URBANIZATION AND INDUSTRIALIZATION: MODELING SWEDISH DEMOECONOMIC DEVELOPMENT FROM 1870 TO 1914

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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 socio-economic 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.

This paper describes the urbanization and development experience of Sweden during the years 1870–1914. A general equilibrium demoeconomic model is outlined that seeks to capture characteristics specific to the Swedish situation. Following a number of earlier papers on the Mexican and Polish case studies, Urban Karlström's analysis of Swedish development further expands the collection of national case studies that are envisioned as part of the Population, Resources, and Growth Task.

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

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INTRODUCTION

One of the most challenging problems in Third World countries is the rapid growth of metropolitan areas. The two most important questions are: Is urbanization a necessary and desirable consequence of the process of development, or is it a constraint on further development? In order to understand the interaction between economic growth and urbanization in the developing world today, there has been increasing interest in the analysis of the historical experiences of developed countries. This is the purpose of the Swedish case study. Through an analysis of the crucial factors in Swedish demoeconomic development, it is hoped that further insights into the interactions of economic and demographic variables can be gained.

The prewar period, 1870–1914, is chosen for this study in order to follow 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 (Heckscher 1957). To consider 1914 as a watershed terminal year seems reasonable even from the economic point of view: the war caused dramatic changes on the world market, thus influencing in a positive way the conditions for industrialization in Sweden. One of the most striking changes was the alteration of Sweden's status from a capital importing to a capital exporting nation. A second dramatic change was the ending of the great migration to America. The emigration started in the 1860s and played a vital role during Sweden's industrialization. For an examination of the industrial breakthrough in Sweden, see Gårdlund (1942), Jörberg (1961, 1970), and Montgomery (1947). The beginning of the First World War, therefore, is the terminal point of this study. The influence that the war had on Sweden's demoeconomic development is not our concern here; the 44 years between 1870 and 1914 are challenging enough as a subject of study.

During these 44 years the per capita income of Sweden grew at an annual rate of 2 percent, a rate exceeded only by Japan and the United States. As

Kuznets has pointed out, it was the rather low increase in the population that gave Sweden this leading position (Kuznets 1956, p. 13). The Swedish population grew from almost 4.2 million in 1870 to slightly more than 5.6 million by the outbreak of the war, showing an annual growth rate of only 0.7 percent. (These figures have been derived from the tables in Appendix A.) This low rate was largely due to emigration, which drained the population of roughly 1.1 million people.

Not only the demographic but also the economic consequences of Sweden's migration patterns were far-reaching. The heavy emigration has been regarded as beneficial in its increasing effect on real wages even though it is rather difficult to estimate its total consequences for the economy (Henricsson 1969). Internal migration was also considerable during this period and was reflected to some extent in the rate of urbanization. The proportion of the population living in towns and cities increased from 13 to 31 percent between 1870 and 1914. This reallocation of the labor force from a low-productivity agricultural sector to a modern industrial sector with higher productivity contributed positively to the economic growth. These gains from labor force reallocation have been estimated and the results can be seen in Appendix Table A3. The gains differ among the decades, but over the whole period nearly 24 percent of the increase in total labor productivity was due to urbanization. [Åberg (1969) calculated almost the same figures using older data.]

These general remarks on Swedish development show the potential magnitude of demographic and economic interrelations. This interplay is especially critical for a study that highlights urbanization. In particular, the analysis of migration requires taking into account the existence of causality in both directions, which in turn affects the choice of methodology for this study. Many migration studies employ the underlying assumption that

> . . . while the various explanatory factors influence migration, migration does not in turn influence these factors. If this assumption does not in fact hold, the parameter estimates of the various models possess a simultaneous equations bias that may be great enough to vitiate the findings. (Greenwood 1975, p. 412)

When one considers how important economic variables (for example, wages) seem to be in the migration decision, and how the reallocation of the labor force between sectors works as an equilibrating factor on wages, one finds that a general equilibrium approach is most suitable for the problem. Only within such a framework can the complicated relations between the various demographic and economic variables be satisfactorily analyzed (Rogers 1977).

Thus the model that this paper deals with is of the general equilibrium type. It is within the tradition of the so-called multisectoral growth (MSG) models, first developed by Leif Johansen (see, for example, his 1974 revised book on the subject) and later extended by Bergman, among others (Bergman

1978; Bergman and Pór 1980). The models also draw from the theory of dualistic economic growth formulated in a general equilibrium framework by Kelley and Williamson (Kelley, Williamson, and Cheetham 1972; Kelley and Williamson 1974 and 1980).

The general equilibrium model presented in this report is designed to fit the Swedish prewar development for the purpose of undertaking counterfactual analysis. If the actual demoeconomic development between 1870 and 1914 corresponds closely to the model simulations, it will be possible to place some confidence in counterfactual studies. Through changes in one or more of the exogenous variables or parameters in the model, the importance of the variables or parameters on the economy can be explored through a comparison between the actual development and the counterfactual history. Some of the aspects that will be analyzed are the following:

1. What role did emigration play in Sweden's development? Its consequences have been discussed since Wicksell pointed out in the 1880s that emigration solved the proletarianization problem in Swedish agriculture (Wicksell 1882). But what were the long-run consequences of emigration? Would a larger population have increased the economic growth because of its enlargement of the home market? Was emigration a substitute for internal migration?
2. How crucial were the effects of the growth of world trade and the changes in terms of trade on the performance of economic growth? Were the trade tariffs stipulated in the 1880s important for the development of the Swedish consumer-goods industry? What was the impact of the participation of the agricultural sector in foreign trade on out-migration from rural areas?
3. Was the import of foreign capital a prerequisite for economic growth? What would have been the consequences for industrial growth and urbanization if there had been more borrowing? Was the saving generated in the agricultural sector to any substantial extent transferred to industry or was it absorbed by the investments within the sector?
4. How important were capital formation and technical progress in agriculture to development? And moreover, what effect did capital formation have on out-migration and urbanization?
5. How important to growth was internal demand? How did differences in consumption patterns between rural and urban households influence industrial growth?

The list of questions can easily be extended. These and other aspects of Swedish development will be analyzed with the help of the model. The study not only may be of some historical interest, but also, it is hoped, may increase our understanding of the forces behind the urbanization process as well as its implications in a small and open economy such as that of Sweden.

TABLE 1 The production sectors in the model and their empirical counterparts.

Sector subscripts	Sector[a]
1	Agriculture, forestry, and fishing
2	Export-oriented industry (mining and metal, wood products, pulp, paper, and printing)
3	Home-market-oriented industry (textile and clothing, leather, hair and rubber, chemical industries, power stations, waterworks and gasworks, stone, clay, glass, and food products)
4	Service (commerce and other services, public administration, transport and communication, services of dwellings)
5	Building and construction

[a]Sectors 2–5 are sometimes treated as one group, the urban sector (U), as opposed to the agricultural sector (A).

THE SECTOR DIVISION

The structure of the model is based on the duality between a traditional agricultural sector and a more modern industrial sector. But in order to capture the specific mechanisms that have driven Swedish economic growth, it is necessary to extend the model beyond the simple two-sector analysis. Therefore, the modern sector has been subdivided into four different sectors.*

The five production sectors and their empirical counterparts are displayed in Table 1. This division is based on two aspects: the relationship of each sector to the world market, and the importance of investments in railways and housing. The continuing industrialization in Europe increased foreign demand on Swedish exports, especially iron, steel, and sawmill products. Exports can, therefore, be considered a driving force in the economic development of Sweden (Jörberg 1961; Ohlsson 1969). Exports accounted for 19 percent of the GNP in 1871–1875, 22 percent in 1891–1895, and 27 percent in 1911–1915 (see Table 2). The industrial sectors have been divided into three groups according to their dependence on foreign trade: export-oriented industries, home-market-oriented industries, and branches of industries sheltered from international competition. Table 2 also shows exports and imports in relation to gross production in the various sectors (the main criteria for the grouping of sectors) and in the economy as a whole.

*Agricultural activities are treated within one sector in the model. For a model where agriculture is disaggregated, see Colosio (1979).

TABLE 2 The shares and ratios of exports (EX) and imports (IM) by sector and period in Sweden.

Sector number	Sector	Export share (EX_i/EX)			Export ratio (EX_i/gross output[a])			Import share (IM_i/IM)			Import ratio (IM_i/gross output[a])		
		1871–1875	1891–1895	1911–1915	1871–1875	1891–1895	1911–1915	1871–1875	1891–1895	1911–1915	1871–1875	1891–1895	1911–1915
1	Agriculture, forestry, and fishing	22	10	4	8	4	3	27	27	28	9	12	16
2	Mining and metal	21	14	22	38	27	34	12	12	17	22	22	22
	Wood products	27	28	17	80	71	59	1	1	1	3	2	3
	Pulp, paper, and printing	2	5	14	33	51	59	1	2	1	17	17	4
3	Food products	4	16	10	6	17	13	26	15	12	35	17	13
	Textiles and clothing	1	2	1	4	8	6	20	18	10	86	72	33
	Leather, hair and rubber	–	1	–	–	6	10	2	4	4	25	39	24
	Chemical industries	2	3	4	16	27	26	7	11	13	56	86	100
	Power stations, waterworks, and gasworks	–	–	–	–	–	–	–	–	–	–	–	–
	Stone, clay, and glass	1	3	3	14	41	23	7	10	14	229	120	110
4	Commerce and other services	6	7	8	5	4	8	–	–	–	–	–	–
	Public administration	–	–	–	–	–	–	–	–	–	–	–	–
	Transport and communication	14	14	15	58	43	41	–	–	–	–	–	–
	Services of dwellings	–	–	–	–	–	–	–	–	–	–	–	–
5	Building and construction	–	–	–	–	–	–	–	–	–	–	–	–
	Total	100	100	100	19[b]	22[b]	24[b]	100	100	100	19[b]	22[b]	21[b]

[a]Gross output is the domestic production of commodity i, including intermediate goods.
[b]Total exports and total imports as shares of gross domestic production.
SOURCE: Adapted from Johansson (1967).

The strategic role that building and construction activities have played in the economy has motivated a division of the trade-sheltered sector into a service sector and a building and construction sector. The building industry produced railways and housing, both of which played a crucial role in the Swedish development. A further argument for disaggregating this sector is that it is quite "population sensitive." Swings in emigration and urbanization can have substantial effects on building (see Wilkinson 1967).

When it is important, however, to stress the dualism between agriculture and industry, the four nonagricultural sectors are treated as one sector and designated as "urban."

PRODUCTION AND TECHNOLOGY

The dualism between Swedish agriculture and industry during the 19th century was to a large extent a question of differences in production conditions which resulted in a much lower productivity within the agricultural sector than the industrial sector.

The sources of productivity growth are not exactly the same in agriculture as in industry. In agriculture, productivity can be divided into two parts

$$\frac{X}{L} \equiv \frac{X}{R} \quad \frac{R}{L}$$

where X/L refers to the agricultural output per worker, X/R measures the agricultural output per unit area, and R/L equals land area per worker. The identity is another way of stating that an increase in output per worker can come about through an improved yield per unit area, through a larger area per worker, or through a combination of both.

Between 1870 and 1912 the output per worker grew at an annual rate of 1.19 percent. Of this growth 62 percent was due to an increase in output per unit area and the rest to an increase in land per worker.* In the 1880s the labor force started to decline, but cultivated acreage increased during the whole prewar period. Holgersson has estimated its growth to be 12–15 percent between 1870 and 1914.

It is worth noting that the processes of bringing more land under cultivation and increasing agricultural productivity had gone on for a long time before industrialization began. During the 100-year period between 1750 and 1850, the net population increase was 1.3 million. Roughly 80 percent of the population was dependent on agriculture, and since the rate did not change during

*The figures underlying the estimates are taken from the following sources: *output*, Krantz and Nilsson 1975, p. 172; *employment*, Jungenfelt 1966, p. 224; and *cultivated acreage*, Holgersson 1974, p. 47. The new data for cultivated acreage which have been estimated by Holgersson indicate that the agricultural output is 10 percent too low in the 1860s (see Krantz and Nilsson 1975, p. 35). Therefore, we have used figures for X in 1870 that have been increased by 10 percent.

that period, slightly more than 1.0 million people were absorbed by the agricultural sector. Through increased acreage of cultivated land, introduction of new production techniques, and land reform, the agricultural sector managed to absorb its growing population (Thomas 1941, p. 49). However, this trend did not continue after 1850.

