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# **SERIE RESEARCHMEMORANDA**

MEASUREMENT AND TESTS OF  
LONG-TERM URBAN-SPATIAL EVOLUTION

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## 1. Introduction

Problems of decentralisation are not a new issue in economic analysis, but a standard ingredient which came already into being since the days of Adam Smith. This issue however received full scale attention in the post-war period due to the increasing role of public policy (cf. Samuelson, 1954). In this context also the regional (or spatial) allocation of public expenditures (either to pure collective goods or to publicly provided private goods) received a great deal of attention (cf. Tiebout, 1956). The issue of decentralisation has recently gained renewed interest, as it is often assumed that a centralized and bureaucratic public policy structure causes so much inertia and inefficiency that a flexible adjustment to new economic and technological conditions in the eighties is precluded. Therefore, also in recent years the Tiebout model is still a matter of scientific discussion (see, for instance, Bewley, 1981, and Stahl and Varaiya, 1983).

A major limitation however in all contributions to public expenditures is caused by the neglect of the dynamics of a local or regional system. The functional boundaries of cities and areas in a spatial system are permanently shifting, the consumption, income and production pattern in cities and regions are exhibiting a long-run dynamic evolution, while also the location pattern of activities is usually unstable.

Therefore, more profound attention for spatial dynamics is a prerequisite for understanding the issues of centralisation and decentralisation of public policy. The present paper will first discuss the issue of spatial-urban dynamics by mainly concentrating on three competitive theoretical explanations. The validity of these three paradigms will be tested by means of a case study for Amsterdam. In the sequel of the paper a simple formal model will be designed that may serve to illustrate spatial-urban interactions in a dynamic context, while also its implications for decentralisation issues will be discussed.

## 2. Urban and Regional Dynamics

Urban and regional systems appear to exhibit complex and turbulent fluctuations. These spatiotemporal developments are often due to structural changes and differential dynamics in various components of a spatial system.

Structural change is here conceived of as a perturbation of the parameters and/or the relationships describing a systemic structure. Differential dynamics refers to the phenomenon that various main components of a spatial system (industry, housing, demographic patterns etc.) are marked by significant differences in adjustment processes regarding external disturbances; see also Nijkamp and Schubert (1983). Structural and differential dynamic processes may lead to unstable behaviour of systems.

Recently, much attention has been paid to urban dynamics; see among others Brotchie et al.(1984), Jacobs (1977) and Nijkamp and Rietveld (1981). These studies tried to explain drastic changes in urban agglomerations (for instance, with regard to growth rates of urban income per capita, average urban employment, in- and outmigration ratios, economic base multipliers, capital and trade flows, etc.). A uniformly valid theory describing and explaining structural changes in an urban system does not exist. A study of the literature reveals a great diversity in economic theories and explanations; see Nijkamp et al.(1984). Despite this diversity, several central themes like technological development, efficiency of production factors, and bottleneck factors can be bound in most studies on urban dynamics.

Three major fields of scientific research in structural urban change may be identified, viz.

- (1) technological changes and industrial dynamics. These contributions focus special attention on the impact of industrial innovations and technology adjustments upon the growth and decline of urban agglomerations. These contributions will be termed here innovation theories.
- (2) social overhead capital and urban policy. These contributions aim at identifying the role of public infrastructure capital for urban development. These contributions are named here bottleneck theories.
- (3) differential dynamics in urban systems components. This set of contributions aims at describing and predicting the fluctuations in an urban system by means of an analysis of differential dynamics in various urban components like housing, demography etc. (including feedback mechanisms). These contributions are called here urban dynamics theories.

The literature in this field however, demonstrates that it is extremely hard to test the validity of these explanatory theories and/or models for

urban change by means of empirical facts. In principle, one would have to design a set of three different operational models each specifically based on the hypotheses of the underlying theory at hand. This would no doubt be a very interesting endeavour, but for many practical reasons (lack of appropriate data, shifts in model structure over time, lack of precise information on model parameters and model specifications, and so forth) it is in general impossible to estimate a set of alternative models for the same empirical system; see also Issaev et al.(1982).

Therefore, in the present paper a more modest research strategy will be adopted. The relevance of the abovementioned three classes of theories will be studied by means of a case study for Amsterdam by analyzing:

- (1) whether the hypotheses underlying each of these three models are valid for Amsterdam for the period from 1900 onward
- (2) whether the necessary data are available in order to perform a minimum empirical test of each of these models
- (3) whether the actual developments of Amsterdam are in agreement with the expected pattern that might emerge from the results of each of these three models.

### 3. A Discussion of Three Classes of Dynamic Urban Theories

The measurement of the evolution and performance of a city is not an unambiguous matter, as it is aligned to the theoretical and empirical content of the theory at hand. There is a significant variation in the various theories explaining the dynamic evolution of a city, so that also the measurement of relevant phenomena is necessarily multidimensional in nature. First, however, three relevant theories will concisely be discussed.

