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ABSTRACT

This Working Paper constitutes Chapter 17 of the book manuscript, *Understanding Population-Development-Environment Interactions: A Case Study on Mauritius.* The Mauritius case study was carried out by IIASA in scientific collaboration with the University of Mauritius and funded by the United Nations Population Fund (UNFPA).

The paper presents and discusses findings from the interdisciplinary computer model simulating alternative population-development-environment interactions for the historical period 1962 to 1987, a period of rapid change in Mauritius.

In a first step, population, economic, and environmental developments during the last 30 years are reconstructed by the PDE-Mauritius model on the basis of observed trends. This reconstructed history, which also evaluates the accuracy of the model itself, is used as a reference to which alternative histories are compared.

In subsequent sections, five alternative population histories and nine alternative holistic histories are considered. The role of socio-demographic development, and of the fertility decline in particular, is compared to the importance of the economic boom for the rapid development of Mauritius. Also, the influence of specific economic strategies, like agricultural exports (mainly sugar), industrial exports (mainly textiles), or tourism, and in particular their impact on the environment, are investigated.

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MAURITIUS CASE STUDY: ALTERNATIVE HISTORIES SINCE 1962[1]

Christopher Prinz

1. INTRODUCTION

In the previous chapter alternative future pathways for Mauritius to 2050 were developed and discussed. On the one hand, this analysis showed how PDE-Mauritius can be applied, how scenarios can be created and which results the model can provide. We are now better able to understand some population-development-environment linkages. On the other hand, those scenarios can actually help Mauritian decision makers to evaluate some possible policy actions concerning the population, the economy, and the environment.

PDE-Mauritius cannot only be used for the period 1990 to 2050. It can be used for any period provided data for the starting year are available (due to memory restrictions the model cannot handle more than 60 years). In the following application the period 1962 to 1987[2] has been selected. This is not just another application of the model; there are several good reasons to run PDE-Mauritius for that particular period.

First of all, it is an ideal way of testing the model. If the model is reasonably capable of estimating the demographic and economic structure of Mauritius in the late 1980s and early 1990s based on input parameters for the year 1962, it should also be able to do so for the future based on input parameters for the year 1990. If so, the validity and the reliability of the scenario calculations in Chapter 16 would increase significantly. Since no economic data were available before the early 1960s, the census year 1962 has been chosen as starting year. 1962 is at the same time the most suitable starting year as both the sudden demographic transition and the rapid economic development took place afterwards.

Given the reasonable reconstruction of the period 1962-1987 we can start to specify alternative historical scenarios to improve our understanding of population-development-environment interactions even more. We may perhaps be able to determine some reasons for the rapid economic growth and lots of interesting questions may find an answer. Was the fertility decline a major driving force for development? Or was it rather the rapidly increasing educational level of the population? Was the socio-demographic development important at all, or were external trade and foreign investment the main source of growth? Would economic growth have been possible without signing the Lomé convention which, among other things, regulates amounts and prices of sugar exports? Was setting up the EPZ industries, and especially the textile industry, crucial? Was it worth destroying parts of the coast and polluting the lagoon to provide hotels and beaches for the tourism industry?

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[1]Chapter 17 in the forthcoming book, *Understanding Population-Development-Environment Interactions: A Case Study on Mauritius,* edited by Wolfgang Lutz.

[2]The calculations have been carried out until 2002--and for the population part even until 2022--but without considering changes in any parameter after 1987, i.e keeping all parameters constant as of 1987.

In order to answer those questions a comparison of unadjusted scenarios (see also the discussion at the beginning of Chapter 16) is more appropriate. Only then can we see the impact of one particular variable on overall developments. Adjusting the scenarios carefully--which was important in the previous chapter to give a picture of possible futures of Mauritius--is not done here, as the interest is not in consistent alternative histories but rather in single variable effects. We decided to run the historical scenarios not only up until today, but to project the current parameters further into the future to see in what direction the country would or could have moved under constant 1987 economic conditions.

Section 2 of the present chapter is concerned with testing the PDE-Mauritius model by reconstructing the past, i.e. the period 1962 to 1987.[3] Some of the demographic, economic and environmental variables and parameters are discussed in more detail, including some information on data sources and data estimation. The result of that exercise is evaluated on the basis of observed data for this period and especially for 1987.

Section 3 deals with the Population Module of PDE-Mauritius which can also be run separately. Several historical population scenarios are designed and the demographic results are discussed in detail. The projections are carried out for the period 1962 to 2022 in order to accentuate the long term impact of demographic changes, for example high fertility. Speculations are being made concerning the possibilities for economic growth on the basis of socio-demographic development paths.

