dualism is used in the sense that differences exist between modern and traditional sectors in the technologies employed and in consumption patterns. Quite often this modern-traditional dichotomy is regarded as being synonymous to the urban-rural or industrial-agricultural dichotomy. This is unfortunate because both modern and traditional elements exist in urban and rural, or in agricultural or nonagricultural sectors. Efforts have been

*The work by Zalai was done jointly with the Systems and Decision Sciences (SDS) Area.

made, however, to amend this problem in some of the models reviewed here; Kelley and Williamson (1980a) for example have introduced urban traditional sectors and rural nonagricultural activities while Colosio (1979) divides agriculture into modern and traditional sectors.

In this paper four demoeconomic general equilibrium models are reviewed, and two more models are briefly mentioned in the Appendices. The four models are the representative developing country (hereafter called RDC) model by Kelley and Williamson (1980a), the Mexico model by Colosio (1979), the Sweden model by Karlström (1980), and the Hungary model by Zalai (1980). The two models mentioned in Appendices 1 and 2 are the model built by Kelley, Williamson, and Cheetham (1972) and the Japan model by Shishido (1981). The former is included here because it has been the intellectual source of dualistic general equilibrium modeling at IIASA. There is also, in Appendix 3, a brief summary of the three case-study models, including some mathematical statements.

Before the models are reviewed, however, the assumptions underlying general equilibrium models and arguments for and against their use in the study of developing economies are given. It is considered important that the reader be aware of the pros and cons of general equilibrium models because it is a highly controversial issue. It is hoped that this review will stimulate the interaction of demographers and economists with those interested in general equilibrium theory for the further development of this field of research.

2. GENERAL EQUILIBRIUM AND SIMULATION MODELS IN DEVELOPMENT STUDIES

The use of the Walrasian general equilibrium theory—the core of neoclassical economics—in the study of developing economies has often been a source of heated arguments. Opponents to the use of this framework argue that general equilibrium assumptions are unrealistic, and although some authors make explicit counter arguments, the most honest feelings among builders and users of such models can be summarized in a statement made by Lysy and Taylor (1978:6-6)

> Though of dubious validity, the neoclassical apparatus is used without apology, because there is so little other theory that has been mathematized sufficiently to support numerical work.

What kind of assumptions are "of dubious validity" in the neoclassical general equilibrium analysis, and what kind of "wedges" do the model builders use to amend this dubiousness? The skeleton of the assumptions needed for the existence of the Walrasian general equilibrium theory is the following.

(1) Many competitive price-taking firms with given technologies try to maximize their profit. This results in factor demand and commodity supply at each price vector.

(2) Many consumers (households) with given preferences, try to maximize utility at a given price. This results in factor supply and commodity demand at each price vector.

(3) Prices, both of factors and commodities, adjust flexibly so that all markets clear.

These assumptions are primarily criticized because models based on them postulate that economies will be in equilibrium at each time period. According to the critics, and I agree with them, developing economies are inherently in dynamic disequilibrium. There are not many that are so flexible they clear every period. Furthermore, there can be more than one market, separated

by distance, social institutions, etc., for the same commodity or service. If many markets are therefore not in equilibrium, what is the use, the critics argue, of equilibrium analyses? They also point out that prices do not adjust instantaneously; for example, wages (price of labor) are determined by various institutional factors and *not* by economic forces.

Another argument often heard against neoclassical economics in general, is that in developing economies there are so many elements of imperfect competition—monopoly, oligopoly, imperfect information, etc.—that a model of competition among small price-taking firms is anything but an accurate discription of the economy. Also, application of the neoclassical marginal principles to the population in the traditional sector, has been argued as inaccurate since in this sector labor and captial income are empirically inseparable. In these cases the behavior of the people is often bound by tradition and may not necessarily be maximization oriented.*

Finally, in these general equilibrium models, money is usually a veil. All demand functions are homogeneous of degree zero with respect to prices. Prices are usually simplex ($\sum_i p_i = 1$) or relative (relative to a selected numeraire good.) Inflation, say, of several hundred percent, would not change any real variable. It is argued by many, however, that monetary policy does have some real effects. Especially in developing economies, forced saving by inflation is more pronounced, and it can be argued that general equilibrium model builders should take at least this aspect into account, instead of considering money as completely neutral.

Despite all these criticisms, the amount of literature on general equilibrium analyses of developing economies continues to grow,** and counter arguments showing the ways in which general

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*For discussions on whether people in the traditional sector are rational maximizers or not, see T.W. Schultz (1964), Tax (1953), Lipton (1968) and Eckaus (1976) among others.

**Some such literature not reviewed in this paper is: Adelman and Robinson (1978), de Melo and Robinson (1980), Eckaus, et al. (1979), Lysy and Taylor (1978), McCarthy and Taylor (1977), Yap (1976), and Bergman and Pŏr (1980). This is far from an exhaustive list.

equilibrium theory can be used constructively for studying developing economies continue to emerge. The first criticism of the use of general equilibrium in studying an economy where the economic forces are inherently in disequilibrium, is usually handled by bringing into the broadly defined neoclassical framework some *ad hoc* assumptions, i.e., nonneoclassical and disequilibrium features. Wage rigidity and factor immobility are the most typical of these assumptions. The urban modern sector pays higher wages to their employees than their counterparts in the rural areas for various *institutional* reasons. Factors of production are not highly responsive to their own returns and tend to adjust slowly; for labor, they adjust through intersectoral (usually rural-urban) migration, and for capital, through intersectoral investment. The arguments of migration function are most often the (expected) wage level in the urban sector and the wage level in the rural sector. For the latter, average income is sometimes used due to the proprietor-like nature of peasants and small farmers. Finally, unless explicit unemployment is assumed, and given numerically, unemployment of labor and excess capacity (unemployment) of capital are reflected in the lower rates of return to the respective factors.

The problem of imperfect competition, to the author's knowledge, has not been resolved as yet by general equilibrium model builders with any amendment that is close to reality. (See, however, a comment made by Adelman and Robinson, 1978:30.) Perfect competition among price takers is usually assumed. Negishi (1960) did study equilibria in monopolistic competition, but the path of his literature has developed along the non-Walrasian equilibrium line which, at this stage, does not allow numerical and empirical analyses.

The monetary sector in general equilibrium models has usually been excluded. But the effect of inflation on the poor and on saving patterns can be examined by fixing the nominal wage, for example, of unskilled labor, and letting the general price level go up. This has been done by Adelman and Robinson in their model of Korea and Lysy and Taylor in their Braziiian model. But in the models reviewed here, money is regrettably considered as a veil.

By combining all these neoclassical assumptions, non-neoclassical wedges, and other *ad hoc* features, a so-called computable general equilibrium model can be built. Despite the argument against using the concept of "equilibrium," these models are built to find a fixed point where markets clear *with wedges*. They interpret this point as a proxy of where the real economy is or could be if managed efficiently. For our purposes here we tend to take the former interpretation and use the model for analyses of policy alternatives, hoping that this simulated economy suits this purpose.

At IIASA we have opted for the simulation rather than the optimization method of operationalizing these models. The term "simulation" is vague. Here we follow the tradition of Kelley, Williamson, and Cheetham (1972) or Kelley and Williamson (1974), and use the term in the sense of calibrating a model with available data for a selected base year, with prameters taken from other partial analyses or merely conjectured.* If the output of the iterations converges to a reasonable price vector, we simulate the model and see if it tracks the history to a comfortable degree of precision. After the model passes this *ex post* test, we use it for various comparative counterfactual analyses. The serious problem with this method is the fact that parameters are not determined by a consistent process of estimating a simultaneous equation system in the conventional sense. The richness in specifications seen in these models always insures that there are more parameters than there are series of observations—making the system underidentified. A much longer passage of time would be needed before we could acquire enough data and techniques to obtain robust estimates of most of these paramters. The only alternatives available to us today, therefore, are either to make educated guesses on the values of key parameters, or to adapt a

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*This "guesstimation," as it is popularly called, could be done using other methods such as optimization models, but in this particular method of simulation, its use is more prevalent and extensive mainly because of the richness of specification.

simpler framework using, for example, Cobb-Douglas production functions with only Hicks neutral technical progress. For an example of an elaborate study with a simple framework, see Engle (1979). We have chosen the first alternative because of our desire to include sensitivity and counterfactual analyses where such parameter values as elasticity of substitution play important roles.

3. THE KELLEY-WILLIAMSON RDC MODEL

An Overall Review*

The RDC model developed by Kelley and Williamson (1980a) has various features for studying a small, open, and urbanizing developing country. It is an eight sector model: two modern sectors, three traditional sectors, and three housing sectors. Capital intensive services (KS) and manufacturing (M) are the modern sectors, and the three traditional sectors are urban traditional service (US), rural service (RS), and agriculture (A). Housing sectors include higher-cost urban housing built by the KS sector, lower-cost urban housing built by the US sector, and rural housing built by the RS sector. The two urban housing sectors use land explicitly which means that the urban land is considered as one of the scarce resources, while in the rural area land for residential use is supposedly abundant. Among the services provided by the three service sectors, only those in the KS sector (transportation, electricity, etc.) are interregionally tradeable, and the two traditional service sectors (US,RS) provide nontradeable services. This nontradeability of traditional services, together with the differences in housing cost, gives the cost-of-living differentials between the urban and rural regions, which could become a crucial factor in the decision-making process of rural-urban migration.

There are four production factors: skilled labor, unskilled labor, capital, and land. In the two modern sectors, skilled labor, unskilled labor, and capital are employed. The skilled

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*This review is brief. A more detailed review appears in Sanderson (1980) and only the skeleton of the model is described here.

labor force is trained from the pool of unskilled labor. The training is considered as a human capital investment depending on the return to skill and competing for funds with the physical capital investment. The cost of training is supposed to be covered completely by the two skill-using sectors. In other words, training is totally sector-specific. Another assumption employed in production relations is that capital and skill are complementary (e.g., Fallon and Layard 1975): the more capital equipments exist, the more skill is required. Because of this assumption, capital accumulation increases the demand for skilled labor. Whether or not the wage for skill increases depends on the supply elasticity of skill, which in turn depends on the government's general education policies. It is also noteworthy that the assumption of rigid input-output relations is not used in the RDC model; intermediate inputs are used directly in production functions, allowing for the input substitutions from relative price changes.

Two traditional service sectors (US,RS) only use unskilled labor with diminishing returns, and the laborers receive the average product as their income, while all factors of production in other sectors receive their marginal product. The agricultural sector uses unskilled labor, capital, and land.