#### 3.1 Innovation theories

A key concept in innovation theories is technological change, as this is regarded as the engine stimulating industrial and urban growth processes. Especially basic innovations by private entrepreneurs induce a proces of economic growth and spatial dynamics, inter alia due to input-output linkages and spatial interactions; see among others Freeman et al. (1982) and Mensch (1979).

There is no formal and operational urban model that may be regarded as

representative for the class of innovation theories. So far only partial attempts have been made to link urban fluctuations to product cycle patterns (cf. Norton(1979)) or to innovation diffusions (cf. Robson (1973)), but an integrated formalized model has not yet been developed. The main hypotheses underlying the innovation theory are:

- (IH1) Innovations are usually concentrated in urban agglomerations because of the available information, the external economies and the presence of potential innovators in urban centres;
- (IH2) innovations (especially basic innovations) shape the conditions for urban recovery;
- (IH3) urban developments are usually following the industrial developments
- (IH4) a period of downswing may provide a favourable climate for innovations ('depression trigger' hypothesis).

Despite the absence of operational models, the following results and impacts of innovation and diffusion processes on real-world urban dynamics are generally assumed to take place:

- (IR1) (clusters of) innovations cause fluctuating urban growth patterns, measured by means of indicators like the growth rate of urban population, the housing stock, employment in the secondary and tertiary sector, income per capita, etc.
- (IR2) urban growth caused by basic innovations will generate further growth due to cumulative and circular feedback and multiplier processes;
- (IR3) innovation diffusion in a spatial system of cities is dependent on the size of cities and their mutual distance;
- (IR4) the main centre of multi-plant enterprises stimulates the innovation potential of the city at hand;
- (IR5) diffusion of innovation is very much contingent upon the spatial organization of multi-plant enterprises;
- (IR6) large agglomerations have the necessary conditions for adopting innovations and hence may be expected to have the highest growth rates;
- (IR7) the phase length and the transition points in an 'urban long wave' are very hard to assess due to differential dynamics and spatial spillover effects in urban growth patterns.

### 3.2. Bottleneck theories

Bottleneck theories may be conceived of as a complement to and a generalization of the class of innovation theories. The bottleneck theory focuses particular attention on agglomeration diseconomies that hamper a growth of cities. Two kinds of bottleneck factors may be distinguished:

- lower level bottlenecks (or threshold values) which refer to the absence of facilities that are necessary for a start of urban growth (the so-called 'take-off')
- upper level bottlenecks (or congestion values) which refer to an undercapacity of the existing stock of urban facilities in light of the growing demand.

Threshold values prevent a start of urban growth, while congestion values hamper a continuation of urban growth. Such bottlenecks may be removed by more investments in public overhead capital (or infrastructure capital). Examples are: rapid transit systems, telecommunication services, educational facilities, R&D facilities, socio-cultural amenities etc. The bottleneck theory assumes that technological adjustments (in the form of R&D investments) are necessary in order to make a city more competitive with respect to other cities. Thus structural urban changes are here a result of new public overhead investments; see Nijkamp and Schubert (1983).

The bottleneck theory is a fairly recent theory. Hence, the models based on this theory are still fairly simple in structure; most of them are based on a so-called quasi-production function. Under- and overachievements of urban production output can be assessed on the basis of a crosssection study across multiple cities. The main hypotheses underlying the bottleneck theories are:

- (BH1) bottleneck factors have in general a negative impact on urban growth;
- (BH2) the presence (or extension) of public overhead or infrastructure capital is a prerequisite for inducing and continuing urban growth;
- (BH3) basic technological changes in overhead capital are main driving forces behind urban development;
- (BH4) the presence or extension of R&D activities provides a breeding place for new urban activities.

So far, only a few attempts have been made to test empirically the bottleneck theory, but the following results may be expected, given the hypotheses underlying this theory:

- (BR1) capacity limits tend to generate a dynamic and cyclical growth pattern for an urban system, the shape of the growth curve being determined by the initial city size, and the growth rates of the individual urban production factors;
- (BR2) R&D activities stimulate innovations, so that an urban policy oriented toward shaping a sound breeding place for R&D activities may lead to an accelerated urban growth rate.

### 3.3. Urban dynamics theories

An exposition on urban dynamics theories can be found in Forrester (1969), who applied concepts from systems analysis to urban development phenomena. These theories describe the long-run trajectory of a closed urban system subdivided into various components each having its own specific time path. Positive and negative feedback effects between these components lead to a differential dynamics in an urban system, so that various long-term fluctuations (including stagnation and decay) can be generated. Such urban systems may lead to self-organizing equilibrium paths in the long run. There are two major phases of this process, viz. growth and stable equilibrium.

The following hypotheses make up the foundation stones of the urban dynamics theory:

- (DH1) the urban system is closed, so that all changes have an endogenous cause;
- (DH2) the notion of urban attractiveness is aligned to an 'endless environment', without any specific competitive elements with respect to other cities;
- (DH3) the industrial sector acts as the engine of urban growth processes;
- (DH4) urban growth will terminate, as soon as the limits of the urban territory are reached;
- (DH5) the urban system is composed of three subsystems, viz. business activity, population and housing.