In Section 4 the demographic assumptions of Section 3 are supplemented by economic assumptions to enable the application of the full PDE-Mauritius model for the period 1962 to 2002. Nine alternative scenarios are specified to answer the questions raised in the introduction. Also, answers to the speculations in Section 3 are given. First, results of the scenario calculations are discussed variable by variable (for example GNP per capita, unemployment, etc.). Second, comprehensive conclusions are drawn for each of the scenarios.

2. RECONSTRUCTING THE PAST

Testing a model by applying it to a historical period for which input parameters are available is a common procedure to quantify the quality of a model. Model results and thus the functioning of the model can easily be evaluated on the basis of observed data. The main restriction for such a "controlled experiment" is the availability of input parameters for a sufficiently long period. Not surprisingly, for a country like Mauritius which is just about to leave the stage of a poor developing country, many if not most of the model parameters are simply not known. Since some of the main parameters, like those concerning population development, education, labor force participation, export demand, import demand, wages, or government expenditures, were available or could be reasonably estimated for at least some years in the past, application of the PDE-

[3]Since data for the year 1992 are not available yet, a reliable historical reconstruction starting in 1962 and using a model that is based on five-year calculations should cover the period 1962-1987; moreover, the most recent input-output table available in Mauritius goes back to the year 1987.

Mauritius model starting in 1962 turned out to be possible. In the following sections some of the real and estimated parameters are discussed in detail, for each of the modules separately. Possible data sources are mentioned. The validity and reliability of the model is evaluated by comparing some observed variables, like population size, unemployment, or GNP per capita, with the values of those variables that are provided (modelled) by the PDE-Mauritius model.

2.1. Population

In contrast to other sections of the model, reconstructing the historical population development is to a large extent based on observed data. The structure of the starting population for the year 1962, including information on sex, age and labor force status, was taken from the 1962 census publications. The educational distribution, which is a result of previous (unknown) school leaving rates, was estimated on the basis of a few available figures. The related error is less of a problem as by 1962 still the majority of the adult population had primary education only.

Information on fertility and mortality, the two main components determining population growth, was readily available from the publications of the Central Statistical Office (CSO) in Mauritius (Digest of Demographic Statistics, census publications). Mortality was assumed to be independent of education and labor force status. Since 1962, mortality rates declined continuously to a level that was typical for Europe some 20-30 years ago. Female life expectancy at birth increased by 11 years (from 62 years around 1962 to 73 years in 1988/90), while male life expectancy increased by 6 years (from 59 to 65 years). At the same time, Mauritius experienced an extremely rapid fertility decline and is now beyond the demographic transition. The total fertility rate, which gives the average number of children born to each woman, declined from around 6 children at the beginning of the 1960s to less than two children in 1985/86. It increased slightly since, and has reached a level of 2.3 children in 1990. There is a strong negative correlation between fertility and education, i.e. fertility is lower among well-educated women. Age-specific fertility rates by level of education have only been available for 1983 (from the fertility analysis report of the housing and population census). It was assumed that educational differentials in fertility did not change over the period considered (1962-1987).

Despite the existing data on fertility and mortality it is difficult to reconstruct the exact age structure of the Mauritian population as data on the sex and age structure of migrants to and from Mauritius are missing. The annual number of net emigrants, which fluctuated around 3000 between 1962 and 1988, is the only figure available. Model migration patterns were used to distribute those 3000 annual emigrants across sex and age, while crude assumptions were made concerning their education and labor force status distribution. The basic assumption was that well-educated people have a higher propensity to leave their country, be it for personal or occupational reasons.

Information on age-specific enrollment ratios, which are required for the reconstruction of the educational distribution of the population, was taken from different CSO publications (Digest of Educational Statistics, Education Analysis Report from the census). In the critical age span school enrollment ratios increased significantly, in

particular among women: from 45% to 78% and from 8% to 33% for age groups 10-15 and 15-20, respectively, compared to changes from 60% to 78% and from 24% to 36% among men. Today, there is virtually no gender difference in schooling in Mauritius.

Labor force participation rates among primary and secondary educated women increased rapidly, for example from 14% to 40% and from 33% to 57% at ages 30-39. Among tertiary educated women and among men, economic activity was always between 90 and 100 per cent and did not change significantly during the last three decades.