The factor markets are supposed to be imperfect. The allocation of physical investment among capital-using sectors (KS; M, and A) is determined by a return-differential-minimization algorithm without forcing the disappearance of return differentials. With the imperfect capital market, low cost housing investment is all self-financed. This means that the private saving available for investment in physical capital and human capital is the saving net of the fund required for housing investment. As to the labor market, the most important aspect of its allocation in the model is the rural-urban migration. People are supposed to compare the different levels of welfare they could enjoy in urban and rural areas. At this moment, it is simply assumed in the model that the level of income deflated by cost-of-living in each of the two areas is the major factor determining the level of welfare, and that people would react to different levels of welfare by migrating to the higher welfare area with some time lag.

With regard to consumption demands, the "extended linear expenditure system" (ELES) is employed. Its choice, authors claim, should be warranted because (1) it captures the Engel effects, (2) it is easy to incorporate different demand patterns across regions or sectors, (3) the concept of basic minimum needs can be incorporated, and (4) the endogenous saving ratio is used. All of these are advantageous features for studying a dynamic developing economy.

Finally, the model is closed, with the public and foreign sectors always in balance. All the government revenue, through tariffs and taxes, are spent in the same year, either for public consumption or public investment, and the public investment is influenced not only by the total revenue but also by such a demographic feature as the rate of urbanization by assuming that the higher the pressure of urban growth, the higher the demand for public investment. The foreign trade sector is specified as always in balance when foreign aid is included. These two sectors could include many policy variables which can be used for later anlayses of policy options, e.g., various tax and tariff rates, the amount and kind of public investment, the rate of foreign exchange, and so on.

Observations

The RDC model is a great leap forward from the simple framework of the two-sector general equilibrium the authors used before (Kelley, Williamson, and Cheetham, 1972), with a correct regard given to the situation of data availability in contemporary developing countries. Several observations could be made, however, on various aspects of the model. Although some observations seem to be critical, they are made to remind readers of some underlying assumptions of various parts of the model. These observations, in addition, sometimes seem to demand more complicated specifications. It is, however, a matter of choosing an optimum complexity in the frustrating trilemma of reality-data-availability-and-analytical tractability.

Production

One of the contributions Kelley and Williamson made in the RDC model is to recognize the importance of interregionally non-tradeable commodities (i.e., urban traditional and rural services) which together with housing rent differentials compose interregional cost-of-living differences. These services, therefore, have strong influences on urbanization and consequently on the actual income distribution. It is hoped that they have reversed the past tacit tendency of modelers to simply ignore such sectors, mainly because of the difficulty in getting data.

The capital skill complimentarity is specified by the authors in the nested constant-elasticity-of-substitution (CES) function by $F[\phi(K,S),L]$. Although this is a useful specification, one word of warning is in order here. It assumes the same substitution parameter values between "skill" and capital throughout different development phases. This may bring about some erroneous results if what one is interested in is a long-term structural change. For example, in the early phases of development in Japan, the ratio of investment into construction was higher than into producers' durables; later this ratio was reversed. It is not easy to believe that the increase in capital stock caused mainly by construction could bring about the same increase in demand for "skill" as the investment in primarily machinery and equipment. The complimentarity should be quite higher in the latter case.

The agricultural sector has a Cobb-Douglas production function in this model. This seems to be quite appropriate for the given assumptions regarding a "typical" developing country. Arguments against this specification may be more apparent than real, given earlier studies that show a difficulty in rejecting the hypothesis of unitary elasticity of substitution (Hayami and Ruttan, 1971). Special cases can be analyzed separately (e.g., Colosio, 1979) including large scale commercial agriculture or use of skill in this sector.

In two modern sectors and in agriculture, Kelley and Williamson now use intermediate inputs in the production function, thereby doing away with the rigid assumptions of fixed input-output

coefficients. This is a great improvement. In the past, many studies used fixed intermediate input-output relationships to analyze the structural change of an economy: an inherent contradiction. Still, there are problems with the specification used by Kelley and Williamson. One is the method of estimating production parameters (share parameters). It may be that, with the amount of data available in many developing countries, the estimation could be carried out only by simulation—a choice of the values that replicate history with a certain degree of precision.* Another problem refers to the difficulty in incorporating input—saving technical progress. Only input substitution through relative price change is accounted for. These could be topics for future research.

Urban Land

Kelley and Williamson incorporate the urban land market. This is quite important. In studies focused on urbanization and development, ignoring the fact that urban land is a scarce resource could result in misleading conclusions. It would be unrealistic to assume that the level of utility depends only on income and prices of all consumers' goods except housing. People do take into account how and where they live, and how much it costs them to do so. In a developing country, it is surely more appropriate to assume that the rent and other direct costs matter much more than amenities to a typical resident. In this sense, the specification used by Kelley and Williamson is quite appropriate. They incorporate derived demand for urban land, which determines the rent and the urban area by equilibrating with the derived demand for agricultural land. They ignore the intraurban transport cost, i.e., non-zero sloped rent gradient. Its incorporation is possible but involves the use of highly simplifying assumptions, and should be left for case studies where these assumptions are not so unrealistic (e.g., countries

*Luckily, social accounting matrices (SAM) have become very popular and many, if not all, countries have given efforts for building them. The development in this area would make KW specifications more doable. But having a SAM for only one year, the base year, allows no estimation possibility for rates of change of the use of each intermediate good due to technical progress.

with a high primacy rate, and with big cities that are monocentric and fairly homogeneous).

Consumer's Demand

The use of ELES is proposed in this model rather than linear expenditure systems (LES). This enables endogenization of saving, an attractive feature. Although it may be the most appropriate consumer's demand specification available to date for studies of developing economies, we should be aware of assumptions behind this nice feature. First of all, ELES (or any other specification) does not derive an endogenous savings ratio through carrying out explicit intertemporal utility optimization. It is assumed that the marginal propensity to consume is the ratio of the subjective discount rate and the interest rate and is supposed to remain constant over time. This constant propensity to consume, plus the Frisch parameter* determines the average saving ratio.** Although with the given assumptions these interpretations are excellent, we must be careful to examine the validity of these assumptions, especially in time-series analyses. If the constant marginal propensity to consume is a misspecification, the result may not pass the *ex post* test of simulation, which is likely when we are dealing with as long a period as half a century. It could be that LES or other specifications with exogenous (but variable) saving ratios might be better in some cases.†

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*The Frisch parameter is defined as the inverse of the supernumerary income ratio, or as it is often called "expenditure elasticity of the marginal utility of expenditure."

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$$S = \frac{1}{1 + \frac{W\mu}{1-\mu}} = \frac{1 - \mu}{1 - \mu + W\mu}$$

where S = average saving ratio, μ = marginal propensity to consume, and W = Frisch parameter.

†LES (ELES) also suffers from the asymptotically unitary income elasticity as has been pointed out (e.g., Sanderson, 1980).

Foreign Trade

For foreign trade, the authors chose to use the "vent for surplus" specification. This specification allows an analysis of net trade by sector. The only difficulty seems to be that the agricultural export (X_A) is the balancing factor that ensures the equality of equation (55) in their model (Kelley and Williamson, 1980a:37):

$$\left[\bar{P}_M^W M_M + \bar{P}_Z (Z_{KS} + Z_M + Z_A)\right] - \left[\bar{P}_A^W X_A + \bar{F}\right] = 0$$

where

$\bar{P}_M^W M_M$ = imports of manufacturing (M) goods measured in the world market price

$Z_{KS}+Z_M+Z_A$ = sum of imports of raw material inputs to KS (capital intensive service), M, and A (primary) sectors

$\bar{P}_Z$ = price per unit of raw material imports

$\bar{P}_A^W X_A$ = export earnings of the A sector

$\bar{F}$ = foreign capital inflow

Unless the foreign exchange rate or tariff rates flexibly adjust to the world and domestic conditions to ensure this equality, such phenomena as "famine export" become implicit in this specification, rather than "vent for surplus." If none of these is the intended case, then we need a mechanism to allocate foreign exchange on M_M, Z_A, Z_M, and Z_{KS}, when export earnings are less than import requirements, since all the prices and foreign aids are exogenous in this equation. One solution besides the flexible exchange rate would be to let the balance of payments be endogenous and treat it as foreign saving. Then,

$$M - X = D = FS$$

and

$$PS + GS + FS = I$$

where

M = imports
X = exports
D = deficit
FS = foreign saving
GS = government saving
PS = private saving
I = investment

If trade plays a more important role in the model builder's mind, then the Armington specification would be more appropriate (see Section 5.2).

Dynamic Aspects

The dynamic aspects of this RDC model include investments and migration. Investments in "skill" and housing compete for funds with the conventional physical productive investments. The authors' specification of investment in "skill" is excellent. They assume that skill investment takes place in response to the rate of return on skill, and is carried out as a sector-specific training of two modern sectors. The government is responsible for the general training, which shifts the skill supply curve—or the availability of trainable labor—which is positively sloped reflecting the increasing cost of training. It is a fairly complex specification compared with other models of similar frameworks, which usually ignore the human capital or take different kinds of labor exogenously given. To the extent that the skill accumulation is a necessary condition for rapid economic growth through better utilization of newer technologies (due, again, to the skill-capital complementarity), however, the skill accumulation is not to be ignored.* The complexity of the implementation of this specification, therefore, is a challenge to the modelers which should be taken seriously.

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*If "skill" collects quasi-rents as many authors claim (e.g., Langoni, 1977), then this aspect of the model has an important relevance to the problem of income distribution. See also Tan (1980).

Conventional productive investment allocation, however, is specified as a total return differential minimization algorithm. This may, in some cases, result in an unwanted "bang-bang" solution. Imagine a case where modern service and manufacturing have similar rates of return and agriculture a much lower rate. A small change in $\tilde{r}^*_M$ (the rate of return in the M sector) or $\tilde{r}^*_{KS}$ (that of the KS sector) would result in all investment going into manufacturing in one year, and into the modern service sector the next. This is hardly what can be expected from the real economy.

Rural-urban migration is handled within a Todaro framework, but the interregional wage differentials are deflated by cost-of-living indices, which has become possible due to the authors' incorporation of nontradeables and housing sectors. Also a marginal employment ratio is used for deriving the expected income in the urban area.

Concluding Remarks

Overall, the RDC model is an excellent model for studying the demoeconomics of a developing country. The complete success of the model applied to a specific economy will be established after some of the data problems are solved, especially data related to skill investment and traditional service sectors. The comparative static results that the authors carried out (Kelley and Williamson, 1980b) seem to indicate that the model is quite capable of analyzing a representative developing economy. For the model's use in a specific case study, careful consideration would be needed of the institutional factors of the country and insufficient data. Some simplification is inevitable. We now turn to these case-study models.