Population pressure in the agricultural sector increased during the second part of the century due to an augmented natural population increase in the 1870s and 1880s. Despite an increased transformation of agriculture this sector was no longer totally able to absorb its growing population. The growth in agricultural production during the prewar period was a consequence not only of increased acreage but also of technological development and capital investments. The combine-harvester was an example of production technology becoming more and more capital intensive.

Against this background it has been decided to use three factors of production when modeling agricultural production: land, labor, and capital. The conventional Cobb–Douglas production function is not appropriate unless one is able to justify a unitary elasticity of substitution between each pair of production factors. Instead of assuming this, more flexibility is introduced by using a so-called nested production function.

Labor and capital are considered to be functionally separable from land. This means that growth in the amount of cultivated land results in a proportional increase in the marginal productivity of labor and capital.* Labor and capital are combined by a constant-elasticity-of-substitution (CES) production function into a composite production factor (H). Land and H are then combined in a Cobb–Douglas function. There is some empirical support for not choosing a Cobb–Douglas specification for labor and capital. In a study by Jungenfelt (1966), it was shown that labor's share of value added in agriculture decreased before the First World War (Table 3). Jungenfelt has also estimated the elasticity of substitution between labor and capital to be 0.6.** A Cobb–Douglas specification for these two production factors, therefore, appears to be inappropriate.

The CES production function is used for each nonagricultural sector. Even in these sectors, the development of the labor's share of value added and the elasticity of substitution have been the bases on which the choice has been made. As can be seen in Table 3, neither transport nor industry exhibits constant shares of labor. It is true that the sectors in the present model differ from those of Jungenfelt's, which are displayed in Table 3, but the model's sectors 2 and 3 – the export-oriented and the home-market-oriented industries – compose Jungenfelt's industry sector, and his transport sector constitutes an increasing proportion (6 percent in 1871–1875 and 17 percent in 1911–1915) of the

*For a discussion of the specification of production technology in agriculture see Kaneda (1979, pp. 11–23).

**See Jungenfelt (1966, p. 22). These estimates cover the whole 1870–1950 period, but to our knowledge they are the only ones available that cover the prewar period.

TABLE 3 The labor's share of value added in the Swedish economy as a whole and in agriculture, industry, and transport, 1870–1914.

Period	The whole economy	Agriculture	Industry	Transport
1870–1879	72	84	67	41
1880–1889	72	82	75	46
1890–1899	70	83	71	43
1900–1909	66	80	63	45
1910–1914	64	75	60	47

SOURCE: Jungenfelt (1966) p. 42.

model's sector 4 – the service sector. The elasticities of substitution in industry and transport are estimated to be 0.6 (Jungenfelt 1966, p. 202).

Thus, the production functions in the model have the following form. (The complete mathematical statement of the model can be found in Appendix B. Equation numbers correspond with the mathematical statement.) For agriculture

$$X_1 = A_1 R^{\alpha} H^{1-\alpha} \tag{5}$$

$$H = \left\{ \delta_1 \left(g_1 K_1\right)^{-\rho_1} + \gamma_1 \left(h_1 L_1\right)^{-\rho_1} \right\}^{-1/\rho_1} \tag{6}$$

and for the remaining four sectors

$$X_j = A_j \left\{ \delta_j \left(g_j K_j\right)^{-\rho_j} + \gamma_j \left(h_j L_j\right)^{-\rho_j} \right\}^{-1/\rho_j} \qquad j = 2, \ldots, 5 \tag{7}$$

$$X_{ij} = a_{ij} X_j \qquad \begin{array}{l} i = 1, \ldots, 5 \\ j = 1, \ldots, 5 \end{array} \tag{8}$$

X_j are gross output in sector j, K_j the capital stock, and L_j the employment in sector j. A_j, α, δ_j and γ_j are constants. The formulation allows for different values of these parameters in the different sectors. The substitution parameter is ρ, and it is defined as

$$\rho = \frac{1}{\epsilon_s} - 1$$

where ϵ_s is the elasticity of substitution. The technological parameters are g_j and h_j. And $g_j K_j$ and $h_j L_j$ can be referred to as "efficiency capital" and "efficiency labor," respectively. Deliveries of intermediate goods from sector i to sector j are denoted by X_{ij}, and the input coefficients by a_{ij}.

Technological development is one of the dynamic features of the model. There is historical evidence that technological progress had an extensive growth-creating effect on the economy in Sweden. Åberg has estimated that 42 percent of the growth in productivity between 1870 and 1913 can be explained by technological progress (Åberg 1969, p. 38). It has also been shown that the growth in technology was not neutral but was labor saving (Jungenfelt 1966; Åberg 1969). Moreover, the labor-saving bias was a characteristic not only for the industrial sectors but also for the agricultural sector.

The model formulation captures these characteristics. The technological parameters in the production functions, g_j and h_j, change over time (t) according to exogenously determined growth rates:

$$g_j(t) = g_j(t-1)\exp(\lambda_j^g) \qquad j = 1, \ldots, 5 \tag{54}$$

$$h_j(t) = h_j(t-1)\exp(\lambda_j^h) \qquad j = 1, \ldots, 5 \tag{55}$$

The growth rate λ differs among the different sectors and when $\lambda^h > \lambda^g$ the model exhibits a labor-saving bias in technological growth.

Reflecting the historical situation, the area of cultivated land, R, is enlarged over time in the model

$$R(t) = R(t-1)\exp(r) \tag{53}$$

where r is the annual rate of growth in land acreage.

The different factors of production are assumed to be combined in a way that will maximize profits in each sector. Before the necessary conditions are presented it is worthwhile to point out three specific features of the model.

(1) Because of low agricultural wages, a reallocation of the labor force from agriculture to other sectors took place during the 1870–1914 period. But, as can be seen in Figure 1, the wages were not equalized. For a discussion of the sectorial wages see Bagge, Lundberg, and Svennilson (1933). In a pure general equilibrium model without wage-structure or labor-mobility constraints, the labor force is allocated in each period in such a way as to equalize wages. In our model, which has to reflect the Swedish stylized facts, it is necessary to incorporate such constraints. This is done in two ways: through the specification of an explicitly formulated migration function for rural–urban migration as well as emigration, and through the introduction of a wage structure among urban sectors. Migration is a function of the relative levels of wages in the sending and receiving regions, and the urban wage structure is exogenously determined. Thus there will be a reallocation of labor among the sectors, but not to the extent that wages will be equalized in each period of time.

(2) Total savings in the model make up total gross investments. Investments are divided between rural and urban areas according to an exogenously determined share. Difficulties in modeling the imperfect capital market, which

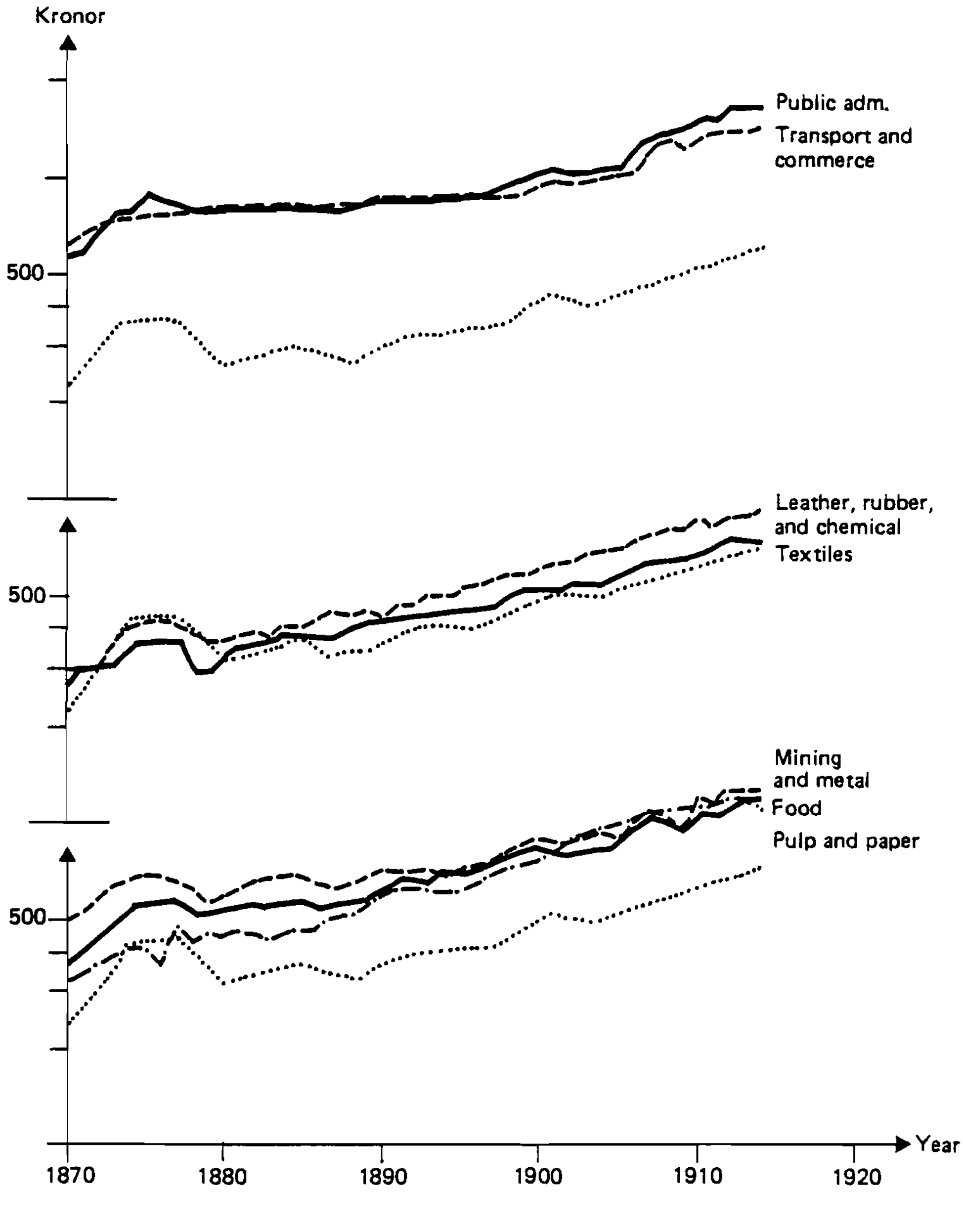

FIGURE 1 Wages in different sectors as compared to the agricultural sector (·····), 1870–1914. Source: adapted from Jungenfelt (1966).

prevailed in Sweden during the prewar period, have made it necessary at this stage to treat this share as exogenous. Within the urban sector the entire "urban" capital stock, not just new investments, is assumed to be completely mobile. The capital stock in the urban sector is thus of the "putty-putty" type. Between the four urban sectors the capital is allocated so that an exogenously given structure of the sectorial rate of returns will be fulfilled in each period of time.