The model structure itself is based on a direct relationship between the urban population sector and the residential sector, and presupposes a parallel trajectory of the demand and supply generated by the three

successive levels in two major subsystems (viz. population and the residential sector, including filtering processes of the housing stock). The industrial sector and the population sector have only indirect linkages. Both the direct and the indirect links in the urban dynamics model exhibit many feedback loops which cause the dynamics of the urban system. The model itself is not based on rigorous statistical and econometric tests, but on a simulation of plausible hypotheses.

The following results are in general plausible in the context of urban dynamic models:

- (DR1) the market forces in a closed urban system generate a fluctuating growth phase of approximately 100 years and - after a stagnation phase of another 100 years - a stable equilibrium state;
- (DR2) the positive and negative feedback processes of the urban system lead to a self-organized stable outcome;
- (DR3) the life cycle of the city is reflected in each major urban subsystem;
- (DR4) a balanced urban system can be best achieved by means of a public policy of (re-)industrialization (in the detriment of the housing stock for low-paid inhabitants).

#### 4. The Long-Run Development Pattern of Amsterdam

From 1900 onwards Amsterdam has exhibited a transition toward a major industrial centre, due to its favourable geographical location, its good accessibility and its growing local and regional market. This development led to a growth in employment and immigration, which caused in turn a shortage on the housing market. Consequently, a phase of suburbanization emerged, causing urban sprawl toward neighbourhood areas. In the post-war period the tertiary sector exhibited a strong growth, while the relative importance of the industrial sector declined. At the moment the share of the tertiary sector is more than 75 percent. On the other hand, the number of inhabitants has drastically declined (with more than 25 percent) in the past decades. This process of urban decay is still continuing, though at a decreasing rate due to urban renewal and compact city policies.

Precise data from 1900 onwards on all aspects of the urban development of Amsterdam are not available, so that a test on the empirical relevance of the abovementioned three urban growth theories is only partial.

Various relevant developments of a selected set of variables pertaining to the urban evolution can be found in the Appendix. Despite the less reliable and sometimes incomplete nature of the data on Amsterdam, a confrontation of the available data with the three urban growth theories leads to various interesting observations and conclusions. These findings will briefly be discussed here; more details can be found in Mouwen (1984) and Mouwen and Nijkamp (1984).

## 5. Relevance of Three Classes of Dynamic Urban Theories

In this section the validity of the three abovementioned classes of dynamic urban theories will be discussed on the basis of the extent to which the actual development pattern of Amsterdam is in agreement with both the underlying hypotheses and the expected empirical results of each class of theories. The results are summarized in Table 1.

### 5.1. Innovation theories

The data on Amsterdam have been used to test the validity of various hypotheses underlying the innovation theories. The following findings were obtained for Amsterdam:

- (IH1) Big cities tend to act as the main incubators of innovations. Innovations have mainly been concentrated in the urban area due to the breeding place function of Amsterdam (presence of information and communication with the market, spatial concentration of potential innovators, and presence of external economies).
- (IH2) Many new technological initiatives (basic innovations, e.g.) appear to run parallel to the urban growth pattern of Amsterdam, but a rigorous test as to whether new industrial activities may be held responsible for urban recovery phases ('upswing') of Amsterdam is hard to perform due to lack of detailed time series data on industrial sectors.
- (IH3) Most innovations have taken place in the industrial sector, so that - especially in the first half of this century - industrial development has had a major impact on the growth of Amsterdam.
- (IH4) The 'depression trigger' hypothesis cannot be confirmed on the

basis of the available (poor) data on innovation efforts in each time period of an urban cycle.

The actual time path of the Amsterdam economy is partly in agreement with the expected results from the innovation theory, although lack of reliable data from 1900 onwards hampers a rigorous statistical test. The following results have been derived:

- (IR1) Many innovations took place in the pre-war period, although the presence of clusters and close relationships with population growth and housing is hard to identify.
- (IR2) Especially in the pre-war period many cumulative and multiplier processes took place in the industrial sector.
- (IR3) A specific distance effect of Amsterdam is hard to identify, although a distance-decay for the Randstad (Rimcity) as a whole could be observed.
- (IR4) Many main centres of multi-plant enterprises (especially in the tertiary sector) are indeed located in Amsterdam.
- (IR5) The diffusion of innovation is also favoured by the spatial organisation of multi-plant companies.
- (IR6) Many highly innovative activities (having also high growth rates) are located in Amsterdam.
- (IR7) Sectoral evolution patterns exhibit many variations, so that the identification of wave patterns is problematic.

Thus the conclusion may be drawn that - despite missing data - various available data confirm the innovation hypothesis so that there is no reason to reject the hypothesis that innovation processes are driving forces of the urban economy.