4. CASE STUDIES

In this section, I shall briefly describe and comment on the ongoing work in the Population, Resources, and Growth (PRG) Task within the HSS Area. These cases include the Mexico model (Colosio, 1979), the Sweden model (Karlström, 1980), and the Hungary model (Zalai, 1980). All three emphasize important aspects of the development of each country: Mexico—bimodal structure of the agricultural sector; Sweden—emphasis on trade and emigration to the USA; and Hungary—aspects specific to a centrally planned economy. Each author has elaborated on the aspects unique to his country and has simplified for the other aspects. Brief mathematical statements of these models are given in the Appendix.* The following comments will mainly be on model specification due to my limited knowledge of the socioinstitutional aspects of these countries.

Mexico Model: An Overview**

This model built by Colosio (1979) tries to capture various aspects seen in Mexican development. His sector division is:

1. Modern industrial
2. Commercial agriculture
3. Small-scale agriculture
4. Urban informal
5. Public

As is clear from this sector division, he introduced dualism in both the rural and urban areas: the modern industrial and the urban informal sectors in urban areas, and the commercial capital-intensive agriculture and the traditional small-scale rainfed agriculture sectors in rural areas.

The modern industrial sector is produced by capital and labor with factor augmenting technical progress. The production function is that of CES. Another urban sector, the informal

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*For comparison a model for Japan (Shishido, 1981) is also briefly described in Appendix 2.

**Part of this model was modified after the publication of Colosio (1979). Although the modified version is used here, the differences will be pointed out.

sector is supposed to be produced only by labor. The production function is linear in Colosio's original paper but in the modified version it is

$$Q_4 = \alpha_4 L_4^{\beta_4} \qquad \text{where} \qquad 0 < 4 < 1$$

bringing in diminishing returns, and renumeration is, of course, the average product. (The difference of average and marginal product is the proprietor's rent.) Note there is no technical progress assumed in this sector.

The two sectors in the rural area have the following production functions: CES for commercialized agriculture with factor-augmenting technical progress and Cobb-Douglas for the small-scale agriculture without factor-augmenting technical progress. The productivity increase from, say, public investment in this sector is assumed to take the form of purely product-augmenting technical progress.

The investment specification which Colosio elected to use is that of an imperfect capital market. A fixed proportion (sector-specific) of the saving from one sector is assumed to be reinvested in the same sector regardless of other investment opportunities and the rest goes into the pool of savings fund which is alloated over different sectors in proportion to the capital returns in the previous year. It is also noteworthy that the proportion reinvested into small-scale agriculture is always one, i.e., there is no agricultural surplus from this sector supporting other sectors.

Migration of the labor force is of the traditional Todaro type, i.e., the employment ratios of formal and informal sectors are the weights in forming the expected income of the urban area or the complete lottery specification (i.e., the sector in which a migrant obtains employment is determined completely by chance).

Observations

The following are basic observations on (1) the bimodal structure of agriculture, (2) the exclusion of intermediate inputs, and (3) the internationally closed nature of the model.

(1) The most attractive feature of the model is the specification of the dualism in agriculture. The production specifications mentioned above (CES in the commercialized subsector, and Cobb-Douglas in the traditional subsector) with varying assumptions of technical progress is quite plausible. Minor comments, however, could be made. One is on the assumed equality of elasticities of substitution between any two of three factors in the commercialized subsector. Some nested form may be employed depending on the estimations of production relations from the data. Next, outputs from the two agricultural subsectors are treated as completely distinct from each other. From the point of view of urban consumers, however, it may be that these outputs are very close substitutes unless the two subsectors have different product mixes. If they are highly close substitutes, the complete separability assumption of the underlying (Stone-Geary) utility function may become problematic.

Third (in the modified version), traditional agricultural labor received value marginal products as wages. It is an old question, but could this specification be warranted from the institutions in rural Mexico? I tend to think not. Colosio's original specification of average product may fit better especially in such a specification as a migration function.

(2) The model is a "final demand" model without consideration of intermediate inputs. The outputs can be treated as net outputs of the own-sector intermediate inputs. Then the remaining question is how important are non-diagonal elements of the input-output (I/O) matrix? Current inputs produced by the modern sector and used in commercialized agriculture may be significant amounts. Or, the products of urban traditional or agricultural sectors can be of importance as intermediate inputs of the modern sector. If, in fact, they are significant as I tend to believe they are, the cost of their exclusion may be higher than Colosio expected. It should be recalled that in a highly simplified framework, the inversed Leontief matrix and the final demands determine the total output, and the impact of the former could be quite high. It could become even higher as the level of intersectoral linkages increase.

(3) As it stands, the model is closed to any foreign relations. This probably is a great drawback. Not only does he exclude all trades, but he also excludes international flows of factors: capital inflow into Mexico in the form of direct investment and foreign aid, and legal and illegal migration to the USA. These may become very important in the study of Mexican development. It would be worthwhile to extend the model to an open economy model.

Some more minor comments can be made on factor allocation, i.e., investment and internal migration. The investment is specified as partially imperfect as has been described. It seems, however, that Colosio assumes that a fixed portion (ζ_i) of the sector's saving is reinvested into the same sector regardless of other opportunities. These ζ_i's are constant. If the model is used for a long run analysis, however, it should be taken into account that as the capital market develops these ζ_i's decrease. For shorter run analyses, this is not a problem of course.

With regard to migration, the simple lottery assumption does leave room for improvement taking into consideration the institutions in employment seen in Mexico. This specification means that a migrant's expectation is formed by the assumption that employers choose anew in every period their employees *randomly* from the pool of all potential urban workers. This could or could not be the institutional arrangement in Mexico. I tend to think not.

Concluding Remarks

The Mexico model is attractive in that it disaggregates agriculture into the modern and the traditional subsectors. It is beneficial because with different price and income elasticities of demand for these commodities (assuming consumers distinguish these two subsector commodities) and different price elasticities of supply (the phenomenon seen in rural Mexico), the apparant bimodality can be replicated by the model setting a stage for analyzing several policy implications. It would be truely advantageous if this model could be extended to include international aspects. The inclusion of intermediate inputs would also make the model more powerful.

Sweden Model: An Overview

Karlström (1980) has built a model for the analysis of the demoeconomics of historical Sweden for the period 1870 to 1914. This time period was chosen because of the "...conventional view that considers the 1870s as the starting decade for the industrialization era in Sweden and a dramatic political event, the outbreak of the First World War, as the terminal year."

Contrary to the Mexico model, this model emphasizes the openness of Sweden's economy in this period, not only in terms of trades and foreign capital inflows, but also in terms of international population movement, especially emigration to the USA. Indeed it is astonishing to see how much this demographic factor has influenced Swedish growth paths. As can be seen in Table 1, the average population growth rate *per decade* in the last one hundred years in Sweden is about one third that of the USA or Japan, bringing the per capita product growth rate to a figure almost as high as that of Japan and more than 10 percent higher than that of the USA.

In order to capture the openness of the economy the sector division of the model is accordingly trade-oriented as shown:

1. Agriculture and primary industry (excluding mining)
2. Export-oriented industry (including mining)
3. Home market-oriented industry
4. Services
5. Construction

Table 1. Average growth rates per decade for Sweden, Japan, and the USA

	Total product	Population	Product per capita
Sweden (1860s - 1960s)	37.4	6.6	28.9
Japan (1880s - 1960s)	48.3	16.3	32.0
USA (1850s - 1960s)	39.2	18.7	17.3

Source: For Sweden and the USA, Kuznets (1971), for Japan, Ohkawa and Shinohara (1979).

The sector division, especially between export-oriented and home market-oriented is determined by considering the export (input) share of a product in total exports (imports) or in the gross output of the product.

Karlström uses a nested function for the agricultural sector; capital and labor are combined in a CES form to make a composite production factor, H, which in turn is related with land in a Cobb-Douglas form. Capital and labor have factor-augmenting technical progress coefficients, but land does not and grows exogenously. The argument for using a CES form to link capital and labor comes from the elasticity of substitution of 0.6 estimated by Jungenfeld (1966). For all other sectors, Karlström uses CES production functions with capital and labor.

The numeraire of this model is the world price of the sector 2 good,* which is equal to the domestic selling price. For the two trade-sheltered sectors' (4 and 5) prices, domestic prices are equal to producer's costs. For the primary and home market-oriented sector, however, the weighted average of world prices and producer's costs are used as a domestic selling price, the weights being the shares of domestic supply and imports in the total domestic demand.

The factor returns are determined by the neoclassical marginal conditions. The rural area contains fixed amounts of capital and labor which determine with the equilibrium market prices their returns. The urban area also contains a given level of homogeneous labor and given capital stock. Wages and rents are assumed to differ between sectors even though the factors are supposedly homogeneous. Assuming that sector 2 is the leading sector in wage determination, and assuming stable shares of skilled labor in each sector relative to other sectors, Karlström specified the wage structure in urban areas as fixed ratios, i.e.,

$$W_j = \bar{\omega}_j W_u \qquad j = 2,\ldots,5$$

*All sectors are specified by the numbers given on p. 21.

where

W_j is the wage in sector j

$\bar{\omega}_j$ is the sector specific constant

W_u is the level of urban wages

Similarly for rents:

$$RC_j = \bar{\varepsilon}_j \, RC_u \qquad j = 2,\ldots,5$$

where

RC_j is the rent of sector j

$\bar{\varepsilon}_j$ is the sector-specific constant

RC_u is the level of urban sector rents

For trade, Karlström assumes less-than-infinite elasticities of substitution between home goods and foreign goods of the same sector [the Armington specification (Armington, 1969)]. The use of this specification avoids the problematic situation that with infinite elasticities (if foreign goods and home goods are complete substitutes) as is usually assumed in the pure theory, one country cannot produce and export a larger number of commodities than the number of primary factors of production. The trade is always in balance in this model. The exports of sector 2 would be the balancing factor, or this sector determines the foreign exchange availability for the whole economy.

With regard to physical investments, Karlström assumes a strong capital market imperfection and excludes cross regional investment, i.e., all saving in the rural area is reinvested in the same area. The same is true for the urban area. The composition of capital stock stays constant, i.e., the porportions of machinery and buildings in capital stock and new investments are always constant.

Karlström's migration specification primarily considers emigration to the USA. The model incorporates the differences between the rural population's own wage and the weighted average of expected income in Swedish urban areas and expected income that could be earned in the USA. Emigration to the USA is then given by a function of the ratio of Swedish urban income to the wage in the USA. As one can see, all are of the Harris-Todaro type of specifications.