(3) There are three sets of prices in the model. The first two sets are domestic production costs (P_i) and domestic prices (P_i^D) of commodity i. Domestic prices are distinguished from domestic production costs through the influence of the world market in the three sectors where foreign trade occurs*

$$P_i^D = \frac{im_i}{1 + im_i} \left(1 + \phi_i\right) P_i^W + \frac{1}{1 + im_i} P_i \qquad i = 1, 3 \qquad (1)$$

where $im_i = IM_i/(X_i - EX_i)$, ϕ is an *ad valorem* custom duty on imports, and P_i^W measures world market prices expressed in Swedish currency (kronor). The export-oriented sector is assumed to be a price-taker on the world market, and the world market price has a total price penetration on the Swedish market. Thus, the domestic price in sector 2 is exogenous in the model

$$P_2^D = P_2^W \qquad (2)$$

And in sectors 4 (service) and 5 (building and construction) there are no imports so no differences will occur between domestic production costs and domestic prices

$$P_i^D = P_i \qquad i = 4, 5 \qquad (3)$$

The third set of prices in the model is introduced to simplify the treatment of intermediary goods. A set of so-called value-added prices, P_i^*, is defined as the production cost of one unit of a commodity after deduction of the cost for the necessary intermediaries to produce that commodity

$$P_i^* = P_i - \sum_{j=1}^{5} P_j^D a_{ji} \qquad i = 1, \ldots, 5 \qquad (4)$$

With these three basic features of the model in mind, the necessary conditions for profit maximization can be presented. First we have the agricultural sector. Because capital stock and available land are exogenous, the profit function is formulated as

$$\Pi_1 = P_1^* X_1 - W_1 L_1 \qquad (10)$$

*The treatment of foreign trade will be more fully discussed in the following section. See also Bergman and Pór (1980).

where Π_1 represents profit in agriculture and W_1 refers to the wage rate. Included in Π_1 are not only remittances to the owners of capital and land, but also the necessary depreciation of the capital stock. Labor is paid in correspondence with its marginal productivity, and this results in the following conditions for profit maximization:

$$\frac{W_1 L_1}{P_1^* X_1} = (1-\alpha)\gamma_1 \left(\frac{H}{h_1 L_1}\right)^{\rho_1} \tag{9}$$

In the four urban sectors profit is defined as

$$\Pi_j = P_j^* X_j - W_j L_j - RC_j(P_2^D K_j^M + P_5^D K_j^B) - \left[P_5^D \kappa^B \zeta_j + P_2^D \kappa^M (1-\zeta_j)\right] K_j$$

The total wage sum ($W_j L_j$), the returns on the capital stock (RC_j), and depreciation are deducted from the "revenues" $P_j^* X_j$. [Observe that the cost for intermediary goods has already been deducted; see eq. (4).] The capital stock is divided into buildings, B, and other capital equipment, M. The annual rate of depreciation of these two types of capital stock is represented by κ^B and κ^M. The share of buildings and plants out of the total capital stock in sector j is ζ_j. If the concept "user cost" of capital, Q_j, (Johansen 1974) is defined as

$$Q_j = P_2^D (RC_j + \kappa^M)(1-\zeta_j) + P_5^D (RC_j + \kappa^B)\zeta_j \qquad j = 2, \ldots, 5 \tag{10a}$$

then the profit function can be rewritten as

$$\Pi_j = P_j^* X_j - W_j L_j - Q_j K_j$$

The resulting necessary conditions derived from this profit function are

$$\frac{W_j L_j}{P_j^* X_j} = \gamma_j \left(\frac{X_j}{h_j L_j A_j}\right)^{\rho_j} \qquad j = 2, \ldots, 5 \tag{11}$$

$$\frac{Q_j K_j}{P_j^* X_j} = \delta_j \left(\frac{X_j}{g_j K_j A_j}\right)^{\rho_j} \qquad j = 2, \ldots, 5 \tag{12}$$

The export sector is assumed to be the sector that leads the way in wages. The wage increases in that sector are followed by increases in other urban sectors and result in a rather fixed wage structure over time. The actual levels of different wages over time, plotted in Figure 1, seem to justify such an assumption. The wages in the branches of industry that form sector 2, are rather close to each other and are also higher than in the home-market-oriented sectors. However, the public administration and the transport subsector have the highest wages. This may be explained by a higher share of skilled labor in these sectors.

The fluctuations in the wages also seem to support the hypothesis that the export sector is wage determining.

Against this background it seems difficult to assume the same wage for all the urban sectors. Instead, the observed wage differences among the urban sectors are built into the model through an assumption of a constant sectorial structure

$$W_j = \omega_j W_U \qquad j = 2, \ldots, 5 \tag{14}$$

Wages in the different sectors are thus assumed to remain at certain constant proportions, ω_j, of the average wage level, W_U, across the entire urban area. In the solution of the model the average wage is normalized to one, and therefore, ω_j values refer to observed wage rates at the base point of time. The supply of labor in the urban sector will be allocated so that this relationship prevails over time and thus implicitly captures such differences between the urban sector as, for example, the share of the skilled worker. This formulation has not changed the assumption of a mobile labor force. Instead of assuming equalization of wages in each period of time, however, the relative increase in wages between two years is equalized.

Because of the lack of data it is more difficult to know the sectorial structure of the rates of return. To make the model flexible, however, we make similar assumptions for these rates as for wages. There are also many reasons to expect sectorial differences in the rate of return on capital, i.e., different risks connected with investments in the sectors, degree of monopolization in various branches, average size of firms, etc. The allocation of the capital stock among the urban sectors is thus determined by the rate of return in such a way as to maintain a certain sectorial structure over time

$$\bar{R}C_j = q_j RC_U \qquad j = 2, \ldots, 5$$

where RC_U is the average rate of return in the urban sector, normalized to unity in the base year, and q_j are constants that reflect the sectorial structure of capital remuneration.*

THE FACTOR MARKET

Different characteristics of the factor markets have been discussed in the previous sections. It is, therefore, enough to present the equations which close the capital and labor markets.

The urban capital market is simply closed by summing the capital stocks in the four urban sectors, and setting the sum equal to the total capital stock

*It is unlikely that the sectorial structure of the rate of return on capital would remain stable over a long period of time, especially the 43 years between 1871–1914. Johansen discusses this formulation of sectorial structure of factor returns (Johansen 1974, p. 259). In the model simulation it will be shown just how realistic the assumptions are.

available to them, K_U

$$\sum_{j=2}^{5} K_j = K_U \tag{18}$$

To complete the labor market picture the supply of labor has to be formulated. The supply is assumed to be a certain share of the total population. But this share (total aggregated labor participation rate) differs between the two labor markets (urban and rural), as well as showing an increase during the industrialization period. The difference between urban and rural participation can be partly explained by different age structures. During the entire 1870–1914 period, the share of the population below the age of 15 was higher in the rural areas. For example, during the 1870s 35 percent of the rural working population was under 15 years of age as compared to 30 percent of the urban population (Thomas 1941, p. 47). This does not, however, explain all the differences between the rural and urban labor participation rates. Even the rate within the working-age group (defined as the part of the population over 15 years of age) differs. How important the age distribution above 15 is for this difference cannot be displayed because of the lack of information about age-specific participation rates. Part of the explanation can be found in the different sex-specific labor participation ratios. Among men, no significant difference existed between urban and rural areas (around 80 percent in both areas in the 1870s). However, for women in the rural areas the rate remained constant at 17 percent during the prewar period while in urban areas it increased from 28 percent in the 1870s to 43 percent in 1920 (Silenstam 1970, p. 103).

To capture these demographic differences affecting the aggregated labor participation rate, the rate is decomposed in the model and supply of labor in the two regions is described by the following conditions

$$L_A = \left[p_A^\Gamma z_A^\Gamma l_A + p_A^\Omega z_A^\Omega (1 - l_A)\right] N_A \tag{15}$$

$$L_U = \left[p_U^\Gamma z_U^\Gamma l_U + p_U^\Omega z_U^\Omega (1 - l_U)\right] N_U \tag{16}$$

where p is the labor participation rate within the working ages, z is the working-age share of the total population (N), and l is the share of females in the total population. All these rates are sex-specific and are indicated by the superscripts Γ for female and Ω for male. The demographic parameters (z, l) remained almost stable over the period studied but the sex- and age-specific labor participation ratios did not. They increase in the model with an exogenously determined growth rate

$$p_j^h(t) = p_j^h(t-1)\exp(\nu_j^h) \qquad \begin{matrix} j = A, U \\ h = \Gamma, \Omega \end{matrix} \tag{56}$$

In order to close the urban labor market, the employment in the different urban sectors must add up to the supply of labor

$$\sum_{j=2}^{5} L_j = L_U \tag{17}$$

The population grows by migration as well as by natural increase; migration is a function of the relative wages between urban and rural areas. The labor supply in the urban sector is, through migration, sensitive to relative wage differences and the labor-supply curve thus slopes upward.

HOUSEHOLD DEMAND AND INCOME

Consumption demand and its pattern have long been suppressed in the explanation of the long-run economic growth process, at least in theoretical studies. The supply condition has always been the primary focus. In some empirical studies, however, the importance of the final demand and its structure has been stressed (Kelley 1968 and 1969).

In a simple two-sector simulation model by Kelley, Williamson, and Cheetham, the effect on the growth process from the demand side was analyzed. The conclusion was that

> . . . demand does play a pervasive and important role in the model through changes in consumer tastes. Indeed, in a simulation experiment we find that the sensitivity of the economy to shifts in tastes toward urban goods may be as stimulatory to structural change in the long run as alterations in savings parameters, the variable of traditional focus in the development literature. Thus, the "demonstration effect," commonly a villain in descriptive analyses of growth and development, may turn out to be as much a hero as the touted puritan ethic regarding high savings and spending prudence. (Kelley, Williamson, and Cheetham 1974, p. 241)

Did demand play a similar role in the Swedish development? In the simulations of the model this question can be answered. From different studies it is clear that there has been a shift in consumption patterns. In a study of the cost of living in Sweden between 1860 and 1930, Myrdal composed two typical household budgets, one for the middle and one for the end of the 19th century (Myrdal 1933, pp. 116 and 138). He found that during this time the consumption pattern changed considerably. For example, the share of the family income spent on food decreased from 65 to 55 percent. In a study by Allen (1955, p. 91) comparing household budgets for industrial and agricultural workers for the year 1913/1914, the same conclusion was drawn. As expected, the share of food expenditure was highest among the lower paid rural workers. These changes in budget shares for different types of commodities are due to both price and income effects. Changes in relative prices affect the allocation of expenditure. When the per capita income grows, the marginal increase in demand for luxuries (industrial goods) is larger than that for necessities (agricultural goods). This so-called Engel effect has been a typical feature of the growth process in various types of countries on different development levels (Houthakker 1957), and Sweden is no exception (Parks 1969, p. 648). The typical relationship between income elasticities of different commodities seems to be that the income elasticity for primary products is lower than for industrial goods, which is, in turn, lower than for services.

Besides these demand-structure characteristics, duality in the demand pattern is sometimes stressed (Kelley, Williamson, and Cheetham 1972, p. 76). The consumers in urban areas disclose a different consumption pattern from the population in the traditional agricultural sector, even for given incomes and prices. Thus urbanization also plays an important, indirect role in the development process through its influence on the pattern of final demand.

Against this background the household demand in the model is captured by two expenditure systems, one for the urban areas (U) and one for the agricultural areas (A). The selected form is the Linear Expenditure System (LES). [A detailed treatment of LES can be found in Powell (1974) where the derivation from underlying utility functions is also discussed.] We use this formulation in the following way:

$$\frac{P_i^D D_{ij}}{N_j} = b_{ij}P_i^D + \beta_{ij}\left(\frac{C_j}{N_j} - \sum_{i=1}^{5} b_{ij}P_i^D\right) \qquad \begin{array}{l} i = 1, \ldots, 5 \\ j = A, U \end{array} \tag{19}$$

$$C_j = (1 - s^l)\left(Y_j^{Dl} - \sum_{i=1}^{5} b_{ij}P_i^D N_j\right) + (1 - s^c)Y_j^{Dc} + \sum_{i=1}^{5} b_{ij}P_i^D N_j \qquad j = A, U \tag{20}$$

where D_{ij} is consumption of commodity i in sector j, b_{ij} is a parameter which represents the per capita subsistence consumption of commodity i in sector j, and β_{ij} stands for the marginal propensity to consume commodities after subsistence expenditures are satisfied. The consumption expenditure C_j is the remaining disposable income (Y_j^D) after deduction for savings. Different savings rates (s^l and s^c) are assumed for labor and capital income. The labor forces are assumed to save only from their "supernumerary" incomes, i.e., after basic-needs consumption is satisfied.