## 5.2. Bottleneck theories

The class of bottleneck theories has also been examined in light of a set of available data for Amsterdam from 1900 onwards. The following conclusions could be inferred:

- (BH1) Bottleneck factors in the city of Amsterdam (lack of dwellings, low accessibility, lack of space, e.g.) have caused a drastic decline in the socio-economic position of Amsterdam.
- (BH2) It is not entirely possible to assess the impacts of urban infrastructure capital on the urban growth pattern due to lack of detailed information on the components of social overhead capital,

- (BH3) Some basic technological changes (for instance, the construction of some tunnels under the Northsea Canal separating Amsterdam into two parts) have had a positive impact on the city, though the data are very scarce in this respect.
- (BH4) The impact of R&D activities on new urban activities is over a period of more than 80 years hard to assess due to lack of data on R&D in previous decades, though recent data suggest a positive effect.

Bottleneck factors (such as congestion and population density) emerging in the fifties and sixties appear to have induced a process of urban decay, so that the urban development pattern of Amsterdam exhibits to some extent a cyclical dynamic pattern. On the other hand, it cannot be clearly demonstrated that lack of R&D capital is responsible for an urban 'downswing'. The following findings in regard to actual developments were obtained:

- (BR1) Not only the urban population, but also various industrial branches exhibit many fluctuations, though a positive correlation between these figures does not always exist.
- (BR2) It is not possible to identify on the basis of available data whether or not lack of R&D capital has been a major obstacle for a stable development of Amsterdam.

The conclusion from this analysis is that due to lack of data a rigorous test of the bottleneck hypothesis is fraught with problems. But the available data appear to be in agreement with the bottleneck hypothesis for urban development (partly in combination with the innovation hypothesis).

### 5.3. Urban dynamics theories

Data for Amsterdam have also been used for testing the validity of urban dynamics theories. The following results were obtained:

- (DH1) The urban growth pattern of Amsterdam is very much determined by external interactions, so that the hypothesis of a closed urban system driven by endogenous forces is not valid.
- (DH2) The urban attractiveness of Amsterdam is a relative concept with respect to other competing residential places, so that the hypothesis of an endless environment is not supported.
- (DH3) The industrial sector has had a major impact on the urban development

of Amsterdam in previous decades, but its impact in recent decades cannot be shown.

- (DH4) The limits of the urban territory and their impacts on urban growth are not unambiguously defined (due to changes in floor space productivity, e.g.), so that the effect of urban limits on urban growth is hardly testable.
- (DH5) The urban development of Amsterdam is to a major extent determined by the geographical accessibility and not exclusively by business activities, population and housing.

As far as the actual developments of Amsterdam are concerned, it has to be mentioned that the actual length of growth phases of the city contradicts the urban dynamics hypothesis, although the specific features of each phase are fairly well in agreement with those mentioned in the urban dynamics approach. Urban housing policy in Amsterdam however, is totally different from the policy assumed in the urban dynamics theory, so that a rigorous test is impossible.

- (DR1) The evolution of Amsterdam exhibits various fluctuations, although the length of the growth phases is not in agreement with the urban dynamics theory assuming a growth phase of 100 years.
- (DR2) The actual growth pattern of the city was determined by exogenous forces and internal urban policies, so that a self-organized equilibrium tendency is highly improbable.
- (DR3) The cycles of various urban subsystems do not run parallel, but exhibit sometimes contrasting shapes.
- (DR4) Re-industrialisation has not been used as a policy device, but rather cheap housing policy and office building policy.

In general, the conclusion may be drawn that only in specific cases the urban development pattern of Amsterdam supports the urban dynamics hypothesis. This is partly due to differences in the urban policy system, partly to lack of satisfactory data.

Innovation theories		Bottleneck theories		Urban dynamics theories	
Hypotheses	Results	Hypotheses	Results	Hypotheses	Results
IH1 + /?	IR1 + /?	BH1 +	BR1 + /?	DH1 -	DR1 + /?
IH2 + /?	IR2 + /?	BH2 + /?	BR2 ?	DH2 -	DR2 - /?
IH3 + /?	IR3 + /?	BH3 + /?		DH3 ?	DR3 -
IH4 ?	IR4 +	BH4 ?		DH4 ?	DR4 - /?
	IR5 +			DH5 - /?	
	IR6 +				
	IR7 +				

Table 1. Summary of tests of dynamic urban theories

Legend: + confirmation

? undecisive result

- rejection

#### 6. Urban Dynamics: A Synthesis

On the basis of the previous analysis, it is plausible to assume that urban dynamics is highly influenced by the following factors:

- threshold values in the city
- innovation efforts
- congestion levels in the city

Clearly, if the functioning of a city is considered in the context of a system of cities or regions, also other elements may play a role in the urban dynamics, viz:

- relative discrepancies with respect to other cities (keeping up with the Joneses effect)
- lack of coordination (or lack of efficient and consistent decentralisation).