Observations

The model has many advantageous features. The use of the Armington specification in trades, and explicit incorporation of the emigration of the population to the USA are definitely among them. In addition the simplicity of the model is a strength in that it gives the user of this model high flexibility and analytical tractability. Care should be given, however, that the straightforward application of all his specifications, without modifications for a long-run analysis, may not be recommendable. The reasons are described together with some other observations regarding:

(1) Factor returns
(2) Investments
(3) Trades

(1) The ratios of factor returns in the four sectors in the urban area are fixed. Karlström explains the wage part from the past behavior seen in the wage determination of various sectors. But there is no clear explanation for the part of capital returns. To assume these relationships is a convenient way of studying an economy with different factor returns in the short run, when one's interest is not on the "cause" of the differentials. But in the long run, this constancy assumption may hamper a careful analysis of the structural change of an economy.

(2) Similar observations can be made on the investment specification. To assume away the cross-regional investment from 1870 to 1914 in Sweden may mean to assume away the gradual capital market development during the phase of Swedish rapid urbanization. To assume, also, that the equipment structure proportions are

always fixed for a half century may become problematic in later analyses. The portion of equipment is expected to increase as the development proceeds. But the distinction of construction stock from the machinery and equipment capital stock is a nice feature of this model. It would be unrealistic to assume they are homogeneous when they come from different sectors, have different prices and lifetimes, have different tradeability, and are produced by different technologies (factor intensities).

(3) Karlström's trade specification is certainly appropriate for studying an open economy. The determination of sector 2 exports, however, is somewhat passive in Karlström's model. It is given the role of the limiting factor in his scenario: i.e., the supply capacity of the sector determines the availability of foreign exchange for other imports. In the mathematical statement, however, it is given a role of a residual. Trades of all other sectors are specified *à la* Armington and determine the amount of export of this sector as

$$P_2^W EX_2 = P_1^W M_1 + P_2^W M_2 + P_3^W M_3 - P_1 X_1 - P_3 - F - RE$$

where

M = imports
X = exports
P = price (superscript W means world price)
F = foreign capital transfer
RE = remittance

and subscripts specify the sectors.

It may be that the role of sector 2 should be reversed in the equations so that it is in agreement with Karlström's scenario. That is, let the world demand determine the export of sector 2 through the Armington specification, incorporating the comparative advantages in the Swedish export-oriented industry. There is evidence that the export prices and domestic prices diverge even for small countries (Kravis and Lipsey, 1977). This specification, therefore, is not in contradiction to the reality of a small country. Some other factor, however, might be needed in

order to balance payments (possibly imports of sector 2), or the balance of payments could be endogenous.

The next point refers to the use of the constant growth rates of the world market. Karlström assumes that

$$Ex_i = EX_i^o \left(\frac{P_i}{P_i^W}\right)^{\varepsilon_i} \cdot e^{\nu_i t} \qquad i = 1,3$$

where all notations are self-evident except for ν_i, which measures a constant index that captures the trend of world trade increase. But there is no need for ν_i to be constant for half a century. The original Armington specification, derived from the CES form is

$$X_{ij} = b_{ij}^{\eta_i} X_i \left(\frac{P_{ij}}{P_i}\right)^{\eta_i}$$

where

X_{ij} = demand of commodity i produced in country j

X_i = total demand of commodity i

P_{ij} = price of commodity i produced in country j

P_i = general price level of commodity i

η_i = elasticity of substitution in the CES aggregate product function nested in the assumed utility function

b_{ij} = a constant (distribution parameter in the CES function)

Then, instead of having

$$b^{\eta_i} \cdot X_i(t) = EX_i^o \cdot e^{\nu_i \cdot t}$$

thereby forcing the world trade to increase at a constant rate, more reality could be incorporated into the model by explicitly using world trade or demand of the commodity.

Concluding Remarks

The advantages of the model include the trade and emigration specifications, as well as the general simplicity of the model, including the complete homogeneity of urban labor and the putty-putty nature of urban capital stocks. With the increased consideration of institutions actually seen in Sweden, the model becomes a highly useful tool for the purpose of analyzing urbanization and growth in Sweden. A slight modification of the model in order to relax some rigid assumptions of the factor returns and investments is worthwhile for long-run analyses.

Hungary Model: An Overview

Zalai developed this model in order to analyze the economy of Hungary. He argues that the technique of applied general equilibrium modeling can be used for centrally planned economies. He also shows that a general equilibrium model and one form of an optimization planning model have exactly the same mathematical form but with different interpretations of the parameters and variables. For this purpose Zalai uses the applied general equilibrium model developed by Bergman and Pór (1980) for Sweden.* The objective function of the assumed optimization problem is the surplus consumption of all goods over and above the planned targets combined in a Cobb-Douglas manner, or

$$g(D) = \prod_j (D_j - \gamma_j)$$

where

D_j = consumption of sector j

γ_j = planned consumption of sector j

*Among the models reviewed in this paper, the model most resembling the Bergman-Pór model is Karlström's.

Zalai's model is still very general. There are n sectors which are all producing, exporting, and importing (in principle) and one book-keeping sector for investments. All of the n sectors have linear homogeneous production functions with respect to capital and labor. The coefficients of intermediate inputs are fixed. The user cost of labor consists of wages and tax on wages. The user cost of capital consists of depreciation and the tax on users of capital. Both taxes are also called net return requirements and are endogenous so that the markets clear. These user costs can be interpreted as solutions of the dual problem. For example, the sector specific user cost of labor (LC_j) is

$$W + W_j^+ - W_j^-$$

where

W = the shadow price for labor in general

W_j^+ = the shadow price associated with the upper limit of the sector j's labor

W_j^- = that associated with the lower limit.

Similarly for the capital:

$$RC_j = P_k \cdot \sigma_j + SK + SK_j^+ - SK_j^-$$

where

RC_j = the total user cost of the capital in sector j

P_k = price of capital goods

σ_j = the depreciation rate

SK, SK_j^+, SK_j^- = the shadow prices associated with total and sectoral upper and lower limits of capital

It is assumed that the production units minimize the cost of production. The selling price is determined by this minimized cost and some required profit rate (in other words a mark-up of the price).

The demand of the household sector takes the form of a LES (Linear Expenditure System). It is naturally derived from the objective function mentioned above. Of course, the so-called minimum subsistence consumption level is now interpreted as the target level of consumption.

Zalai's trade specification is unique in the sense that he distinguishes the rouble and the dollar trade regions. He uses specifications similar to Armington's for competitive imports and exports. Noncompetitive imports are proportionate to the outputs of each sector. Zalai, however, gives several different interpretations to this specification. The competitive imports are assumed to be considered as the perfect substitute of domestic products by consumers. There elasticity parameters are supposedly indicating, instead of elasticities of consumers' preference, the friction that exists in shifting from imports from the dollar (rouble) regions to imports from the rouble (dollar) regions as the relative import prices change. For exports Zalai assumes that even a small country can affect the world price, at least at the margin. He, therefore, says that the elasticity of the export function, in this case, is somewhat lower than the complete price-taker specification.

The total investment, in Zalai's model, is a fixed proportion of the government and household consumption. There is no specific mechanism to determine *ex ante* sector specific investments because as in the Sweden model above, this model assumes a complete putty-putty capital stock.

The demoeconomics of urbanization are explicitly introduced in this model by assuming different consumption patterns between the urban and rural households. Zalai also assumes that nonagricultural activities can be in the rural area by a specified share ($s_{rj} = 1 - s_{uj}$) by the sector. The shares of expenditure between the urban and the rural areas are also fixed at the base year level.

Observations

The proposed model is excellent because of its compactness and clarity, and at the same time reflects so much of the realism of a centrally planned economy. The following observations can be made at this stage:

(1) The interpretations of various parameters
(2) The government and investment
(3) The demoeconomics
(4) The relationship of the binding constraints in optimization and general equilibrium techniques
(5) Future extensions

(1) Zalai tries with ingenuity to at least partially divorce the *technique* of *applied* general equilibrium modeling from the *theory* of general equilibrium. The way he does this is by giving the parameters different meanings, despite the technical similarities with the general equilibrium models, for example, taxes. Producers are assumed to minimize cost of production: labor cost and capital cost.* Labor cost consists of wage and tax; capital cost consists of depreciation and tax. It may be felt that this is too rigid for factor markets to clear, but one soon notices that taxes are endogenous. So this model can be used by central planners to find the tax rates (minimum return requirement) which let the given factor endowments be completely utilized rather than find the factor allocation at given tax rates.

Zalai also calls this model a non-zero profit model by introducing exogenous sector-specific profit rates π_j which are obtained by a mark-up pricing. The form, however, is identical to specifying indirect tax in more of a mixed economy model. So the only difference here is who receives this "profit" and how it is spent. But this difference is more apparent than real if one considers that production in a centrally planned economy is largely organized by the public sector.

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*Intermediate input-output coefficients are fixed.

The interpretations given to the trade specification is again noteworthy. The competitive imports are complete substitutes of the domestic products. The elasticities are "friction parameters" of shifting from dollar region imports to the rouble region imports (or vice versa) depending on shift of relative import prices. This, then, should be considered as a reduced form of some structural relationship other than the Armington utility functions. One could then think of a structural model, whose reduced form includes all of the three prices—prices of imports from dollar and rouble regions and the domestic price—which may be more appropriate. The export function is also non-Armington despite the similarity in form. It is now a *supply* function of exports rather than demand for specific outputs from the rest of the world. It is also interesting that Zalai assumes that even a small country influences world prices. Therefore, the elasticity of exports is specified as lower than the elasticity obtained from the complete price-taker assumption. It would be interesting to see how this discarding of the price-taker assumption would change the whole model behavior for Hungary. It must have a country specific result. Also, distinguishing the actual world price of a commodity from its world general price may be a nontrivial task, but of great interest.

(2) The government sector in the Hungary model is naturally playing a very big role. But it is all implicit. For example, Zalai specifies an exogenous government current expenditure, but he does not say anything about how the money comes. For example, whether or not all the taxes (also called minimum required returns) on factors go to the government, or whether a part or all of the required profit Π_j goes to the government. Depending on these questions, it may be that the way of financing investment may differ. The total investment in the model is proportionate to the sum of public and household consumption. It is a compromise Zalai made to keep the comparability with the optimization model. In the optimization model he used as an example, he had an objective function which had only household consumption as arguments, in an intratemporal framework. Without this or another mechanism for determining investment then, the investment can be

pushed to zero. But it is still unclear if the households' saving plays a role at all, and if so, what the mechanism is.