Already in the 1870s a large range of different taxes and duties existed in Sweden: different property taxes, a proportional income tax, a personal tax for adults independent of income, and so on (Lundsjö 1975, p. 41). In the model, the 19th-century taxation system is roughly described by a proportional tax on capital income, τ^c (including factor returns on land in agriculture), and on wages, τ^l. In eqs. (21)–(24), the disposable incomes are defined as gross income minus taxes

$$Y_A^{Dl} = (1 - \tau^l) W_1 L_1 + RE \tag{21}$$

The term RE in eq. (21) refers to remittances from emigrants, which the agricultural labor force receives in addition to income from wages. These remittances have often been neglected in studies of this period, but they are of a substantial magnitude. The amount fluctuates around an average of 1 percent of the Swedish national product (Lindahl, Dahlgren, and Koch 1937, p. 588). In the model it is assumed that these remittances are sent to people living in the rural areas since these are the main origins of the emigrants. The remittances are exogenously determined in the model. The capital income in the agricultural sector

$$Y_A^{Dc} = (1 - \tau^c)\Pi_1 \tag{22}$$

consists of income from land and capital. In the urban sector, labor income comes only from employment in industries

$$Y_U^{Dl} = (1 - \tau^l) \sum_{j=2}^{5} W_j L_j \tag{23}$$

and capital income comes from returns on capital investments

$$Y_U^{Dc} = (1 - \tau^c) \sum_{j=2}^{5} Q_j K_j \tag{24}$$

EXPORTS AND IMPORTS

As has already been pointed out in the sectorial division discussion of the model, exports have played a crucial role in Swedish economic development. They have affected economic growth in two ways: through an increase in the demand for Swedish products and through an increase in productivity because of competition with foreign supply.

The effects of exports on Swedish economic growth were especially important during the prewar period. Ohlsson (1969, p. 60) has estimated that the direct and indirect effects of foreign trade contributed 56 percent of the growth in the national product between 1870 and 1890 and 29 percent between 1890 and 1913. He also concluded that a large part of the technical progress made during this time can be explained by foreign trade through its positive effect on productivity.

These stimulating effects on the Swedish economy, made possible by a quick adaptation to new world market conditions, altered the structure of Swedish foreign trade.

> At the outbreak of the First World War, about one third of Sweden's exports consisted of goods that 25 years earlier had not, broadly speaking, existed in the Swedish export statistics. The expansive powers in the exports had thereby been usurped by quite other groups of goods than earlier. (Fridlizius 1963, p. 30)

Two characteristic features of this structural change should be stressed. The first is the decline in agricultural exports, as has been shown in Table 2. In the 1870s, agricultural exports made up more than 20 percent of Sweden's total exports. Oats were the most important export product until 1890 when butter took this position. The stagnation in grain exports was due to sharpened competition. Russia and America became strong competitors because of improved transportation facilities. Toward the end of the century grain exports from Sweden almost ended.

The second characteristic feature is the change from exporting raw materials and less refined commodities to more manufactured products. Technical innovations and organizational changes altered this structure. Pig iron had traditionally been the main export product of the iron and steel industry, but due to new ingot-steel processes, steel exports markedly increased. The mining sector changed its character as well. The old mining industries in central Sweden began to concentrate on manufactured products, and phosphorus iron ore in the north became worth mining. Furthermore, in the 1890s, the engineering industry started to expand on the basis of two early Swedish innovations: the separator, originally a Swedish invention, and the telephone. Also, the timber industry began to reflect the typical export pattern – a transition to manufactured products. In the 1880s this industry held a 43 percent share of the world market, but this share decreased considerably by the end of the 1890s. During the same period, however, the pulp and paper industry began to expand.

Initially, imports concentrated on only a few products, as did exports, but as the economy grew imports became more and more diversified (see Table 2). The main import groups were agricultural products (more than 25 percent during the entire period), food products, and textiles and clothing. As can be seen in Table 2, imports existed in sector 2, the export-oriented industry.

In order to allow for both exports and imports in the sectors, one has to assume a finite elasticity of substitution between domestically produced commodities and those supplied by foreign producers. Relying on this assumption separate export and import functions are fomulated for each of the trade-participating sectors. Four different export functions are included in the model and should capture the important export-determining factors. The increase in world trade, as well as the development of productivity and production costs in Sweden in relation to the rest of the world, has been pointed out as the important factor behind the growth of Swedish exports (Ohlsson 1969, p. 83). Thus these factors will influence exports in the model.

In sectors 1 and 3, the agricultural sector and the home-market sector, the export functions have an identical formulation

$$EX_i = EX_i^o (P_i/P_i^W)^{\epsilon_i} \exp(\sigma_i t) \qquad i = 1, 3 \qquad (25)$$

Exports from sector i, EX_i, are determined by the relation between Swedish production costs P_i and the world market prices P_i^W, as well as the growth of the world market, σ. The price elasticity parameter, ϵ_i, captures the response between changes in relative prices and exports. EX_i^o is constant.

All the main Swedish export industries are put together into one sector in the model: sector 2, export-oriented industry. Thus one feature of the Swedish export pattern cannot be captured in the model, that is the transition from raw-material exports to the export of manufactured products. (We have not divided this sector into a base-industry sector and a refining-industry sector in order to capture this transition because, to our knowledge, the necessary data are not available.) More than three-fourths of the industrial exports are covered by this sector. In 1899, the total share of Swedish industrial products in the world market was 0.97 percent and in 1913 it was 1.25 percent (Ohlsson 1969, p. 79). It seems reasonable to assume from this that the export industry was a price-taker in the world market, and that these products sold at world market prices in the home market (i.e., $P_2^D = P_2^W$). The export-limiting factor is, therefore, the growth of the capacity of the industry (i.e., productivity increases and capital formation). Against this background the export function in our model cannot be of the same type as it is for sectors 1 and 3. Instead, the exports from sector 2 are determined as a residual in the balance of payments. This means, for instance, that the growth capacity of the export industry will implicitly be the limiting factor on exports through the development of other economic variables in the model

$$P_2 EX_2 = P_1^W IM_1 + P_2^W IM_2 + P_3^W IM_3 - P_1 EX_1 - P_3 EX_3$$
$$- P_4 EX_4 - F - RE \qquad (29)$$

where IM measures imports; F, the net capital inflow from abroad; and RE, the remittances from emigrants.

The exports from sector 4, the service sector, originate from the subsectors of transportation and commerce. The export revenues from commerce are the trade markups on exported goods, and from transportation they are the income earned by Swedish ships in foreign trade (more exactly net income, see Johansson 1967, p. 182). In the model, exports from sector 4 are assumed to be determined as a fixed share of the total exports from sectors 1–3

$$EX_4 = \upsilon \sum_{i=1}^{3} EX_i \qquad (26)$$

The import share in the model is a function of the relationship between domestic production costs and world market prices (plus any custom duty, ϕ, that may occur)

$$im_i \equiv \frac{IM_i}{X_i - EX_i} = im_i^0 \left[\frac{P_i}{(1 + \phi_i)P_i^W} \right]^{\mu_i} \qquad i = 1, 3 \tag{27}$$

where im_i^0 is a constant and μ_i is the price elasticity parameter.

Since, by assumption, no price differences exist in sector 2, prices cannot have an impact on the import share. Instead it is assumed, in correspondence with the figures in Table 2, that the share diminishes over time

$$im_2 \equiv \frac{IM_2}{X_2 - EX_2} = im_2^0 \exp(-\psi t) \tag{28}$$

SAVINGS AND INVESTMENTS

The domestic savings pattern during the 1870–1914 period displayed two different tendencies, as can be seen in Figure 2. During the 1870s and the 1880s, the savings rate diminished from almost 11 percent to around 7 percent. The rate showed a rapid increase, however, at the beginning of the 1890s.

The investment rate exhibited a similar pattern, but the reduction in the 1870s and 1880s was not as pronounced as the decline in the savings rate. The difference between these two rates (when the investment rate is higher than the savings rate) is the net capital borrowing from abroad. From Figure 2 it is obvious that there was an important inflow of foreign capital to Sweden during the industrialization period. The borrowing from abroad, mainly from France, was undertaken primarily by the government (Sundbom 1944). Economic historians have found that foreign capital played a crucial role in Sweden's economic development process. Through capital inflow, Sweden was able to build "cities, railways, and factories at the same time" (Gårdlund 1942, p. 194). Investment in the infrastructure (housing and transportation) made up over 50 percent of total investments during the prewar period. The housing share fluctuated between 30–40 percent and investment in transportation was around 20 percent. Industry's share increased from 16 percent in the 1870s to 25 percent before the First World War and agricultural investments declined from 22 percent to 9 percent of the total investment (Lundberg 1969, p. 142).

During the beginning of the industrial era hardly any financial market existed. The need for industrial capital was to a great extent met by internal sources through retained profits, and the external credit facilities were mainly supplied by private persons with a close connection to the companies. [For a description of the financing of the Swedish industry during the industrial breakthrough, see Gårdlund (1947)]. Toward the end of the century private

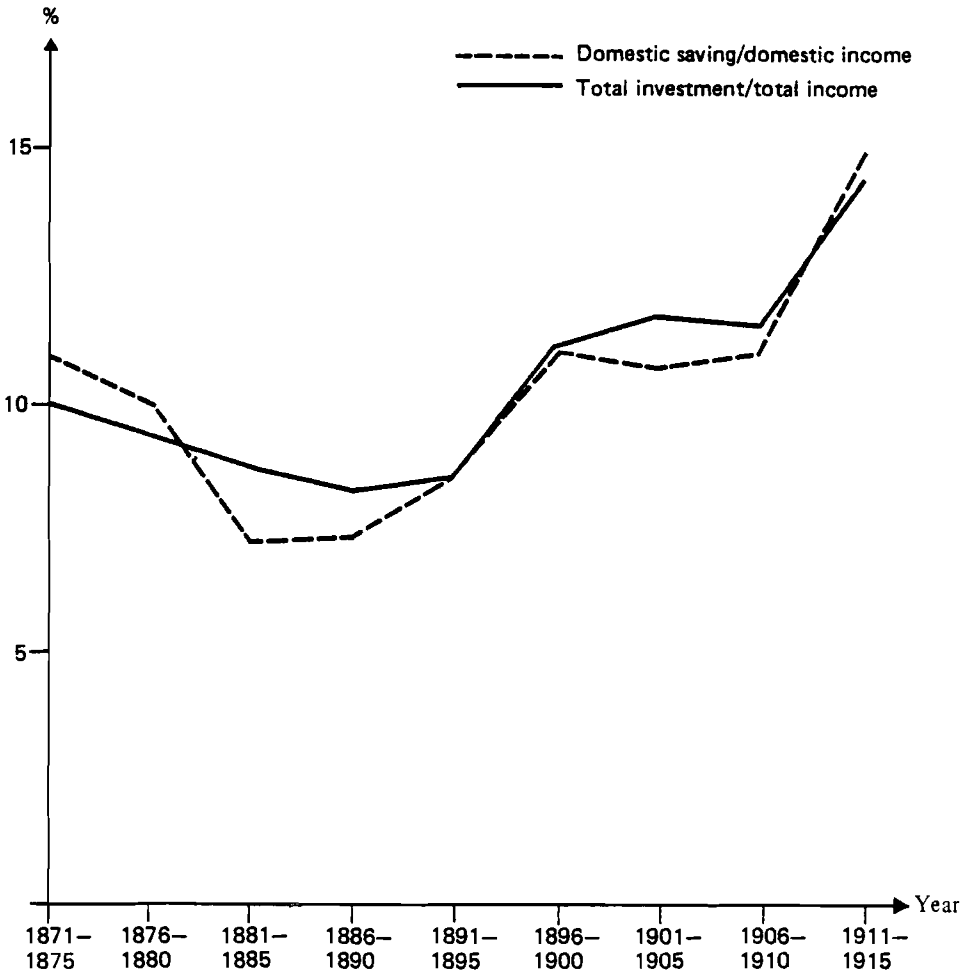

FIGURE 2 Savings and investment rates, 1870–1914. Source: adapted from Krantz and Nilsson (1975) Table 2.2.3, pp. 163, 164.

banks became more and more important as collectors of private savings and suppliers of credit. The growth of financial intermediaries made the capital market less imperfect, but nevertheless by the end of the period, the market was still far from efficient. Thus capital formation in Sweden was characterized by large government investment, foreign borrowing, and a growing but imperfect financial market.