In order to analyse some consequences of these factors, a simplified model for urban dynamics will be used. Assume that the performance (production value, income, employment etc.) of a given city  $i$  is indicated by  $y_i$ . The performance of a competing city  $j$  (or region  $j$ ) will then be indicated as  $y_j$ . In a dynamic context the following prototype model for urban evolution may be assumed (cf. Batten, 1982):

$$\dot{y}_i = \alpha_i y_i - \beta_i y_i \quad , \quad (1)$$

where  $\alpha_i$  and  $\beta_i$  represent the gross expansion rate and concentration rate of city  $i$ , respectively. The expansion rate represents an exponential growth and the contraction rate an exponential decline. The contraction rate may be due to congestion phenomena (involving rapid depreciation), while the expansion rate implies an accelerated growth due to innovation effects.

A permanent exponential growth rate is however impossible due to internal congestion and external competition. Therefore we assume that  $\alpha_i$  may be specified as follows:

$$\alpha_i = \gamma_i [(\bar{y}_i - y_i) - \delta_i y_j] \quad , \quad (2)$$

where

$\bar{y}_i$  reflects the bottleneck level of the city concerned.

Substitution of (2) into (1) yields the following result:

$$\dot{y}_i = \gamma_i y_i [(\bar{y}_i - y_i) - \delta_i y_j] - \beta_i y_i \quad (3)$$

Clearly, if  $\delta_i \geq 0$ , a situation of competition between city  $i$  and area  $j$  is present; a negative value of  $\delta_i$  implies a complementary economic development (see also Sonis, 1983).

Various interesting cases may now be distinguished.

- (1)  $(\delta_i \geq 0) \cap (\delta_j \geq 0)$  : an extreme solution will emerge, in which either city  $j$  will at the end dominate area  $j$  or, inversely, area  $j$  will dominate city  $i$ , depending on the production efficiency of  $i$  and  $j$ .
- (2)  $(\delta_i \leq 0) \cap (\delta_j \leq 0)$  : a mutually complementary situation will emerge, which may lead to fluctuating growth patterns of both  $i$  and  $j$ .
- (3)  $(\delta_i \geq 0) \cap (\delta_j \leq 0)$  : this situation leads to a decline for city  $i$  and a growth for area  $j$ .
- (4)  $(\delta_i \leq 0) \cap (\delta_j \geq 0)$  : this is the reverse case of (3).

It is evident that the abovementioned cases become more interesting, if the bottleneck values  $\bar{y}_i$  and  $\bar{y}_j$  are assumed to be a function of innovation efforts and public infrastructure in the region at hand (see also Nijkamp, 1982, 1984). Further elaborations of this approach can also be found in Johansson and Nijkamp (1984).

## 7. Conclusion

The question whether or not regional and/or urban decentralisation has to be pursued depends on various circumstances. Given the assumption of an maximum efficiency for the spatial system as a whole, three factors are extremely relevant:

- (1) The dynamics of a spatial system - caused by interior driving forces and exterior interactions - has strong repercussions for the welfare trajectory of a city and hence for the extent to which a certain decentralisation policy aiming at increasing the efficiency has to be implemented.
- (2) The competition between actors (cities, e.g.) in a spatial system requires a certain coordination at a higher level in order to prevent some cities or regions from being destroyed due to strong competition.
- (3) The key factors for internal dynamics of an urban system (viz. the provision a reasonable threshold level of infrastructure endowment, the support of innovative activities stimulating structural changes, and the removal of bottleneck factors) have also an impact on the spatial system as a whole, so that a coherent policy of centralisation and decentralisation is needed.