(3)* The demoeconomics of Zalai's Hungary model is peculiar in a sense that he does not model the spatial migration of the labor force, but rather the industrialization of the rural area. In other words, by changing the value of sector-specific shares of activities located in the rural area, Zalai promotes industrialization but keeps the people in the rural area with their rural pattern of consumption. It is an interesting way of modeling demoeconomics where population movements not only depend on micro-individual motives, but also on the planned resource allocation in accordance with national objectives. One thing that remains inconsistent is that despite the fact that he lets the mix of economic activities change in the rural areas, the total expenditure share of the rural area is fixed at the base-year level. This may leave room for improvement. Also, to the extent that we see some population movement in the centrally planned economies, migration could be more explicitly a part of the model.

(4) As Zalai says in the paper, the ability of a static optimization programming model to simulate a general equilibrium resource allocation with prices derived from a dual solution is a known feature. However, this applies *only* when real constraints are binding. The central planners quite often have loosely defined limitations, including political constraints and such constraints as investment absorption capacity. When these not-well-understood constraints are binding, the interpretation of the model as reflecting a general equilibrium breaks down. Zalai, in this model, tries to avoid any of these problems or corner solutions by nonlinearity. To apply this model in reality, however, requires continued attention in this regard.

(5) It is not surprising to see that the planned economy model and the applied general equilibrium model of Bergman and Pór have almost identical forms mathematically, given Zalai's specification of the "typical" objective function and his "typical"

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*I have benefitted from discussion with U. Karlström in writing this observation.

optimization model being static. Quite often central planners have operational models rather than analytical models that are intertemporal rather than intratemporal. As a result, planners often have an objective function with investment or capital stock as arguments in a more dynamic framework. Given the advantageous features of the Hungary model, it would be interesting to extend Zalai's efforts, i.e., it would be interesting to see the dynamic aspects captured more explicitly, and the model modified to be more operational.

Another way to extend this model is by incorporating more disequilibrium. Dynamic disequilibrium is one major source of growth in a planned economy, although disequilibria especially in factor markets, are very common in market economies as well. Zalai claims the model as it stands is a *demand* constrained model. Because the supply constraints are more commonly observed in many centrally planned economies, however, the reality of this assumption could be questionable. Also his specification is that of equilibrium with endogenous levels of prices. Then his statement that demand determines supply holds trivially at equilibrium. It may be quite useful to extend this model into a more explicit quantity constrained model.

Concluding Remarks

This model is general and more of a prototype for centrally planned economies but at the same time offers useful insights into the technique and theory of modeling. It would be of great interest to see the model actually used for Hungary's case study, and then extended to incorporate more dynamic and disequilibrium aspects.

5. SOME FINAL OBSERVATIONS ON FUTURE DEMOECONOMIC MODELING

This paper has reviewed four general equilibrium models built in order to study causes and consequences of urbanization and economic growth.

The RDC model incorporates the advantages of the earlier Kelley, Williamson, and Cheetham (KWC) model (Appendix 1) and expands it for use as a prototype for models analyzing developing countries. The authors endogenize investment in human capital, housing, and the urban land market. They also introduce the distinction between tradeables and nontradeables. These are excellent improvements in model building and are in line with the real situations existing in contemporary developing countries; they allow researchers to highlight issues on urbanization and migration in a growing economy.

The three ongoing case studies in HSS emphasize aspects of development peculiar to Mexico, Sweden, and Hungary. Each adjusts the RDC model to suit the country studied, accentuating some aspects and simplifying others. As of today, however, none of these case studies has been simulated with empirical data thus preventing any further review. Inevitably, the discussion should now turn to "what next?"

In the short run, these three case studies should be tested with empirical data. This should be followed by case studies that include more of the contemporary, small, and open developing economies. Comparison of these with Sweden's (and Japan's) historical case would probably shed more light on the process of economic development.

More efforts should be given to combine, explicitly, demographic aspects with the kind of modeling expressed here.* With the population growth rate exogenously given, and labor force assumed as a constant proportion of the population, the only demographic aspect in these models so far is rural-urban migration (and emigration for the Swedish case) which is now only a function of some form of income differentials between origin and destination areas. Many studies show that internal migration is much more complex: age, skill level, educational level, the status of potential migrants in the rural area, family status, and sex all

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*See, however, Schmidt (forthcoming) for efforts to combine demographic aspects with the RDC model.

matter.* A simple Harris-Todaro framework** is not enough when one is interested in more than just macro aggregates and in more demographic aspects of the economy. Hay's study, among others, uses the probability specification to cope with this complexity (Hay, 1980). In view of these, we could proceed toward the more explicit inclusion of aspects that are of interest to both demographers and economists by disaggregating the population by age, income, education, and/or family size and by estimating the continuous migration propensity in the key variables if possible: if not, *group-specific* migration propensity can be used instead.† We have to be reminded, however, of the data requirement of these disaggregations. Studies, must, unfortunately, begin with available data; where data are not available, more efforts should be given to the improvement of data bases.

Another aspect that should be extended in future studies is income distribution, an important issue for contemporary developing countries. It is now included in our modeling efforts *only* to the extent that the computer will print out the functional distribution of income for each sector—shares of labor and capital. This is within the framework of a general equilibrium model. An extension of this framework would enable us to disaggregate the population by income. This would require a mapping of the functional distribution of income into a size distribution. [In order to do this, Adelman and Robinson (1978) assumed sector-specific size distribution of income, and Lysy and Taylor (1978) disaggregated the population into a total of 130 income recipient classes.] In our future efforts in HSS, it would be more fruitful if the aspect of income distribution were included. This would enable both a more detailed study of demographic characteristics and a more accurate analysis of various welfare levels and distributional policies.

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*See, for example, Caldwell (1968), Brigg (1971), Byerlee (1974), Nelson (1974), Yap (1976), Cornell et al. (1975), Hay (1980), and Barnum and Sabot (1975).

**Todaro (1969), Harris and Todaro (1970). For modifications see Johnson (1971), Porter (1973), Bhagwati and Srinivasan (1974), Corden and Findlay (1975), and Fields (1974).

†This also holds for consumption-saving patterns, factor supply patterns, and, if feasible, fertility rates.

Finally, the models reviewed here are all static, period-by-period equilibrium models. Although this method is very useful, there are always more approaches to be considered. Two such possibilities are dynamization and the introduction of non-Walrasian equilibrium or disequilibrium concepts. The problem with dynamization is primarily one of computation capabilities. The latter concepts, however, are very abstract and do not seem to be advanced sufficiently to handle numerically a whole economy in this kind of a computable model. They do seem to contain, however, possibilities that are worth pursuing in the hopes of future application to development countries, which are inherently in disequilibrium.

APPENDIX 1: THE KELLEY, WILLIAMSON, AND CHEETHAM MODEL

The KWC model (Kelley, Williamson, and Cheetham, 1972) is included in this Appendix since the later work of Kelley and Williamson is an expansion of their original model. This model is simple enough for readers to see the structure of a computable general equilibrium model and is flexible enough to allow policy analyses.

Basically what the authors did was to introduce dualistic consumption demand into the ordinary neoclassical two-sector growth model. The supply side of a dualistic economy has been studied by many including Lewis (1954), Fei and Ranis (1964), Jorgenson (1961), Zarembka (1970), and Sato and Niho (1971). These studies are based on the idea that developing economies are supply-constrained and that for the analysis of long-term structural change, demand is relatively unimportant. But we know that demand does have strong effects on the path of development. Japanese economic development is a good example of a country that has been supported by the strong propensities of its population to consume traditional (indigenous) sector goods rather than modern (usually imported) sector goods. Such important aspects of development as urbanization and income distribution are also strongly influenced by the terms of trade between agriculture and industry, which, in turn, are directly affected by patterns of

demand. More discussion on the role of demand can be found in Cheetham, Kelley, and Williamson (1974). Simply said, the KWC model is a modified two-sector, two-class economic growth model. The modification comes from the fact that their "consumers" in two classes consume outputs from both of the two sectors.

I shall go through the skeleton of the structure of the model here. The sufficient conditions for existence, and uniqueness of the solution are summarized in their book (Kelley, Williamson, and Cheetham, 1972). For a more detailed discussion of this model see Lluch (1977) and Sanderson (1980).

The two sectors in the KWC model are industry (index 1) and agriculture (index 2). Production in both sectors is done by two factors: capital and labor (equations 1 and 2). Both capital and labor are fully employed (equations 3 and 4). Factor returns are simply marginal value products (equations 5 and 6) that adjust instantaneously in the basic model and with certain lags in the modified model. Demands are those of consumption and investment. For consumers who spend all their wage incomes, the linear expenditure system is used with minimum subsistence needs being only food (equations 7 and 8). All capital returns are saved and invested (equation 9). The closed, private sector economy model is complete with market clearing conditions: supply equals demand (equations 10 and 11).

Basic Structure of the KWC Model*

$$Q_1 = F_1 (K_1, L_1) \tag{1}$$

$$Q_2 = F_2 (K_2, L_2) \tag{2}$$

$$\sum L_i = L \tag{3}$$

$$\sum K_i = K \tag{4}$$

*Technical progress, in the case of factor augmenting can be incorporated by just measuring capital and labor in efficiency units.

$$W = P_i \left(\frac{\partial F_i}{\partial L_i} \right) \tag{5}$$

$$r = P_i \left(\frac{\partial F_i}{\partial K_i} \right) \tag{6}$$

$$P_1 D_{1j} = \beta_{1j} (W - P_2 \gamma) L_j \qquad j = 1,2 \tag{7}$$

$$P_2 D_{2j} = \left\{ P_2 \gamma + \beta_{2j} (W - P_2 \gamma) \right\} L_j \qquad j = 1,2, \tag{8}$$

$$P_1 I = r \sum_j K_j \tag{9}$$

$$Q_1 = \sum_j D_{1j} + I \tag{10}$$

$$Q_2 = \sum_j D_{2j} \tag{11}$$

(Numeraire = P_2)

$$\dot{K} = I - \delta K \tag{12}$$

$$\dot{L} = \{ n_1 u + n_2 (1 - u) \} L \tag{13}$$

where

Q_i Output or value added of sector i, i = 1,2

K_i Capital employed in sector i

L_i Labor employed in sector i

K Total capital stock

L Total labor

W Wage rate

r Rate of return on capital

P_i Price of sector i good

I Total investment

D_{ij} Household demand of category j for sector i good

γ_{ij} Minimum basic need of good i by household category j

β_{ij} Marginal propensity to consume from supernumerary income of good i by household category j.