Therefore, to assume a perfect capital market and rate of return equalization among all the sectors seems to be an incorrect way to describe the real situation. The ideal model, of course, should have investment functions that capture this imperfect market. But, at this stage it appears to be too difficult a task. Instead a simpler treatment is chosen as previously described.

Total investments in the economy, I, are allocated between agriculture and the rest of the economy, the four urban sectors, by an exogenously chosen parameter

$$I_1 = \xi I \tag{33}$$

$$I_U = (1-\xi)I \tag{34}$$

where ξ is simply the share of total investment that went into agriculture, and I_1 and I_U the investments in the two sectors. The capital stock in period t consists of the stock in period $t-1$ plus gross investments minus depreciations

$$K_j(t) = K_j(t-1) + I_j(t-1) - \left[\kappa^B \zeta_j + \kappa^M (1-\zeta_j)\right] K_j(t) \qquad j = A, U \tag{50}$$

where κ^B and κ^M are different depreciation rates of the two types of physical capital of which the capital stock is assumed to consist: namely, buildings and plants, superscript B, and other capital equipment, superscript M. The sector's share of buildings and plants in the capital stock is denoted by ζ_j. The reason for this formulation is that the investments are produced in two different sectors: buildings and plants in sector 5, and other capital equipment in sector 2.

$$I_1^B = \zeta_1 I_1 \tag{35}$$

$$I_1^M = (1-\zeta_1)I_1 \tag{36}$$

$$I_U^B = \zeta_U I_U \tag{37}$$

$$I_U^M = (1-\zeta_U)I_U \tag{38}$$

Within the four urban sectors, capital stock is assumed to be completely mobile, thus of the putty-putty type, and is allocated so that a specific structure of the sectorial rate of return is established [see discussions about eq. (13)].

Savings originate from two different sources: private savings and government saving. Private savings are derived from labor and capital incomes in both agricultural and urban sectors. As was discussed earlier, some parts of the expenditure are devoted to cover basic needs of the population. It seems reasonable to assume, therefore, that savings are deducted from the remaining part of the income, the supernumerary income

$$S_j = s^l \left(Y_j^{Dl} - \sum_{i=1}^{5} b_{ij} P_i^D N_j\right) + s^c Y_j^{Dc} \qquad j = A, U \tag{30}$$

where s^l and s^c denote the share of savings from labor and capital incomes. It is assumed that the savings ratio from capital income is higher than from labor income. Notice that demographic changes influence savings. A higher fertility, *ceteris paribus*, leads to a decrease in savings because a larger part of the income has to be devoted to subsistence consumption.

Furthermore, savings are also undertaken by the government and these savings, S^G, are what remains after governmental expenditures, C^G, are deducted from governmental income. This income originates from three sources, taxes on wages and capital incomes, customs duties, and foreign borrowing

$$S^G = \sum_{j=1}^{5} \tau^l W_j L_j + \tau^c \Pi_1 + \sum_{j=2}^{5} \tau^c Q_j K_j + \sum_{i=1}^{3} \phi_i P_i^W IM_i + F - C^G \tag{31}$$

Government spending (C^G) is an exogenous variable. The total savings in the model determine the amount of resources that are available for investment in a certain year. Thus, total savings equal total investments

$$I = S_A + S_U + S^G \tag{32}$$

MIGRATION

As has already been pointed out, the differences in economic forces between the agricultural sector and the more modern industrial sectors caused a reallocation of the most mobile production factor: the labor force. Migration was stimulated by industrialization and a strong relationship can be seen between the increase in migration and the industrial breakthrough.

Swedish migration began during the second part of the 19th century. Until the 1840s Sweden had been a rather static society with little and well regulated migration. In the 1840s the urban share of the total population was around 10 percent, a figure that had remained constant for decades (Öhngren 1977, p. 265). But at the end of the 1840s the urbanization rate started to increase, slowly but definitively. Even so, as late as the 1870s only slightly more than 13 percent of the population lived in towns and municipal communities, but 40 years later the urban population had increased to 30 percent of the total population.*

However, at this point, it is necessary to notice one specific feature of Swedish industrialization; namely, that the industries, to a great extent, were located in rural areas and not in towns and cities (Population Movements and Industrialization 1941). In particular, the industries that initiated the new epoch, the wood, mining, and metal industries, can be characterized as rural

*The definition of towns in early Swedish statistics is based on administrative rather than functional factors. From 1910 onwards, however, statistics have been available for the more functional definition of towns: "densely populated areas." In that year 34 percent of the population lived in such areas, so the difference between the two concepts is small, at least at the end of the period of study (Historical Statistics of Sweden 1969).

TABLE 4 The share (in percent) of industrial workers occupied in the rural areas of Sweden by branches of industry, 1896 and 1913.

Branches of industry	1896	1913
Mining and basic metal	99.9	98.7
Metal manufacturing	47.5	37.2
Stone, clay, and glass	85.4	86.2
Lumber, etc.	84.1	81.0
Paper and printing	56.1	60.0
Food products	40.5	40.4
Textile and clothing	36.1	35.9
Leather, rubber, etc.	34.2	23.9
Chemical	43.0	33.6
Power, light, and waterworks	50.0	22.0
All branches	63.3	58.2

SOURCE: Thomas (1941) p. 179.

based. Table 4 displays the percentage of industrial workers in rural industries in 1896 and in 1913. In 1896, about 63 percent of all industrial workers were employed in rural areas. The figure decreased to 58 percent in 1913. This decrease not only reflects the fact that urban industries had increased their employment share but also points to a typical feature of the Swedish urbanization process – the creation of new and larger towns. This phenomenon occurred through the growth of population agglomerations around rural industries. After some time, these settlements either received town charters or were incorporated into neighboring cities. Thus, urbanization in Sweden did not reflect the total movement of the population.

This point is important to remember when interpreting the model. In the model all nonagricultural activities are characterized as urban. The simulation result will thus yield a higher degree of urbanization compared with real data, but this rate will reflect more accurately the actual proportion of the population movement than will the official figures on urban growth. Moreover, the model cannot be given a spatial interpretation as has been done in similar studies of Third World countries (see, for example, Kelley and Williamson 1980, p. 13).

As has already been stressed, Swedish emigration was largely directed toward the United States.* The extent, character, and causes have been investigated in several studies (for example, Thomas 1941; Runblom and Norman

*Immigration amounted to slightly more than 200,000 people during the period of study, but 50 percent of them originated in the USA and consisted of emigrants who returned to Sweden after some years in America (Historical Statistics of Sweden 1969, Part 1: Population, pp. 120–125). In the present model immigration is not explicitly treated and the migration concept is thus net migration.

1976). Econometric studies have been made that deal with factors influencing emigration (Wilkinson 1967 and 1970; Williamson 1974; Quigley 1972; Hamberg 1976). The results strongly support the view that economic factors such as employment opportunities and real income gains were most important in the explanation of emigration. These studies also deal with the economic situation in Sweden and the USA at the time, i.e., the push/pull factors, which were crucial to emigration. There seems to be no disagreement that the situation in both the sending and the receiving country strongly influenced the migration even though the relative importance that various studies place on each factor differs. In studies made by historians, push and pull factors explain different waves of emigration. The first wave of emigrants occurred at the end of the 1860s (Figure 3) mainly as a consequence of the famine during those years. The remaining waves during the 19th century were more closely related to industrial recession and agricultural crises. After the turn of the century emigration seemed to be caused mainly by pull factors in the United States (Carlsson 1976).

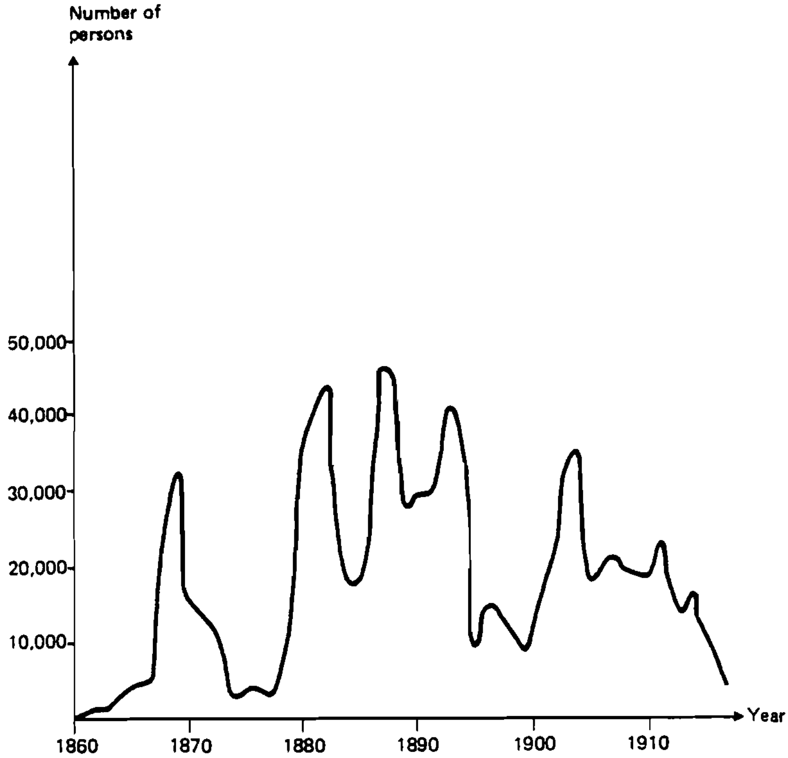

FIGURE 3 Registered emigration from Sweden to non-European countries, 1860–1915. Source: adapted from Runblom and Norman (1976) Table 5.1, p. 117.

In some migration studies, however, it is the relationships between expected income in the different regions that are considered to be the determining factors in migration. By stressing the comparison of the expected income in various regions and not simply what the economic situation is in one region independent of another, the distinction between push and pull factors becomes artificial. This hypothesis is not only supported by empirical findings (Hamberg 1976) but also can be justified from the theoretical point of view (Greenwood 1975; Sjaastad 1962). The theoretical foundation lies in human capital theory. Migration is looked upon as an investment, and it is the present value (*PV*) of an investment in migrating from one region to another that determines whether the move was made or not. The present value of migrating from region *A* to region *U* can be defined as

$$PV_{AU} = \sum_{t=1}^{n} \frac{Y_{Ut} - Y_{At}}{(1+r)^t} - \sum_{t=1}^{n} \frac{C_{Ut} - C_{At}}{(1+r)^t}$$

where *Y* refers to incomes in the different regions, *C* to the costs associated with residence in the two localities, and *r* to the rate of discount. Only if $PV > 0$ will an individual residing in *A* move to *U*, and in a choice between different moving possibilities, the one that maximizes *PV* will be chosen. When applying this model, one has to make some very rough approximations.

In this model the present value of future earnings is approximated by current wages in different localities. In some migration studies the income variables have been disaggregated into wages and the probability of working, the latter approximated by the unemployment rate (Todaro 1969). But since the model that will be used in the Swedish case study assumes full employment, and since the wages derived in the model and used in the migration function are sensitive to the supply conditions of labor, there is no need to explicitly capture this aspect in the formulation.

The cost differences between the three possible localities in the model – rural areas, urban areas, and the United States – are captured through a cost-of-living index (*COL*) specific to the different regions. Of course, the costs of transportation across the Atlantic did play a large role, but at present there is no general agreement among historians on whether the price of the ticket explains the fluctuation in emigration or not, even though the price fell in relation to wages over the period studied (Semmingsen 1972, p. 58). On the other hand, the transportation costs do explain the low emigration rate among the poorest social classes, but this effect is captured by parameter values in the migration functions.