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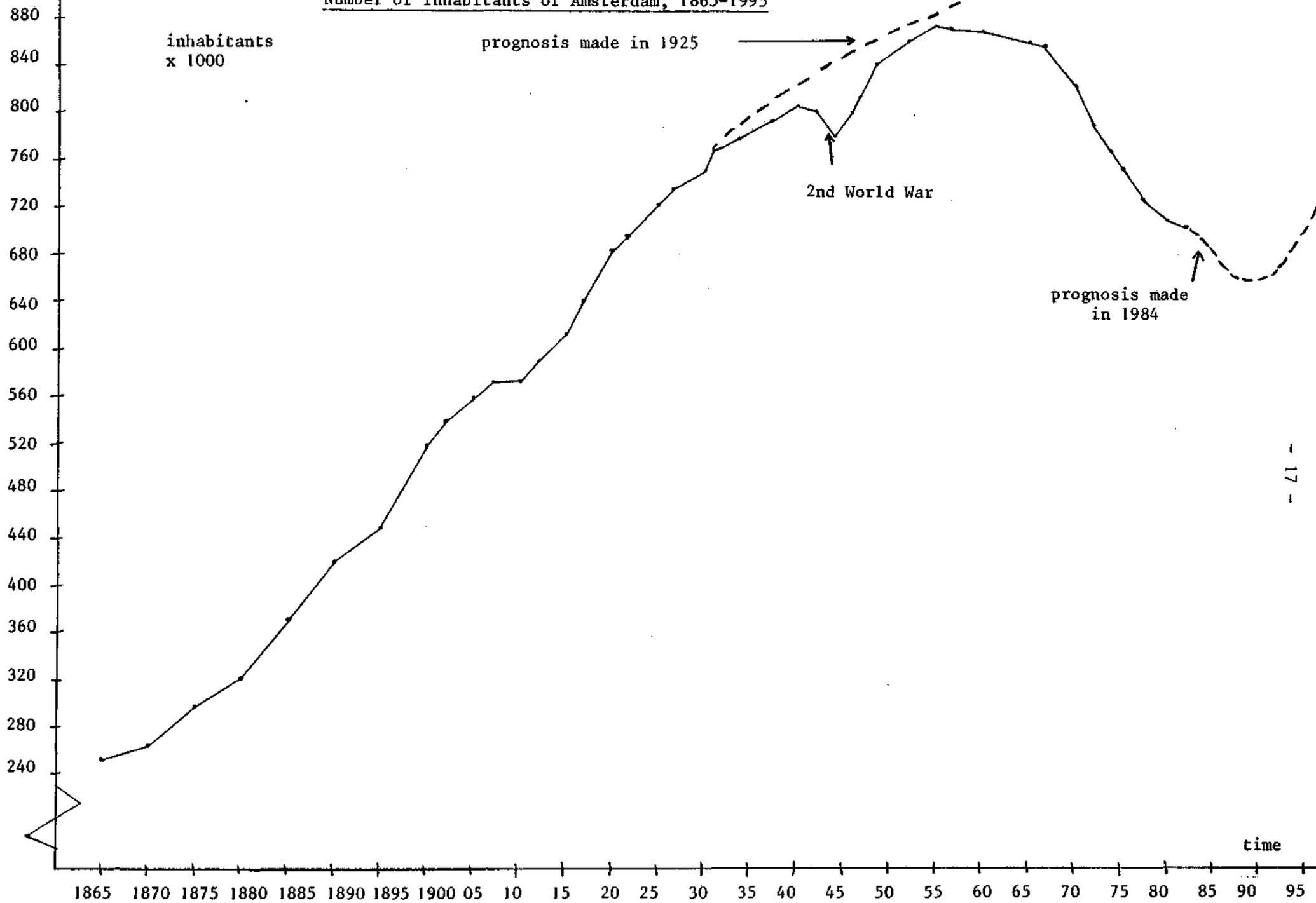
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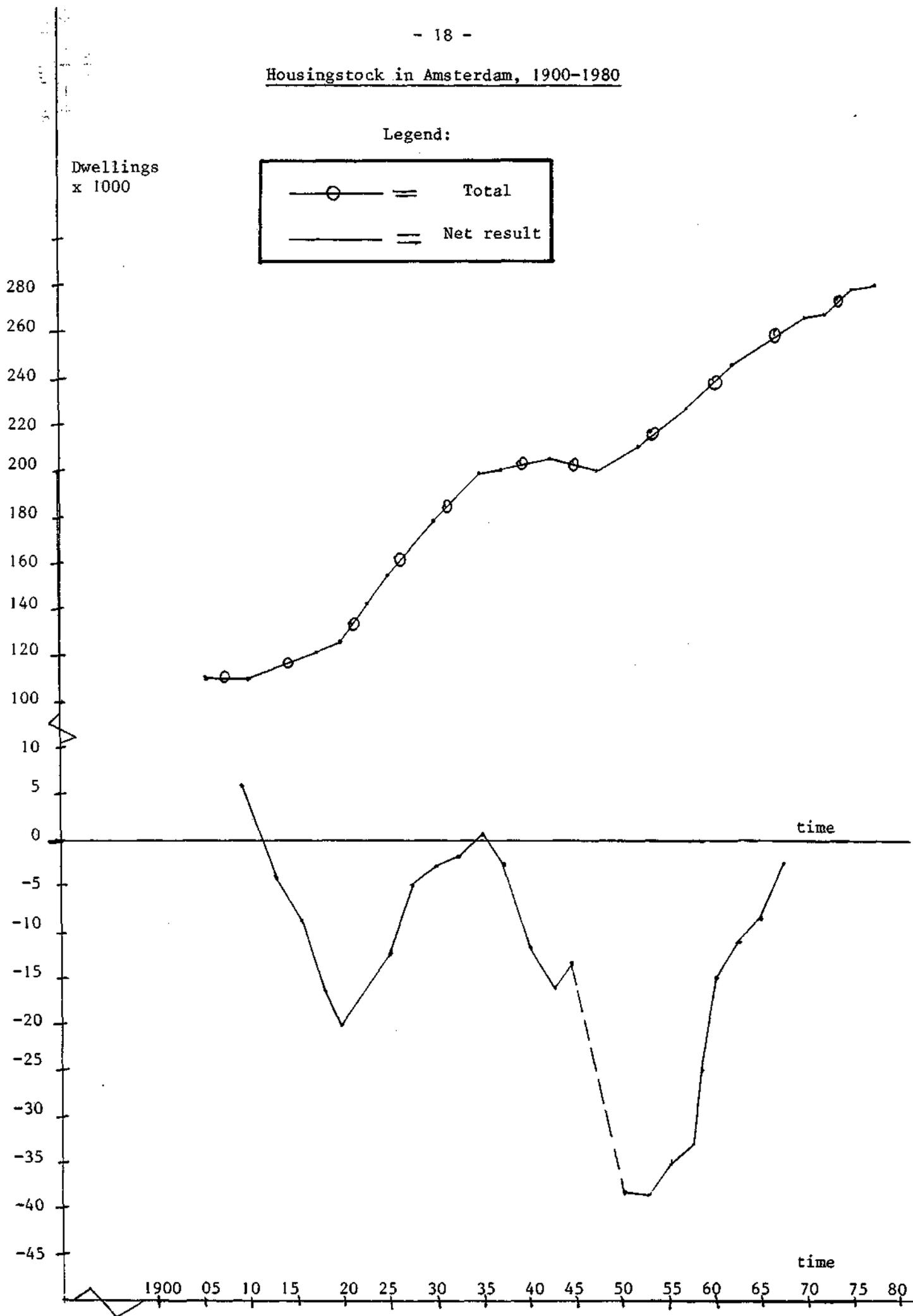
## APPENDIX