$\dot{K}$ Rate of capital stock increase

δ Rate of depreciation

$\dot{L}$ Rate of labor-force growth

n_1 Rate of urban labor-force growth

n_2 Rate of rural labor-force growth

u Proportion of labor-force living in urban area

Dynamic aspects in the basic model besides technical progress are capital accumulation and labor-force growth (equation 13). For the latter the authors assume different growth rates between urban (industrial) labor force (n_1) and rural (agricultural) labor force (n_2). In chapter 7 the authors bring in the factor market imperfection. The instantaneous factor market adjustment is abandoned. The intersectoral investment is now

$$\frac{I_{ij} \cdot P_1}{S_j} = i_{ij} = 1 - e^{-\mu[r_i - r_j - \tau]} \qquad \text{if } r_i - r_j > \tau$$

$$i_{ij} = 0 \qquad \text{if } r_i - r_j \leq \tau$$

where I_{ij} is the investment into sector i out of saving in sector j (S_j), and μ and τ are parametric constants. That is, unless the factor return differentials are higher than τ there would be no cross-sector investment. Even if the difference is more than τ, the flow of investment into the other sectors would occur gradually (Figure 1).

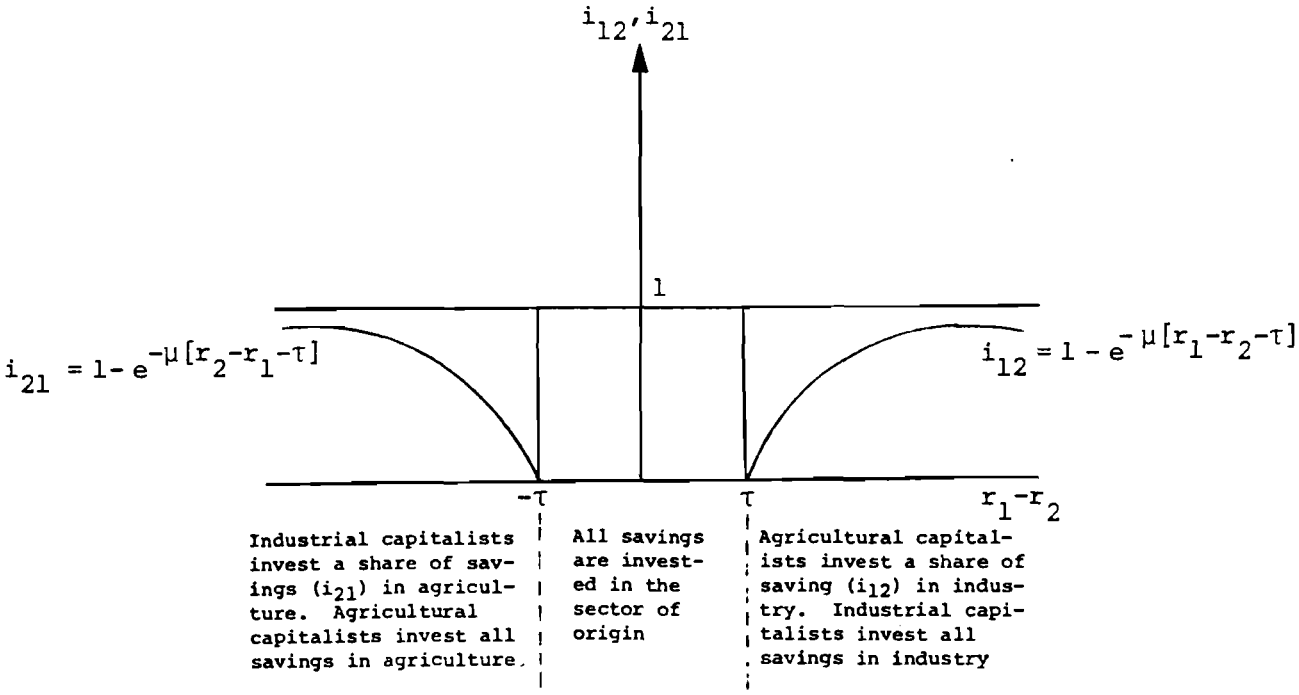

Figure 1. The rate of intersectoral flow of investment (source: adapted from Kelley, Williamson, and Cheetham, 1972:242).

A similar case exists for labor migration. The population responds to differentials between urban wage (W_1) and rural wage (W_2) and migrates to the higher wage area with some time lags. Different behavioral patterns are assumed, however, between rural and urban populations. The former feels that there is some cost (θ) to migration, and will not start moving into the city unless the wage differential exceeds this cost, while the latter does not consider the cost and starts migrating to the rural area as soon as the rural wage becomes higher than the urban wage (Figure 2). Thus,

$$m_{12} = \frac{M_{12}}{L_2} = 1 - e^{-\rho[W_1 - W_2 - \theta]} \qquad \text{if } W_1 - W_2 > \theta$$

$$\text{otherwise } m_{12} = 0$$

and

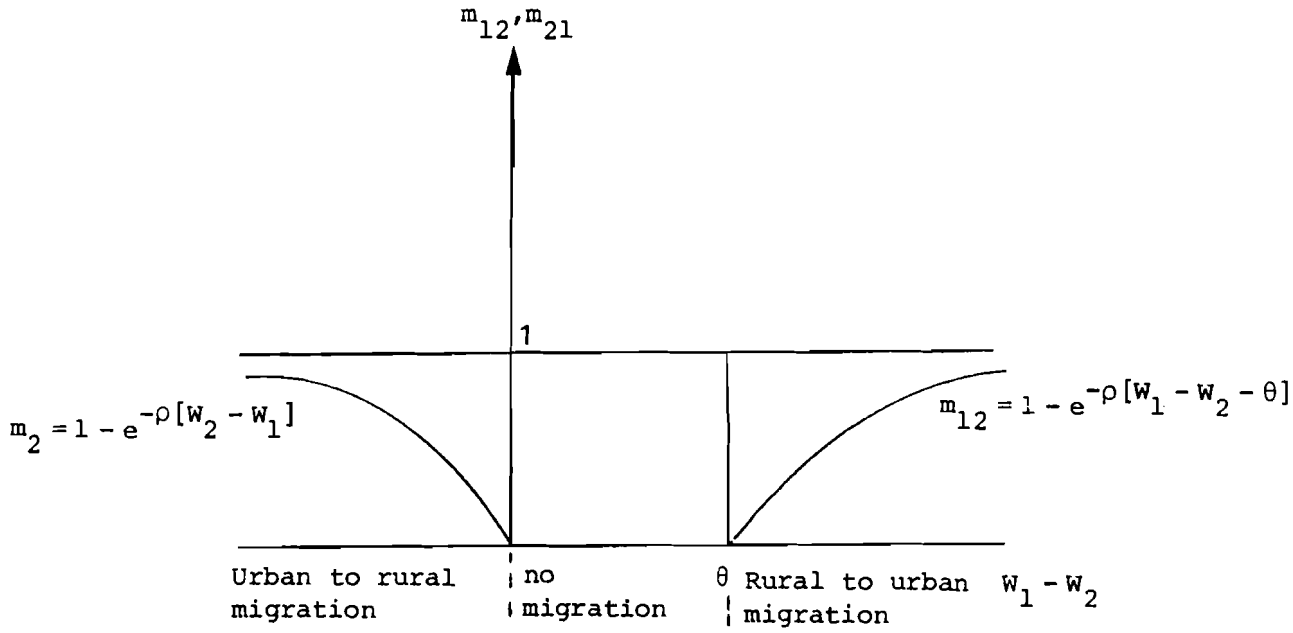

Figure 2. The rate of intersectoral migration of labor due to changes in wages (source: adapted from Kelley, Williamson, and Cheethem, 1972:250).

$$m_{21} = \frac{M_{21}}{L_1} = 1 - e^{-\rho[W_2 - W_1]} \qquad \text{if } W_2 > W_1$$

$$\text{otherwise } m_{21} = 0$$

where M_{ij} is migration from sector j to sector i.

Kelley and Williamson basically use this model for studying Japanese experiences from 1889 to World War I (Kelley and Williamson, 1974). Because of the method they used (simulation and incomplete estimation of parameters and the neoclassical assumptions, see section 2 of this paper) their work was received with less-than-expected enthusiasm by Japanese development economists and economic historians. But, the book also puzzled the Japanese:

> ...their solution is very close to reality as far as the trends of basic variables (prices, wages, output, labor, etc.) are concerned... Anyway, the model's capacity to replicate actual history is much higher than expected from the basic assumptions of perfect factor mobility, perfect competition, full employment,

> rational economic agents, and so on, especially if we take into consideration the social background of Meiji, Japan (Tokoyama, 1975:426, translated by this author).

It is worth our while to pursue the ideas presented in the KWC and the previous Kelley-Williamson model when analyzing economic development for both past and present, despite some unsolved methodological issues, *inter alia*, the impossibility of testing. This is exactly what has been done by the scholars at HSS and which has now been reviewed in this paper.

APPENDIX 2: THE JAPAN MODEL

The Japan model, which I am using (Shishido, 1981) emphasizes Japan's urbanization and economic growth between 1905 and 1930 and between 1953 and 1963, especially the dualism not only in the rural-urban dichotomy, but also in the urban sector—principally that of manufacturing. In the course of Japanese economic development, wage rates in small scale and large scale firms for similar work began to diverge, and the differentials persisted for a long time. It is argued by many that wage differentials emerged after World War I, and the distinctive "differential structure"* remained until the end of the 1960s.

During this long dualistic period, the traditional part of the economy played a very important role. First, during the early phase of development, agriculture supported the incipient stage of economic development: supplying sources of capital accumulation (i.e., land tax to the government which accumulated public capital, and rent to landlords who accumulate private capital) and supplying foreign exchange through raw silk exports.

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*This term is that of Ohkawa's (Ohkawa, 1972). He avoids the use of "dualistic" since it implies dichotomy and he finds the Japanese economy to be a "continuous" differential structure. But the term "dualistic" is used here for consistency in this review.

In the following phases, traditional sectors in rural and urban areas played the important roles of absorbing labor that was not hired by the still small modern sector, of supplying sources of sub-contract work for the modern sector, and consequently keeping the age-rental ratio "right" in view of the overall factor endowments of the economy.