Thus, in the present model, the propensity to emigrate (*em*) from Sweden (*S*) to the United States (*USA*) is only a function of the relation between the current real wages (*W*) in the two countries

$$em = f\left(\frac{W_{USA}/COL_{USA}}{W_S/COL_S}\right)$$

Migration from rural to urban areas within Sweden and from Sweden to the United States is determined in two stages in the model. First, the out-migration rate from agriculture (m) is defined. It is a function of the relation between a weighted real wage in the in-migration regions (the urban areas and the United States) and in agriculture*

$$m \equiv \frac{M}{N_1} = 1 - \exp(-\eta W^*) \tag{45}$$

$$W^* = \left[d \frac{W_U}{COL_U} + (1-d) \frac{W_{USA}}{COL_{USA}} \right] \Big/ \frac{W_1}{COL_1} \tag{46}$$

Second, the emigration rate, em, is treated as a function of the relation between real wages in the urban areas and the United States

$$em \equiv \frac{E}{M} = 1 - \exp(-\theta W^{**}) \tag{47}$$

$$W^{**} = \left(\frac{W_{USA}}{COL_{USA}} \right) \Big/ \left(\frac{W_U}{COL_U} \right) \tag{48}$$

where M is the total amount of net migrants out of the rural areas, E is the amount of net emigrants moving abroad and η, θ, and d are parameters. The costs of living in the agricultural and urban areas are determined endogenously. But the cost of living, COL_{USA}, and the wage level, W_{USA}, in the United States are exogenous variables

$$COL_j = \sum_{i=1}^{5} P_i^D \frac{P_i^D D_{ij}}{C_j} \qquad j = A, U \tag{49}$$

Recall from the labor market discussion that wages in the urban sectors are in a close relationship to each other. Therefore, W_U, which is used in eq. (14) to capture this relation, can be interpreted as a wage index for the urban sectors.

POPULATION GROWTH

One of the dynamic forces in the model is the growth of the population. The Swedish population experienced great changes during the second part of the 19th and the beginning of the 20th century. With an average growth rate of 0.7 percent per year, the population increased from 4.2 million to slightly

*This formulation of the migration functions is rather *ad hoc*. It would be more consistent with the underlying assumption of rationality in the rest of the model if the functions were derived from utility maximization conditions.

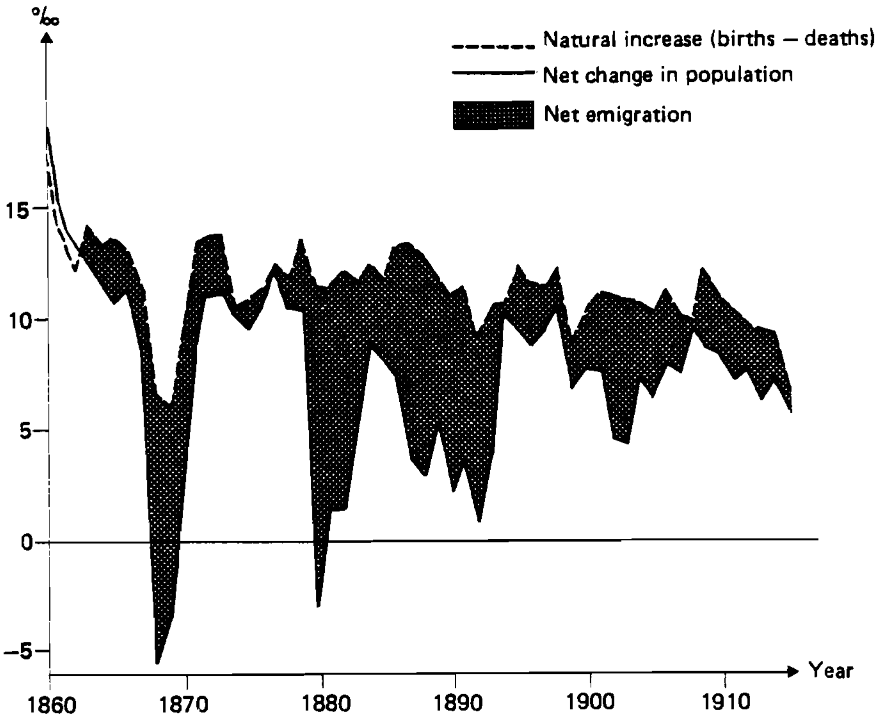

FIGURE 4 Changes in the population of Sweden, 1860–1914. Source: adapted from Historical Statistics of Sweden (1969) Table 28, pp. 95–97.

more than 5.6 million at the outbreak of World War I. As shown in Figure 4, this was not a smooth increase but a fluctuating one which was due to both changes in birth and death rates and to emigration. Fridlizius (1979), in a study about the demographic transition in Sweden, pointed out that the 1890s were the dividing years between a period of accelerating population growth, due mainly to decreasing mortality (1810–1890), and the third phase of demographic transition characterized by a strong decline in fertility.

The magnitudes of the demographic variables are very different between rural and urban areas. In Table 5 the crude birth and death rates, and the resulting increases in population, are displayed for the two types of regions. The urban areas showed higher rates for both births and deaths during the initial years of industrialization. The great difference between the urban and rural death rates is especially notable when one considers that the proportion of the

TABLE 5 Changes in crude birth and death rates in Sweden, 1861–1920.

Period	Crude birth rates			Crude death rates			Natural increase rates		
	Rural	Urban	Ratio of urban to rural (× 100)	Rural	Urban	Ratio of urban to rural (× 100)	Rural	Urban	Ratio of urban to rural (× 100)
1861–1870	31.2	33.0	106	19.3	26.2	136	11.9	6.8	57.1
1871–1880	30.2	32.1	106	17.3	24.1	139	12.9	8.0	62.0
1881–1890	28.7	31.1	108	16.4	19.7	120	12.3	11.4	92.7
1891–1900	27.2	27.1	100	16.1	17.4	108	11.1	9.7	87.4
1901–1910	25.7	25.9	101	14.9	14.9	100	10.8	11.0	101.9
1911–1920	22.7	20.5	90	14.6	13.5	92	8.1	7.0	86.4

SOURCE: Thomas (1941) Table 9, pp. 44, 45.

population in the ages 15–60 was higher in urban areas than in rural areas (Thomas 1941, p. 29). The decline in crude birth and death rates was, on the other hand, higher in the urban areas causing the relation in ratios between the two types of areas to be reversed at the end of the First World War. The patterns of change were similar even though the magnitudes differed. Decline in mortality and fertility began more or less simultaneously in both rural and urban regions. The demographic dualism between rural and urban areas was thus reflected in the initial differences in the demographic variables rather than in the patterns of change.

In the model, population growth is more or less exogenous. Even though there is evidence for causal links between economic factors and some demographic variables, for example, fertility (Wilkinson 1973), it has not been possible at this stage of modeling to endogenize them. Emigration is, on the other hand, endogenous in the model and is responsible for a major part of the change in the Swedish population (see Figure 4). Population growth is described by the following two equations, one for the rural, and one for the urban areas

$$N_1(t) = N_1(t-1)(1+f_1) - M(t-1) \tag{51}$$

$$N_U(t) = N_U(t-1)(1+f_U) + M(t-1) - E(t-1) \tag{52}$$

The changes in population are thus a consequence of the natural rate of population increase (f) and migration. Rates of natural population increase differ between regions and over time, and are, therefore, treated as exogenous variables and not as fixed parameters in the model.

This formulation of population growth makes the model useful for analyzing the phenomena of "long swings" or "Kuznets cycles" in the Swedish prewar development. The Kuznets-cycle hypothesis is concerned with the fluctuations of 15 to 25 years duration in the rate of growth of different variables. A discussion of these cycles can be found, for example, in Kuznets (1958), Abramovitz (1961), and Easterlin (1966). Morris Wilkinson (1967) has found evidence of long swings in the growth of the Swedish population and in some related economic variables. The population growth exhibits long swings, and emigration was primarily responsible for its amplitude until the first decade of the 20th century. He also found that the growth of capital formation and manufacturing output can be described by long waves. Furthermore, swings in manufacturing appear to lead to waves in population growth which are followed by changes in capital formation. He concludes by discussing the sources of the swings in manufacturing:

> It would be very convenient to place the source of the swings in Swedish manufacturing in the growth of the British economy. There is considerable evidence of long swings in significant sectors of the British economy. Furthermore, the turning points of the British long swings are provocatively

> close to the turning points of the Swedish long swings. Swedish exports do indeed give some support for this line of thinking. Prior to 1900, the growth of Swedish exports exhibits swings which consistently lead the swings in manufacturing. (Wilkinson 1967, p. 38)

In the present model, foreign trade is a crucial variable. The formulation makes it possible for long swings in manufacturing output to be initiated through exports, and eventually such swings can, via wage formation, be transmitted to emigration as well as to urbanization, and thus cause waves in population growth.

CONCLUDING REMARKS

This report has discussed a multisector growth model for Sweden during the 1870–1914 period. The model is based on the basic notion of neoclassical theory: prices are flexible enough to balance supply and demand on different markets. But some disequilibrating mechanisms have also been introduced into the model to capture some structural imbalances. The labor market, for instance, is separated between rural and urban areas and linked by migration. Migration, therefore, plays a crucial role in the development process and highlights some of the interrelationships among demographic and economic variables.

Our purpose has been to capture the most important aspects of Swedish demoeconomic development without making the model too large and too complicated. On the one hand, the model is intended to represent the key factors of a huge and complicated system, and on the other hand it should not be so large that the driving mechanisms become hidden in a "black box." This model is a compromise between these two aspects. In future work some parts of the model may be changed and others extended. For the purpose of highlighting demographic aspects and removing some simplifying assumptions, three desirable extensions are briefly discussed.

1. Investments and capital formation are exogenous in the agricultural and urban sectors. This is because of the difficulties in finding a reasonable allocation mechanism to capture the imperfect capital market. If such an allocation could be modeled, it would be possible to analyze how important a growing and more efficient capital market was in the Swedish case.
2. Demographic variables, with the exception of migration, are exogenous in the model. There is evidence indicating a strong influence of economic factors on demographic variables such as fertility (see, for example, Wilkinson 1973). An endogenizing of the natural increase of the population would cast further light on the interrelationships between demographic and economic factors.

3. The role that residential building played in Swedish development has been questioned in studies of the prewar period. Its share of the total investment adds up to one-third of the increase in the investment ratio. Construction of dwellings is one obvious consequence of urbanization and has also been stressed as one of the explanatory variables of the Kuznets cycle (Easterlin 1966). Therefore, it would be worthwhile to treat the housing sector – its demand and investment requirements – more explicitly in the model, and thus analyze its importance in Swedish demoeconomic development.

This report is only the first step in the study of Swedish urbanization and industrialization. The next step will be a simulation of the model and an analysis of numerous crucial questions through counterfactual simulations. It is in the empirical usage that the fruitfulness of this approach will be revealed. It is still open to question whether or not the model can shed further light on the demoeconomic development of industrialization in Sweden; however, the model does lay a foundation for future research in this field.

REFERENCES

Åberg, Y. (1969) Produktion och produktivitet i Sverige 1861–1965 (Production and Productivity in Sweden 1861–1965). Stockholm: Almqvist and Wiksell.

Abramovitz, M. (1961) The nature and significance of Kuznets cycles. Economic and Cultural Change 9: 225–248.

Allen, G.R. (1955) A comparison of real wages in Swedish agriculture and secondary and tertiary industries, 1870–1949. Scandinavian Economic History Review 3: 85–107.

Bagge, G., E. Lundberg, and I. Svennilson (1933) Wages in Sweden 1860–1930, I–II. London: P.S. King and Son Limited.

Bergman, L. (1978) Energy Policy in a Small Open Economy: The Case of Sweden. RR-78-16. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Bergman, L., and A. Pór (1980) A Quantitative General Equilibrium Model of the Swedish Economy. WP-80-4. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Carlsson, S. (1976) Chronology and composition of Swedish emigration to America. Pages 114–148 in: A History of Migration, edited by H. Runblom and H. Norman. Minneapolis: University of Minnesota Press, and Uppsala: Universitatis Upsaliensis, University of Uppsala.

Colosio, D. (1979) Urbanization and Economic Development in Mexico. WP-79-19. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Easterlin, R.A. (1966) Economic–demographic interactions and long swings in economic growth. The American Economic Review 56(5): 1063–1104.

Fridlizius, G. (1963) Sweden's exports 1850–1960: A study in perspective. Economy and History 6: 3–100.

Fridlizius, G. (1979) Sweden. Pages 340–405 in: European Demography and Economic Growth, edited by W.R. Lee. New York: St. Martin's Press.

Gårdlund, T. (1942) Industrialismens samhälle (The Industrial Society). Stockholm: Tidens förlag.