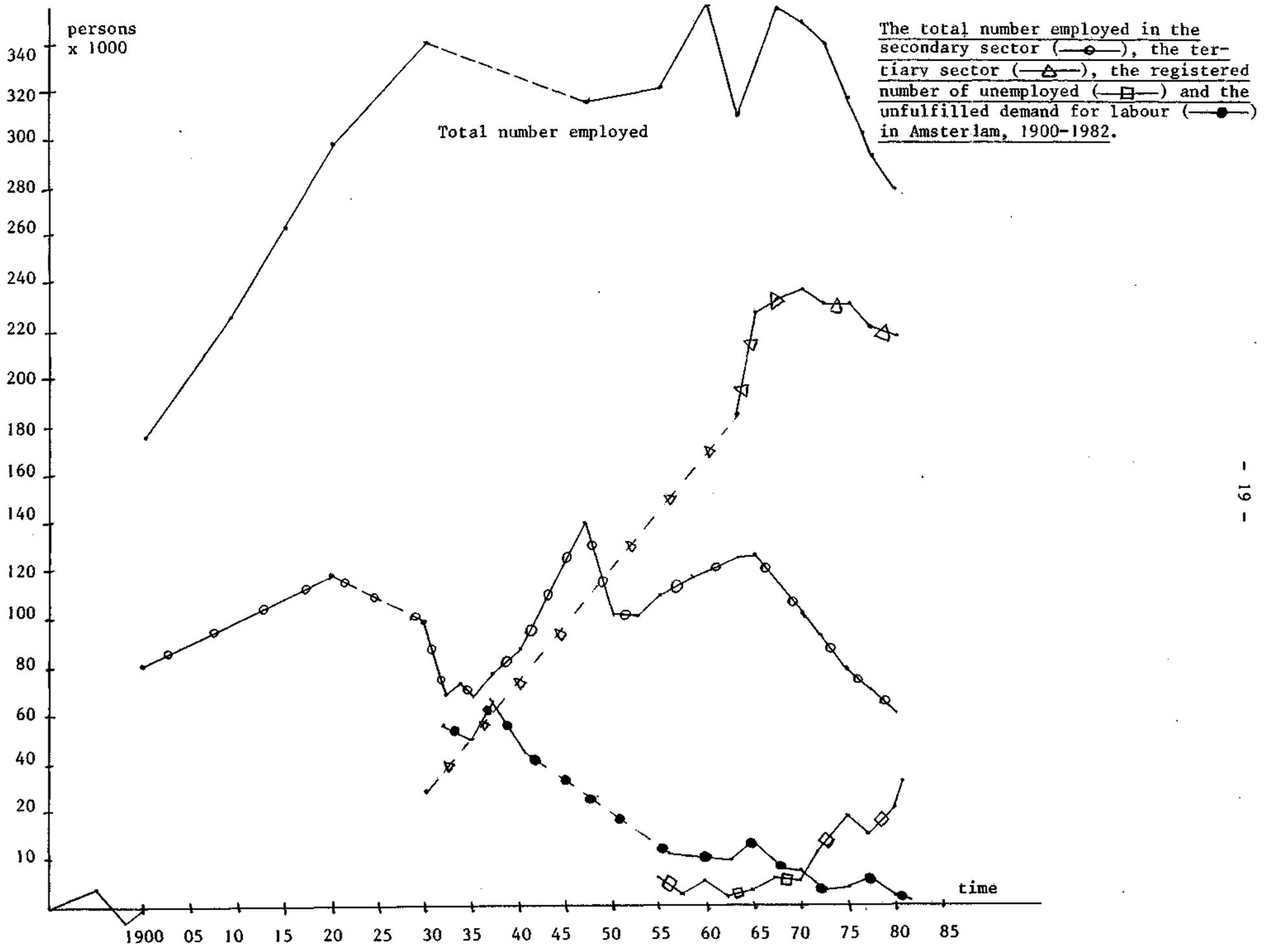
Relevant graphical information on the long-term  
development of Amsterdam.