One thing observers notice about the Japanese modern sector's employment pattern was that it has largely been demand-dominated. So the employment patterns, and the economic growth path, were largely determined by the investment patterns of various sectors. An emphasis is placed, therefore, on different investment behaviors of different sectors, and different technologies over time have been chosen. It is assumed that the technologies are putty-semi-putty, with very limited *ex post* substitutability for the modern sectors; putty-semi-putty but with substantial *ex post* substitutability for traditional manufacturing; and putty-putty for agriculture and other sectors. Investment is carried out according to expectations on sector-specific wage-rental ratio and future demand.

The following summarizes the features of the model:

(1) Different sector divisions are used.
(2) Embodied technical changes (a vintage model) are used with sector-specific technologies over time.
(3) Capital stock is disaggregated into structure and equipment.
(4) Investment is carried out according to expectations and the availability of funds from saving.
(5) The labor cost includes the technology-specific training cost.
(6) Transport cost is explicitly incorporated.
(7) Rural-urban migration depends on the number of jobs newly available in each sector.
(8) A distinction is made between competitive and non-competitive imports. The Armington specification is used for competitive imports and exports.

The sector division employed for pre-World War II is as follows:*

1. Modern Industry
2. Textile Industry
3. Traditional Industry
4. Modern Service
5. Construction
6. Urban Traditional Service
7. Rural Service**
8. Agriculture†
9. Urban housing
10. Rural housing

Use of Vintage Model

Embodied technical changes, the rates of which differ by sectors, are assumed in the model. Figure 3 gives a schematic explanation of what this means. Because of little substitutability between factors in the modern sectors, the available capital and investment of year t almost determines the employment of the year t+1. Then the rest of the urban labor force will be employed in the traditional sectors pushing down the wage in these latter sectors.

There are familiar theoretical problems with embodied technical progress. We know different vintage machines should have different input-output coefficients. We know that unless the rates of return on different vintages grow at a steady state they may differ. We know there is the aggregation problem unless technical progress is purely capital augmenting. (Recall steady states are compatible with only labor augmenting technical progress.) The lifetime of each vintage should be endogenous due to the economic obsolescence. But I am ready here to

*For post-World War II, results of Motai and Ohkawa (1978) will be used extensively.

**This includes retail in the rural area, local transport service (animal-drawn carts, etc.), rural personal services as well as rural housing construction. But the data are at best meager and will be excluded from the base simulation except for housing construction.

†Raw silk, fishery, and forestry are also in this sector.

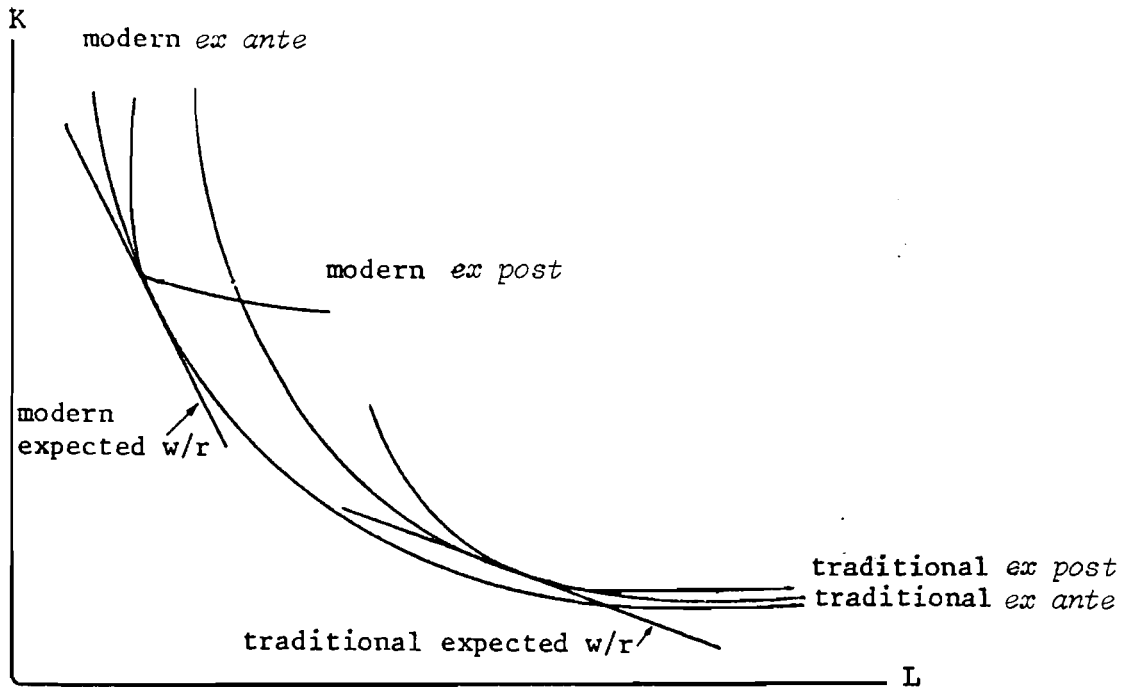

Figure 3. Different *ex ante* functions and different wage-rental expectations.

make drastically simplifying assumptions. *Either* the input-output relationship other than that of primary production factors would be assumed constant for the simulation period *or* marginal (best-practice firms) input-output relationships would be estimated from the very crude conversion of average to marginal coefficients using two input-output tables at different times. The lifetimes of vintages are determined by physical and economic obsolescence. For the latter, if any stock of a vintage has a negative net rate of return for two consecutive years, the whole vintage is disposed of without any cost. For the former, both fixed rate and one-hoss-shay assumptions will be examined with respect to depreciation. Finally, I assume the products from different vintages in the same sector at the same year are complete substitutes to consumers. For example, for consumers, cloth woven in the same year by a 20-year-old machine and a new machine is completely the same product.

Some of these assumptions are unrealistic. Especially that of input-output relationships. But with the limited data, it may be of no use to complicate the picture any further, especially for the pre-World War II period.

For investment, investors are assumed to have myopic-adaptive expectations. They formulate expectations on wages, capital, costs, output prices, and on future demand. They are also aware of *ex ante* production functions. So their intended investment would be the most efficient *ex ante* capital output ratio multiplied by expected demand increase over and above the present capacity. The total investment is made equal to saving either by arbitrarily scaling down (up) total investment or by forced saving.

Migration

From the observation of migration patterns in the past in Japan, it seems to be highly likely that demands for labor by urban sectors are determining the trend of population movement as well as income differences: I take the combination of both aspects and specify rural-urban migration flows.

$$M = m \cdot \ln \frac{W_u}{W_r}$$

where

$$W_u = \frac{\sum_{i,j} \zeta_i^j W_i^j}{\sum_{i,j} \zeta_i^j}$$

i = urban sectors
j = skilled, unskilled

$$\zeta_i^j = I_i(-1) \cdot \frac{L_i^j(-1)}{K_i(-1)} + b_i^j L_i^j(-1)$$

b_i^j = rate of turnover in sector i for skill level j

$$W_r = \rho_1 Y_0 + \rho_2 Y_p + (1 - \rho_1 - \rho_2) Y_N$$

$$(0 \leq \rho_1, \rho_2 \leq 1)$$

Y_0 = average income of owner cultivators

Y_p = average income of peasants

Y_N = average income of nonagricultural workers

In words, the number of available openings in urban areas and the wage (urban) and average income (rural) difference (deflated by cost-of-living differences) will determine the magnitude of the flow of migration.

Transportation

Beside the trade specification, which is Argmington's, and which was discussed above in the section on the Sweden model, the only remaining major feature that differs from the RDC model is the inclusion of transport cost. Transport cost is used solely for commodities transported from rural to urban or urban to rural. The unit cost (trade mark-up which is sector specific is exogenous, and this will be related to the cost-of-living differences used to deflate the income difference between urban and rural for the migration specification.

Concluding Remarks

This model is ambitious in its use of vintages, its *ex ante* and *ex post* distinction in the production function, and its determination of investment through expectations in each sector. It may be overly ambitious in view of the availability of data in pre-World War II periods [although I shall simulate the post-World War II period (1953-1963) during which time characteristics of development could be seen as very similar to the early 20th century]; this may be the biggest drawback of the model. It is hoped however, that the underlying structure of the model captures a good part of the mechanism of Japanese economic development within the limit of the general equilibrium framework.

APPENDIX 3: SUMMARIES OF THE THREE CASE STUDY MODELS

NOTATIONS*

Q_i	output of sector i
K_i	capital stock of sector i
L_i	labor force of sector i
R_i	land area of agricultural sector i
P_i	producer's price of sector i commodity
P_i^{VA}	value-added price of sector i commodity
P_i^D	domestic purchaser's price of sector i commodity
P_i^W	world price of sector i commodity
P_{ik}^W	world price of sector i commodity from region k (k = dollar region, rouble region - Hungary model)
W_i	wage rate of labor in sector i
r_i	rate of return on capital in sector i

*These notations are slightly different from the notations employed in the respective original papers, in order to make the comparison of the three models easier.
A superscript o means the base-year value of the variable concerned.

LC_i user cost of labor in sector i

RC_i user cost of capital in sector i

I investment

I_j investment in sector (area) j

I_{ij} investment in sector j from savings of sector i - Mexico model

I_j^k investment in sector j of capital stock type k (k = buildings, machines - Sweden model)

D_{ij} consumption demand of labor (household) in sector (area) j for sector i commodity

E total consumption expenditure

E_j total consumption expenditure of labor (household) in sector (area) i

β_{ij} marginal propensity to consume sector i commodity out of supernumerary income of labor (household) in sector j

β_{ij}^k marginal propensity to consume sector i commodity out of supernumerary income of capitalists (k = c) or laborers (k = l) in sector j (Mexico model)

γ_{ij} minimum subsistence level of consumption (target level of consumption for the Hungary model) of sector i commodity for laborers (household) in sector (area) j

γ_{ij}^k minimum subsistence consumption of sector i by population in sector j, class k (k = capitalists, laborers - Mexico model)

S savings

S_i savings from labor (households) in sector i

M_i competitive imports of sector i commodity

M_{ik} competitive imports of sector i commodity from region k (k = dollar region, rouble region - Hungary model)

$\bar{M}_i$ noncompetitive imports of sector i commodity

$\bar{M}_{ik}$ noncompetitive imports of sector i commodity from region k (k = dollar region, rouble region - Hungary model)

X_i export of sector i commodity

X_{ik} export of sector i commodity to region k (k = dollar region, rouble region - Hungary model)

a_i ratio of competitive imports and domestic supply of sector i commodity - Sweden model

m_{ik} ratio of competitive imports from region k and domestic supply of sector i commodity - Hungary model

μ_i elasticity parameter of a_i with respect to relative prices (world price and domestic price) - Sweden model