2.2. Economy

Reconstructing the economic history of Mauritius is more difficult in the sense that several parameters had to be estimated on the basis of very limited information. It is at the same time less difficult in the sense that it has to match less criteria, i.e. it has a higher degree of freedom. First, the heart of the economic module, the input-output (I-O) table, had to be estimated for the starting year 1962. Second, for each parameter a reasonable time path had to be invented. The 1962 I-O table was built and adjusted combining our knowledge on Mauritius with information from the Annual Digest of Statistics (CSO), publications from the Bank of Mauritius, and the Economic and Social Data Sheets published by the UN. Changes over the period 1962-1987 were assumed to have taken place exponentially in order to match the observed 1987 data. Since each of the parameters had to be specified sector by sector, the whole exercise involved estimation of the time path of some 600 parameters, the most important ones being discussed below.

In 1962, export demand was dominated by sugar milling. Sugar exports were equal to 3000 mln Rupees (1987 prices) or 87% of all exports. By 1987 sugar milling exports increased to 4400 mln Rupees, but their share among total export demand declined to less than 30%. The EPZ textile sector was the leading sector in 1987 (5500 mln Rupees or 37% of all exports), transport&communication (11%), EPZ other (7%), tourism (7%), and finance (5%) also being of significance.

Throughout the period 1962-1987, unit import demand for fuel mainly came from the sector transportation&communication. In 1962, unit import demand for other than fuel mainly came from non-EPZ manufacturing, while in 1987 several sectors showed a significant import demand, higher than that of non-EPZ manufacturing in 1962: EPZ textiles, non-EPZ manufacturing, tourism, EPZ other and construction. The increase over the period 1962-87 was lowest in the sugar cane sector (127%), generally around 300%, and more than 1000% in the tourism and the EPZ sectors.

Wages increased 5% per five-year period, in all sectors and for each educational level. Sectoral and educational differentials were kept at the 1987 level throughout the period. For example, wages in the finance sector are five times higher than in the other agriculture sector; wages for tertiary are two times the wages for secondary educated; and wages for secondary are again two times the wages for primary educated.

Government expenditure is either calculated according to student status (education expenditure), or according to age and sex (health expenditure), or per capita (other

government expenditure, except water). These status and age patterns were kept throughout the period 1962-87, but per unit government expenditure was assumed to have doubled since 1962. This assumption is partly based on observed data, and partly on the necessity to match government revenues in 1962 approximately.

In 1962, value added per unit of output was highest in the wholesale&retail and in the sugar cane sector. Similar to import demand, value added per unit output generally increased by some 300% over the period of study. In 1987, still wholesale&retail and sugar cane, but also EPZ textile, transport&communication, government services and non-EPZ manufacturing were sectors with high values added per unit of output.

For some parameters, like for example unit domestic household demand (by type of demand and by sector) or the capital/output ratios (by sector), 1987 data were used throughout the whole period. Other parameters, like labor productivity increase from technological change (by sector), employment per unit of output (by sector and education), or unit domestic intermediate demand, the centerpiece of the input/output matrix, have been specified in detail but are not discussed here.

2.3. Land Use

For the land use module, which is tightly connected to the economic module, only a few parameters have to be specified in order to reconstruct the history. Some parameters, like the total usable land available, 1189 km^2, are constant by nature. Another very important land use variable, fertilizer use, can be set constant at current level throughout the period because approximately the same amount of fertilizers was already used in the 1960s. Intercropping, i.e. planting tomatoes, etc., within sugar cane fields, was very limited by the beginning of the 1960s. We specified the percentage of other agriculture obtained from intercropping sugar cane fields to have increased linearly from 0% in 1962 to the observed 40% in 1987.

Land use productivity, a critical parameter as far as economic growth is concerned, has increased steeply. Depending on the sector, the respective increase was in the range of 5% to 30% in each subsequent five-year period. The lower rates of increase are typical for agricultural activities, while the higher rates are typical for urban activities. The maximum increase, 30%, was observed in the tourism sector.

2.4. Water

In the historical analysis, the water module is a very special case. All of the numerous parameters can be kept constant at current levels. Some parameters were kept constant due to natural and physical reasons, like precipitation, river length, river velocity, the minimum available flow, the dissolved oxygen saturation level, or the ratios of BOD to nitrates and BOD to phosphates in waste water. Other parameters, like water quality standards, are qualitative. Water supply, which is determined not only by precipitation and evaporation but also by the availability of reservoirs is also constant, as all (except one small) reservoirs were completed between 1914 and 1962. Some features of the water module, like waste water disposal and treatment, are not of importance for the historical exercise.

Water demand by sector per unit of output has to be kept constant at current level as no information exists for the past. It seems at the same time reasonable that gross water intake and the rate of water loss per unit (by sector) did not change significantly.

2.5. Quality of Projections

Table 1 gives observed 1962 and 1987 values for some of the most important output variables together with the 1987 value projected by the model and, in the last column, the proportion of the observed change that was projected by the model.