Number of inhabitants of Amsterdam, 1865-1995



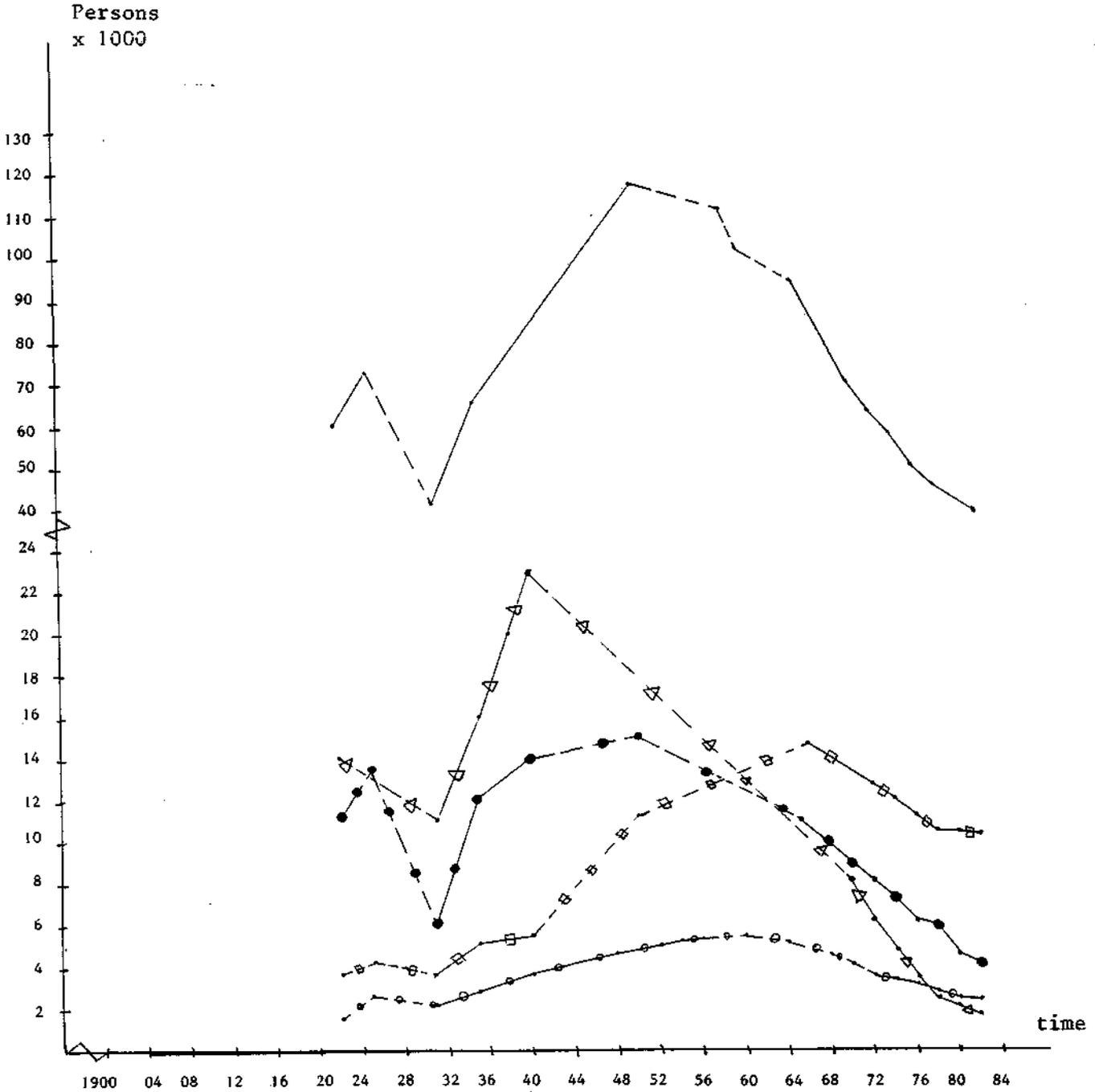
Housingstock in Amsterdam, 1900-1980





The total number employed in the secondary sector (—○—), the tertiary sector (—△—), the registered number of unemployed (—□—) and the unfulfilled demand for labour (—●—) in Amsterdam, 1900-1982.

The number of persons employed in some industrial classes and the total industry in Amsterdam, 1922-1982.



Legend:

- = total industry
- △— = manufacture of textiles
- = printing, publishing and allied industries
- = chemical industry
- = manufacture of foodstuffs, beverages, tobacco products.

Population development of Amsterdam in relation to employment development in the chemical industry (A), the banking and insurance sector (B) and the transport, storage and communication sector (C).