Gårdlund, T. (1947) Svensk industrifinansiering under genombrotts skedet 1830–1913. (Financing of the Swedish Industry during the Industrial Breakthrough 1830–1913). Stockholm.

Greenwood, M.J. (1975) Research on internal migration in the United States: A survey. Journal of Economic Literature 13: 397–433.

Hamberg, E.M. (1976) Studier i internationell migration (Studies in International Migration). Stockholm: Almqvist and Wiksell International.

Heckscher, E.F. (1957) Svenskt arbete och liv (Swedish Work and Life). Stockholm: Albert Bonniers förlag.

Henricsson, R.G. (1969) An Interpretation of the Significance of Emigration for the Growth of Economic Welfare in Sweden, 1860–1910. Unpublished Ph.D. thesis. Evanston, Illinois: Northwestern University.

Historical Statistics of Sweden (1969) Part I: Population. Stockholm: Statistika Centralbyrån.

Holgersson, B. (1974) Cultivated land in Sweden and its growth, 1840–1939. Economy and History 17: 20–51.

Houthakker, H.S. (1957) An international comparison of household expenditure patterns commemorating the centenary of Engel's Law. Econometrica 25: 523–551.

Johansen, L. (1974) A Multi-sectoral Study of Economic Growth. Amsterdam: North Holland.

Johansson, Ö. (1967) The Gross Domestic Product of Sweden and Its Composition 1861–1955. Uppsala: Almqvist and Wiksell.

Jörberg, L. (1961) Growth and Fluctuation of Swedish Industry 1868–1912. Lund: Almqvist and Wiksell.

Jörberg, L. (1970) Svensk ekonomi under 100 år (The Swedish economy over one hundred years). Pages 21–25 in: Svensk ekonomi (The Swedish Economy) edited by B. Södersten. Stockholm: Rabén and Sjögren bokförlag.

Jungenfelt, K.G. (1966) Löneandelen och den ekonomiska utvecklingen (The Share of Wages and Economic Development). Uppsala: Almqvist and Wiksell.

Kaneda, H. (1979) Issues in Policy Analysis of Agricultural Development and Internal Migration. WP-79-109. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Kelley, A. (1968) Demographic change and economic growth: Australia 1861–1911. Explorations in Entrepreneurial History 5: 209–277.

Kelley, A. (1969) Demand patterns, demographic change, and economic growth. Quarterly Journal of Economics 83: 110–126.

Kelley, A., and J. Williamson (1974) Lessons from Japanese Development. Chicago and London: The University of Chicago Press.

Kelley, A., and J. Williamson (1980) Modeling Urbanization and Economic Growth. RR-80-22. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Kelley, A., J. Williamson, and R. Cheetham (1972) Dualistic Economic Development. Chicago and London: The University of Chicago Press.

Kelley, A., J. Williamson, and R. Cheetham (1974) Demand, structural change, and the process of economic growth in nations and households. Pages 239–264 in: Essays in Honor of Moses Abramovitz, edited by P.A. David and M.W. Leder. London: Academic Press Inc.

Krantz, O., and C.A. Nilsson (1975) Swedish National Product 1861–1970. Lund: Liber.

Kuznets, S. (1956) Quantitative aspects of the economic growth of nations I. Economic Development and Cultural Change 5(1): 5–94.

Kuznets, S. (1958) Long Swings in the Growth of Population and in Related Economic Variables. Proceedings of the American Philosophical Society 102(1): 25–52.

Lundberg, L. (1969) Kapitalbildningen i Sverige 1861–1965 (Capital formation in Sweden 1861–1965). Stockholm: Almqvist and Wiksell.

Lundsjö, O. (1975) Fattigdomen på den svenska landsbygden på 1800 – talet (Rural Poverty in Sweden during the Nineteenth Century). Stockholm: Department of Economic History, University of Stockholm.

Lindahl, E., E. Dahlgren, and K. Koch (1937) National Income of Sweden 1861–1930, I–II. London: P.S. King and Son Limited.

Montgomery, A. (1947) Industrialismens genombrott i Sverige (The Breakthrough of Industrialization in Sweden). Stockholm: Skoglunds bokförlag.

Myrdal, G. (1933) The Cost of Living in Sweden. London: P.S. King and Son Limited.

Ohlsson, L. (1969) Utrikeshandeln och den ekonomiska tillväxten Sverige 1871–1966 (Foreign Trade and Economic Growth in Sweden, 1871–1966). Stockholm: Almqvist and Wiksell.

Öhngren, B. (1977) Urbaniseringen i Sverige 1840–1920 (The Urbanization in Sweden 1840–1920). Pages 261–352 in: Urbaniseringsprosessen i Norden, del 3 – Industrialiseringens første fase (The Urbanization in the Nordic Countries, Part 3 – The First Phase of Industrialization). Oslo: Universitetsförlaget.

Parks, R.W. (1969) Systems of demand equations: An empirical comparison of alternative functional forms. Econometrica 37: 629–650.

Population Movements and Industrialization (1941). London: P.S. King and Son Limited.

Powell, A.A. (1974) Empirical Analytics of Demand Systems. Lexington, Massachusetts: D.C. Heath.

Quigley, J.M. (1972) An economic model of Swedish emigration. Quarterly Journal of Economics 111–126.

Rogers, A. (1977) Migration Resources and Development. RR-77-14. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Runblom, H., and H. Norman, eds. (1976) A History of Migration. Uppsala: Almqvist and Wiksell.

Semmingsen, I. (1972) Emigration from Scandinavia. Scandinavian Economic History Reviews 20: 45–60.

Silenstam, P. (1970) Arbetskraftsutbudets utveckling i Sverige 1870–1965 (The Development of the Supply of Labor 1870–1965). Stockholm: Almqvist and Wiksell.

Sjaastad, L.A. (1962) The costs and returns of human migration. The Journal of Political Economy 70: 80–93.

Sundbom, I. (1944) Sveriges kapitalimport från Frankrike 1870–1914 (Swedish import of capital from France 1870–1914). Pages 228–237 in: Studier i Ekonomi och Historia tillagnade Eli F. Heckscher (Studies in Economy and History in Honor of Eli F. Heckscher). Uppsala: Almqvist and Wiksell.

Thomas, D.S. (1941) Social and Economic Aspects of Swedish Population Movements 1750–1933. New York: The MacMillan Company.

Todaro, M.P. (1969) A choice of labor migration and urban unemployment in less developed countries. American Economic Review 138–148.

Wicksell, K. (1882) Om utvandringen: Dess betydelse och orsaker (About Emigration: Its Importance and Causes). Stockholm: Albert Bonniers förlag.

Wilkinson, M. (1967) Evidences of long swings in the growth of the Swedish population and related economic variables, 1860–1965. Journal of Economic History 27(1): 17–38.

Wilkinson, M. (1970) European migration to the United States: An econometric analysis of aggregate supply and demand. Review of Economics and Statistics 52(3): 272–279.

Wilkinson, M. (1973) An econometric analysis of fertility in Sweden 1870–1965. Econometrica 41(4): 633–642.

Williamson, J.G. (1974) Late Nineteenth Century American Development: A General Equilibrium History. Cambridge, Massachusetts: Cambridge University Press.

Appendix A

THE SWEDISH ECONOMY, 1871–1915: EMPLOYMENT BY SECTOR, PRODUCTION BY SECTOR, AND CHANGES IN PRODUCTIVITY DUE TO REALLOCATION OF LABOR FORCE

APPENDIXES

TABLE A1 The number (in thousands) and share of people employed in different sectors in Sweden, 1871–1915.

Period	Agriculture		Manufacture		Transport and communication		Public administration		Total[a] employment	Total population
	Number	Share	Number	Share	Number	Share	Number	Share		
1871/1875	1060.7	0.793	200.5	0.150	27.5	0.021	48.9	0.036	1337.6	4274.0
1876/1880	1079.9	0.775	212.2	0.152	39.9	0.027	61.8	0.044	1393.8	4500.0
1881/1885	1081.0	0.755	236.4	0.166	44.5	0.031	69.2	0.048	1431.1	4604.7
1886/1890	1070.9	0.742	254.7	0.177	43.9	0.030	74.1	0.051	1443.6	4741.7
1891/1895	1060.6	0.712	302.1	0.203	48.9	0.032	78.7	0.053	1490.3	4831.8
1896/1900	1054.3	0.667	390.0	0.247	57.7	0.036	79.3	0.050	1581.3	5032.1
1901/1905	1027.5	0.631	443.1	0.272	70.8	0.043	87.3	0.054	1628.7	5214.3
1906/1910	990.7	0.602	483.5	0.244	85.6	0.052	85.8	0.052	1645.5	5405.9
1911/1915	970.1	0.574	531.6	0.314	94.1	0.056	95.4	0.056	1691.2	5620.4

[a]Building activities, commerce, and domestic services are excluded.
SOURCE: Jungenfelt (1966) Table 1, p. 224.

TABLE A2 National product by sector of origin: volume values.[a]

Period	Agriculture	Manufacture	Building and construction	Transport and communication	Personal private services	Public administration	Housing
1871/1875	495	134	121	32	253	186	176
1876/1880	525	151	144	42	297	103	187
1881/1885	560	193	129	55	331	110	196
1886/1890	585	220	130	64	359	113	208
1891/1895	645	317	122	81	408	115	217
1896/1900	681	473	158	114	465	117	230
1901/1905	658	611	184	158	560	118	249
1906/1910	785	823	175	209	682	121	265
1911/1915	848	996	216	256	832	127	282

[a]Millions of Swedish kronor.

SOURCE: Krantz and Nilsson (1975) Table 3.2.1, pp. 172–174.

TABLE A3 Productivity gains due to reallocation of employment among sectors, 1871–1915.[a]

Period	Agriculture and manufacturing			All industries except building and construction, housing and domestic services		
	Change in productivity (%)		Gains (= percentage of actual change due to reallocation)	Change in productivity (%)		Gains (= percentage of actual change due to reallocation)
	Actual	Hypothetical		Actual	Hypothetical	
1871/1875–1876/1880	0.94	0.90	4	1.02	0.57	44
1881/1885–1886/1890	1.23	1.10	11	1.19	1.01	15
1891/1895–1896/1900	2.51	1.91	24	2.38	1.79	25
1901/1905–1911/1915	3.60	3.15	13	3.34	2.80	16
1871/1875–1911/1915	2.28	1.84	19	2.17	1.66	23

[a]The gains in productivity due to reallocation of the labor force are estimated by comparing the actual change in productivity (sectorial value added divided by labor force) with a hypothetical change. The hypothetical change is the development of productivity keeping each sectorial share of the employment constant, i.e., the same as in the beginning of the study period.