μ_{ik} elasticity parameter of m_{ik} with respect to relative prices [world (region k) price and domestic prices] - Hungary model

ε_i export elasticity* - Sweden model

ε_{ik} export elasticity to region k - Hungary model

α_i share of noncompetitive imports from the rouble region

δ_i elasticity of α_i with respect to the relative prices - Hungary model

ρ trend parameter for the import of sector 2 commodity - Sweden model

ν_i trend parameters for export of sectors 1 and 3 - Sweden model

ϕ exchange rate

ϕ_k exchange rate with currency of region k (k = dollar region, rouble region - Hungary model)

G government consumption

C total private consumption

ICR consumption-investment ratio - Hungary model

*This is the elasticity of substitution of the CES form aggregate product function. See, Armington (1969).

t	time
t_i	indirect tax in sector i commodity
t_d, t_r	tariff on goods imported from dollar and rouble regions respectively - Hungary model
t^x_{id}, t^x_{ir}	tariff on goods exported to dollar and rouble regions respectively - Hungary model
t_w	tax on wages - Hungary model
MIG	total migrants from rural area - Sweden model
mig	ratio of migrants from rural area to the rural population - Sweden model
EM	total emigrants from Sweden to the USA - Sweden model
em	ratio of emigrants to total migrants - Sweden model
η, θ	reaction parameter of potential migrants/emigrants to wage differentials
W^*	ratio of the weighted average of the urban sector wage and the wage in the USA to the rural sector wage, all deflated by respective cost-of-living indices - Sweden model
W^{**}	ratio of the USA wage rate and the urban sector wage rate, deflated by respective cost-of-living indices - Sweden model
COL_i	cost-of-living index for area i, i = rural, urban, and USA - Sweden model
d	weight in migration functions - Sweden model
$\bar{\omega}_j$	relative rates of return on labor in urban sector - Sweden model
W_u	average wage in urban sector - Sweden model
$\bar{\varepsilon}_j$	relative rates of return on capital in urban sector j - Sweden model
RC_u	average rate of return on capital in urban sectors - Sweden model

σ_i rate of depreciation of capital stock in sector i

κ return requirement on capital - Hungary model

λ_i Lagrangian multiplier on production cost minimization ($= p_i^{VA}$) - Hungary model

ζ_i share of saving from sector i reinvested in the same sector regardless of rates of return on capital in other sectors - Mexico model

$\bar{\zeta}_i$ share of structure capital (buildings, etc.) in total capital stock - Sweden model

N_u, N_r population in urban and rural areas respectively

s_{ij} share of employment in region i of sector j, i = urban, rural - Hungary model

a_{ij} input-output coefficients

π_i rate of mark-up on price of sector i commodity

τ_i net turnover (or subsidy) on sector i commodity - Hungary model

MEXICO MODEL

Sector Division

1. Urban modern/industrial
2. Commercialized agriculture
3. Small-scale agriculture
4. Urban informal
5. Public

Major Features

1. Disaggregation of agriculture into commercialized and small-scale sector.
2. Assuming no technical progress in the small-scale agriculture and informal sectors.
3. Capital market fragmentation expressed by the exogenous ζ_i, i.e., the share of sector saving which is reinvested

into the same sector regardless of the return in its own and other sectors ($0 < \zeta_1, \zeta_2 < 1, \quad \zeta_3 = 1$)

4. Government investment sector-specific but exogenous.

Supply

$$Q_i = Q_i\ (K_i, L_i) \qquad i = 1$$

$$Q_i = Q_i\ (K_i L_i R_i) \qquad i = 2,3$$

$$Q_i = Q_i\ (L_i) \qquad i = 4$$

Factor Returns

Marginal principle applies to all sectors except for labor in sector 4 where average product is received.

Consumption Demand

$$D_{ij}^k = \beta_{ij}^k \left\{ E_j^k - P_3\ \gamma_{3j}^k \right\}$$

$$D_{ij}^k = P_3\ \gamma_{3j}^k + \beta_{3j}^k \left\{ E_j^k - P_3\ \gamma_{3j}^k \right\}$$

$i = 1,2,3,4$
$j = 1,2,3,4$
$k =$ capitalists, laborers

Investment

$$I_{11} = \frac{1}{P_1} \left[\frac{r_1 + r_2\zeta_1}{r_1 + r_2} \right] S_1$$

$$I_{21} = \frac{1}{P_1} \left[\frac{r_2 - r_2\zeta_1}{r_1 + r_2} \right] S_1$$

$$I_{22} = \frac{1}{P_1} \left[\frac{r_2 + r_1\zeta_2}{r_1 + r_2} \right] S_2$$

$$I_{12} = \frac{1}{P_1} \left[\frac{r_1 - r_1\zeta_2}{r_1 + r_2} \right] S_2$$

$$I_{33} = \frac{S_3}{P_1}$$

$$I_i = I_{i1} + I_{i2} + I_{i5}$$

(savings ratio given)

SWEDEN MODEL

Sector Division

1. Primary
2. Export-oriented industry
3. Homemarket-oriented industry
4. Services
5. Construction

Major Features

1. Explicit specification of emigration from Sweden to USA.
2. Emphasis on the world trade with less-than-infinite elasticity of substitution between home goods and foreign goods of the same category.
3. Factor returns: exogenous ratio of rates of return between different sectors.
4. No inter-sector capital movement, fixed proportion of capital (and investment) for buildings and structures.

Production

$$Q_i = Q_i \left[R_i, \psi (K_1, L_1)\right] \qquad i = 1$$

$$Q_i = Q_i (K_i, L_i) \qquad i = 2,3,4,5$$

Factor Returns

$$W_j = \bar{\omega}_j \, W_u$$

$$RC_j = \bar{\varepsilon}_j \, RC_u$$

Prices

$$P_i^D = a_i(1 + t_i) \, P_i^W + (1 - a_i) \, P_i \qquad i = 1,3$$

where

$$a_i = \frac{M_i}{Q_i - X_i}$$

$$P_2^D = P_2^W$$

$$P_i^D = P_i \qquad i = 4,5$$

$$P_j^{VA} = P_j - \sum_{i=1}^{5} P_i^D \, a_{ij}$$

Demand

$$D_{kj} = \gamma_{kj} + \frac{\beta_{kj}}{P_k^D} \left(E_k - \sum_{i=1}^{5} \gamma_{ij} \, P_i^D \right)$$

Trade

$$X_i = X_i^o \left(\frac{P_i}{P_i^W} \right)^{\varepsilon_i} e^{\nu_i t} \qquad i = 1,3$$

$$X_2 = \frac{1}{P_2}\left(\sum_i P_i^W M_i - P_1 X_1 - P_3 X_3\right)$$

$$a_i = \frac{M_i}{Q_i - X_i} = a_i^o \left(\frac{P_i}{(1+t_i) P_i^W}\right)^{\mu_i} \qquad i = 1,3$$

$$\frac{M_2}{Q_2 - X_2} = a_2^o e^{-\rho t}$$

Investment (B = Building, M = Machinery, u = urban area)

$$I_1^B = \bar{\zeta}_1 I_1$$

$$I_1^M = (1 - \bar{\zeta}_1) I_1$$

$$I_u^B = \bar{\zeta}_u I_u$$

$$I_u^M = (1 - \bar{\zeta}_u) I_u$$

$$I_u + I_1 = S$$

Migration

$$mig = \frac{MIG}{N_r} = 1 - e^{-\eta W^*}$$

$$W^* = \left(d \frac{W_u}{COL_u} + (1 - d) \frac{W_{USA}}{COL_{USA}}\right) \Bigg/ \left(\frac{W_1}{COL_1}\right)$$

$$em = \frac{EM}{MIG} = 1 - e^{-\theta W^{**}}$$

$$W^{**} = \left(\frac{W_{USA}}{COL_{USA}}\right) \Bigg/ \left(\frac{W_u}{COL_u}\right)$$

HUNGARY MODEL

Sector Division

1. Not determined (n sectors)
2. $(n + 1)^{th}$ sector investment goods sector

Major Features

1. Disaggregation of foreign trade into dollar and rouble trade
2. User cost of factors determined by endogenous taxes
3. Prices marked up by exogenous required profit rates
4. Investment proportionate to consumption
5. Industrial activities possible to locate in rural areas

Supply

$$Q_i = Q_i\ (K_i, L_i) \qquad i = 1,\ldots,n$$

Factor Returns

$$RC_j = (\sigma_j + \kappa)\ P_{n+1} = \lambda_j \frac{\partial Q_j}{\partial L_j}$$

$$LC_j = (1 + t_w)\ W_j = \lambda_j \frac{\partial Q_j}{\partial K_j}$$

Household Demand

$$D_{kj} = \gamma_{kj} + \frac{\beta_{kj}}{P_k}\left(E_k - \sum_{i=1}^{n} P_i\ \gamma_{ij}\right) \qquad \begin{matrix} i,k = 1,\ldots,n \\ j = \text{urban, rural} \end{matrix}$$

$$E_j = \frac{E_j^o}{E^o} E$$

Investment

$$I = \frac{G + C}{ICR}$$

Trade

Competitive Imports

$$m_{ik} = m_{ik}^{o} \left[\frac{P_i}{(1 + t_k)\ \phi_k\ P_{ik}^{W}} \right]^{\mu_{ik}} \qquad \begin{array}{l} k = \text{rouble, dollar} \\ i = 1,\ldots,n \end{array}$$

$$M_{ik} = m_{ik}\ (Q_i - X_i)$$

Noncompetitive Imports

$$\bar{M}_{ir} = \alpha_i\ \bar{M}_i$$

$$\bar{M}_{id} = (1 - \alpha_i)\ \bar{M}_i$$

$$\alpha_i = \alpha_i^{o} \left[\frac{(1 + t_d)\ \phi_d\ P_{id}^{W}}{(1 + t_r)\ \phi_r\ P_{ir}^{W}} \right]^{\delta_i}$$

Exports

$$X_{ik} = X_{ik}^{o} \left[\frac{P_i}{(1 + t_{ik}^{x})\ \phi_k\ P_{ik}^{W}} \right]^{\varepsilon_{ik}}$$

Prices

$$P_i = (\sum_j P_j^D a_{ji} + \lambda_i)(1 + \pi_i)(1 + \tau_i)$$

P_j^D = weighted average of domestic producers' cost, dollar and rouble region import price

Employment

$$N_i = \sum_{j=1}^{n} s_{ij} L_j \qquad i = \text{urban, rural}$$

$$\sum_i s_{ij} = 1$$

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