Appendix B

MATHEMATICAL STATEMENT OF THE MODEL

PRODUCTION SECTOR SUBSCRIPTS

1	agriculture, forestry, and fishing
2	export-oriented industry
3	home-market-oriented industry
4	services
5	building and construction

HOUSEHOLD SECTOR SUBSCRIPTS

A	households in the agricultural sector (i.e., production sector 1)
U	households in the urban sector (i.e., production sector 2–5)

INCOME SUPERSCRIPTS

l	income from wages
c	income from capital

ENDOGENOUS VARIABLES

P_i	domestic production cost of commodity $i = 1, \ldots, 5$
P_i^D	domestic price of commodity $i = 1, \ldots, 5$
P_j^*	value-added prices in sector $j = 1, \ldots, 5$
X_j	gross output in sector $j = 1, \ldots, 5$
X_{ij}	deliveries of intermediate goods from sector i to sector j
H	composite of labor and capital input in the agricultural sector
L_j	employment in sector $j = 1, \ldots, 5$
L_U	employment in urban sectors
W_U	index of the level of wages in the urban sectors
W_j	wage rate in sector $j = 1, \ldots, 5$
Π_1	rent in the agricultural sector
RC_j	rate of return on capital in sector $j = 2, \ldots, 5$
RC_U	index of rates of return in the urban sectors
S_A	savings in the agricultural sector
S_U	savings in the urban sectors
Y_j^{Dl}	disposable income by workers in sector $j = A, U$
Y_j^{Dc}	disposable income by capitalists in sector $j = A, U$
D_{ij}	consumption of commodity $i = 1, \ldots, 5$ in sector $j = A, U$
C_j	total consumption expenditure in sector $j = A, U$
COL_j	cost of living in sector $j = A, U$
EX_i	export of commodity $i = 1, \ldots, 4$
IM_i	import of commodity $i = 1, \ldots, 3$
S^G	savings by the government
M	total number of net migrants from the rural areas
E	total number of net emigrants
I	total investment
I_j	investment in sector $j = A, U$

I_j^B	investments in buildings and plants in sector $j = A, U$
I_j^M	investments in other capital equipments in sector $j = A, U$
K_j	capital stock in sector $j = 2, \ldots, 5$
Q_j	user cost of capital in sector $j = 2, \ldots, 5$

EXOGENOUS VARIABLES AND PARAMETERS

K_j	capital stock in sector $j = A, U$
P_i^W	price level expressed in Swedish currency, on international markets on commodity $i = 1, \ldots, 3$
h_j	labor augmenting technological change in sector $j = 1, \ldots, 5$
g_j	capital augmenting technological change in sector $j = 1, \ldots, 5$
f_1	net natural rate of population increase in the rural areas
f_U	net natural rate of population increase in the urban areas
COL_{USA}	cost of living in the USA
W_{USA}	wage level in the USA
F	net capital inflow
C^G	consumption expenditures by the government
R	total land acreage
N_1	total population in the rural areas
N_U	total population in the urban areas
RE	remittances from emigrants
p_j^h	sex-specific labor participation rate in sector $j = A, U$ $h = \Gamma$ (female), Ω (male)
z_j^h	share of population in working ages, $j = A, U$ $h = \Gamma, \Omega$
l_j	share of females in total population, $j = A, U$
ϕ_i	*ad valorem* custom duty of imports of commodity $i = 1, \ldots, 3$
a_{ij}	input of commodity $i = 1, \ldots, 5$ per unit of output in sector $j = 1, \ldots, 5$
a, δ_j, γ_j	distribution parameters in the production function of sector j
ρ_j	substitution parameter in sector $j = 1, \ldots, 5$
ω_j	index of the relative wage rate in sector $j = 2, \ldots, 5$
β_{ij}	marginal propensity to consume commodity $i = 1, \ldots, 5$ by household in sector $j = A, U$
b_{ij}	per capita subsistence consumption of commodity $i = 1, \ldots, 5$ in sector $j = A, U$
s^l, s^c	rate of savings from labor income (l) and capital and land income (c)
ϵ_i	price elasticity parameter in the export demand for commodity $i = 1, \ldots, 3$
μ_i	price elasticity parameter in the import demand for commodity $i = 1, \ldots, 3$
σ_i	annual rate of change of world market trade with commodity $i = 1, \ldots, 3$
ψ	annual rate of change in import of commodity 2
τ^l, τ^c	tax rate from labor income (l) and capital and land income (c)
κ^B, κ^M	annual rate of depreciation of buildings and plants (B) and other capital equipment (M)

ζ_j	share of buildings and plants in the capital stock of sector $j = 1, \ldots, 5$
ξ	share of total investment in agriculture
r	annual rate of growth in land acreage
λ_j^g, λ_j^h	annual rate of technological change in sector $j = 1, \ldots, 5$
η, θ	parameters in the migration and emigration functions
A_j	constant in the production functions $j = 1, \ldots, 5$
v	export share in sector 4
ν_j^h	growth rate in labor participation $j = A, U$ $h = \Gamma, \Omega$
d	weight in the migration function
q_j	index of the relative rates of return in sector $j = 2, \ldots, 5$

PRICES

$$P_i^D = \frac{im_i}{1 + im_i}(1 + \phi_i)P_i^W + \frac{1}{1 + im_i}P_i \qquad i = 1, 3 \tag{1}$$

$$P_2^D = P_2^W \tag{2}$$

$$P_i^D = P_i \qquad i = 4, 5 \tag{3}$$

PRODUCTION AND TECHNOLOGY

$$P_i^* = P_i - \sum_{j=1}^{5} P_j^D a_{ji} \qquad i = 1, \ldots, 5 \tag{4}$$

$$X_1 = A_1 R^\alpha H^{1-\alpha} \tag{5}$$

$$H = \left\{\delta_1 (g_1 K_1)^{-\rho_1} + \gamma_1 (h_1 L_1)^{-\rho_1}\right\}^{-1/\rho_1} \tag{6}$$

$$X_j = A_j \left\{\delta_j (g_j K_j)^{-\rho_j} + \gamma_j (h_j L_j)^{-\rho_j}\right\}^{-1/\rho_j} \qquad j = 2, \ldots, 5 \tag{7}$$

$$X_{ij} = a_{ij} X_j \qquad \begin{array}{l} i = 1, \ldots, 5 \\ j = 1, \ldots, 5 \end{array} \tag{8}$$

$$\frac{W_1 L_1}{P_1^* X_1} = (1 - \alpha)\gamma_1 \left(\frac{H}{h_1 L_1}\right)^{\rho_1} \tag{9}$$

$$\Pi_1 = P_1^* X_1 - W_1 L_1 \tag{10}$$

$$Q_j = P_2^D (RC_j + \kappa^M)(1 - \zeta_j) + P_5^D (RC_j + \kappa^B)\zeta_j \qquad j = 2, \ldots, 5 \tag{10a}$$

$$\frac{W_j L_j}{P_j^* X_j} = \gamma_j \left(\frac{X_j}{h_j L_j A_j}\right)^{\rho_j} \qquad j = 2, \ldots, 5 \tag{11}$$

$$\frac{Q_j K_j}{P_j^* X_j} = \delta_j \left(\frac{X_j}{g_j K_j A_j} \right)^{\rho_j} \qquad j = 2, \ldots, 5 \tag{12}$$

$$RC_j = q_j RC_U \qquad j = 2, \ldots, 5 \tag{13}$$

$$W_j = \omega_j W_U \qquad j = 2, \ldots, 5 \tag{14}$$

FACTOR MARKETS

$$L_A = [p_A^\Gamma z_A^\Gamma l_A + p_A^\Omega z_A^\Omega (1 - l_A)] \, N_A \tag{15}$$

$$L_U = [p_U^\Gamma z_U^\Gamma l_U + p_U^\Omega z_U^\Omega (1 - l_U)] \, N_U \tag{16}$$

$$\sum_{j=2}^{5} L_j = L_U \tag{17}$$

$$\sum_{j=2}^{5} K_j = K_U \tag{18}$$

HOUSEHOLD DEMAND AND INCOME

$$\frac{P_i^D D_{ij}}{N_j} = b_{ij} P_i^D + \beta_{ij} \left(\frac{C_j}{N_j} - \sum_{i=1}^{5} b_{ij} P_i^D \right) \qquad \begin{matrix} i = 1, \ldots, 5 \\ j = A, U \end{matrix} \tag{19}$$

$$C_j = (1 - s^l)(Y_j^{Dl} - \sum_{i=1}^{5} b_{ij} P_i^D N_j) + (1 - s^c) Y_j^{Dc} + \sum_{i=1}^{5} b_{ij} P_i^D N_j \qquad j = A, U \tag{20}$$

$$Y_A^{Dl} = (1 - \tau^l) W_1 L_1 + RE \tag{21}$$

$$Y_A^{Dc} = (1 - \tau^c) \Pi_1 \tag{22}$$

$$Y_U^{Dl} = (1 - \tau^l) \sum_{j=2}^{5} W_j L_j \tag{23}$$

$$Y_U^{Dc} = (1 - \tau^c) \sum_{j=2}^{5} Q_j K_j \tag{24}$$

EXPORTS AND IMPORTS

$$EX_i = EX_i^o \left(\frac{P_i}{P_i^W} \right)^{\epsilon_i} \exp(\sigma_i t) \qquad i = 1, 3 \tag{25}$$

$$EX_4 = \upsilon \sum_{i=1}^{3} EX_i \tag{26}$$

$$im_i \equiv \frac{IM_i}{X_i - EX_i} = im_i^o \left[\frac{P_i}{(1+\phi_i)P_i^W}\right]^{\mu_i} \qquad i = 1, 3 \tag{27}$$

$$im_2 \equiv \frac{IM_2}{X_2 - EX_2} = im_2^o \exp(-\psi t) \tag{28}$$

$$P_2 EX_2 = P_1^W IM_1 + P_2^W IM_2 + P_3^W IM_3 - P_1 EX_1 - P_3 EX_3 - P_4 EX_4 - F - RE \tag{29}$$

SAVINGS AND INVESTMENTS

$$S_j = s^l \left(Y_j^{Dl} - \sum_{i=1}^{5} b_{ij} P_i^D N_j\right) + s^c Y_j^{Dc} \qquad j = A, U \tag{30}$$

$$S^G = \sum_{j=1}^{5} \tau^l W_j L_j + \tau^c \Pi_1 + \sum_{j=2}^{5} \tau^c Q_j K_j + \sum_{i=1}^{3} \phi_i P_i^W IM_i + F - C^G \tag{31}$$

$$I = S_A + S_U + S^G \tag{32}$$

$$I_1 = \xi I \tag{33}$$

$$I_U = (1 - \xi) I \tag{34}$$

$$I_1^B = \zeta_1 I_1 \tag{35}$$

$$I_1^M = (1 - \zeta_1) I_1 \tag{36}$$

$$I_U^B = \zeta_U I_U \tag{37}$$

$$I_U^M = (1 - \zeta_U) I_U \tag{38}$$

BALANCING EQUATIONS

$$X_1 = D_{1A} + D_{1U} + \sum_{j=1}^{5} a_{1j} X_j + EX_1 - IM_1 \tag{39}$$

$$X_2 = D_{2A} + D_{2U} + \sum_{j=1}^{5} a_{2j} X_j + I_U^M + I_1^M + EX_2 - IM_2 \tag{40}$$

$$X_3 = D_{3A} + D_{3U} + \sum_{j=1}^{5} a_{3j} X_j + EX_3 - IM_3 \tag{41}$$

$$X_4 = D_{4A} + D_{4U} + \sum_{j=1}^{5} a_{4j} X_j + C^G + EX_4 \tag{42}$$

$$X_5 = D_{5A} + D_{5U} + \sum_{j=1}^{5} a_{5j} X_j + I_U^B + I_1^B \tag{43}$$

$$GDP = X_1 + X_2 + X_3 + X_4 + X_5 - \sum_{i=1}^{5} \sum_{j=1}^{5} X_{ij} \tag{44}$$

MIGRATION

$$m \equiv \frac{M}{N_1} = 1 - \exp(-\eta W^*) \tag{45}$$

$$W^* = \left[d \frac{W_U}{COL_U} + (1-d) \frac{W_{USA}}{COL_{USA}} \right] \Bigg/ \frac{W_1}{COL_1} \tag{46}$$

$$em \equiv \frac{E}{M} = 1 - \exp(-\theta W^{**}) \tag{47}$$

$$W^{**} = \left(\frac{W_{USA}}{COL_{USA}} \right) \Bigg/ \left(\frac{W_U}{COL_U} \right) \tag{48}$$

$$COL_j = \sum_{i=1}^{5} P_i^D \frac{P_i^D D_{ij}}{C_j} \qquad j = A, U \tag{49}$$

DYNAMICS

$$K_j(t) = K_j(t-1) + I_j(t-1) - [\kappa^B \zeta_j + \kappa^M (1 - \zeta_j)] K_j(t) \qquad j = A, U \tag{50}$$

$$N_1(t) = N_1(t-1)(1 + f_1) - M(t-1) \tag{51}$$

$$N_U(t) = N_U(t-1)(1 + f_U) + M(t-1) - E(t-1) \tag{52}$$

$$R(t) = R(t-1)\exp(r) \tag{53}$$

$$g_j(t) = g_j(t-1)\exp(\lambda_j^g) \qquad j = 1, \ldots, 5 \tag{54}$$

$$h_j(t) = h_j(t-1)\exp(\lambda_j^h) \qquad j = 1, \ldots, 5 \tag{55}$$

$$p_j^h(t) = p_j^h(t-1)\exp(\nu_j^h) \qquad j = A, U;\; h = \Gamma, \Omega \tag{56}$$

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