Table 1. Evaluation of the PDE-Mauritius model.

Variable	Unit	1962 observed	1987 observed	1987 modelled	projected change
Population size	1000 people	687	1,022	1,020	99 %
Population 60 and over	per cent	4.2	7.3	7.0	90 %
Size of the labor force	1000 people	191	416	367	78 %
Primary ed. labor force	per cent	78.3	54.5	51.1	114 %
Unemployment	per cent	7.7	5.2	4.4	132 %
GNP per capita	US $	441	1,799	1,679	91 %
Sugar production	mln tons	3,416	7,038	6,659	90 %
Total exports	mln Rs.	2,406	13,618	12,869	93 %
Trade balance	per cent	-5.6	21.8	28.7	125 %
Government expenditure	mln Rs.	839	2,974	2,774	91 %
Budget balance	per cent	-10.6	-4.1	-2.7	122 %
Land used for sugar	per cent	88.0	67.3	67.3	100 %
Water requirement	mln m^3	6.1	12.45	12.3	98 %
Organic waste in lagoon	per cent	0.01	0.041	0.045	113 %

Generally speaking, the selected variables were closely reproduced; the historical projections seem to prove the validity of the model. During the short period 1962 to 1987 almost all variables changed drastically. And, if we look at the last column of Table 1, those changes were largely discovered by the model. Three variables were exactly projected: total population size, land used for sugar, and water requirement. For five variables, namely the proportion of the population aged 60 and over, GNP per capita, sugar production, total exports, and government expenditure, 90% to 93% of the actual change were projected by the model. Changes in the educational distribution of the labor force and in pollution of lagoon water by organic waste were overestimated some 13-14%. Only changes in the economic balances, the trade balance, the budget balance and the labor balance, which are very sensible towards small changes in one of the two factors involved, were overestimated by some 20% to 32%. The largest underestimation of change concerns the size of the labor force (only 78% of change projected) which can be attributed to the assumptions concerning labor force participation rates, i.e. published participation rates seem to underestimate actual economic activity.

Given the satisfactory reconstruction of the period 1962 to 1987, one can start thinking about questions in the form of "what would have happened on the island of Mauritius, if...". In the following we first discuss population histories independent of the economic and environmental modules. The reason is that the population module can be run separately which is in turn due to the fact that some of the project members, including the author, are demographers. In a subsequent section, the main section of the current chapter, population-development-environment histories are discussed.

3. POPULATION HISTORIES

The uniqueness of the population module lies in its combination of pure demographic factors--fertility, mortality, and migration--and some socio-demographic factors, namely student status, completed education status, and labor force status. The advantage of a classification of that sort will be clear when reading Section 3.3 on socio-demographic dependency ratios. To accentuate the long term impacts of demographic changes the following analysis will be based on projections for the period 1962 to 2022.

3.1. Scenario Specification

Before we can turn to the discussion of "what-if" questions, we have to specify some alternative population histories in detail. Five scenarios were selected for the analysis.

1. *Observed development* scenario: assuming observed development between 1962 and 1987, i.e. assumptions for this period correspond to the assumptions in Section 2.1, and keeping all parameters constant after 1987.

2. *Constant development* scenario: keeping all parameters constant at their 1962 level throughout the whole period 1962-2022, evaluating what would have happened until today and further into the future if nothing would have changed since 1962.

3. *No fertility decline* scenario: assuming constant 1962 fertility throughout the whole projection period, everything else being equal to the observed development scenario, thus isolating the socio-demographic effect of the rapid fertility decline.

4. *Delayed development* scenario: keeping all parameters constant at their 1962 level up until 1977 and shifting the socio-demographic development observed between 1962 and 1987 to the period 1977 to 2002, thus evaluating the effect of delaying the socio-demographic transition by 15 years.

5. *Social stagnation* scenario: combining observed demographic development (i.e. fertility, mortality, and migration assumptions according to observed development) with social stagnation (i.e. education and economic activity constant as of 1962 throughout the whole projection period), evaluating the impact of constant school enrollment ratios and labor force participation rates.

Scenarios 1 to 3 are also used in Section 4 which employs the full PDE-Mauritius model, while scenarios 4 and 5 are only used in the population histories analysis. Scenarios 2 to 5 are all designed under the assumption that observed socio-demographic development

was so rapid that any imaginary alternative can only assume slower or no growth (like the constant development scenario), partial growth (like the no fertility decline and the social stagnation scenario), or delayed growth (like the delayed development scenario).

3.2. Selected Results

The major results of the population histories exercise are given in Table 2, and for the development of the total population size also in Figure 1.

Table 2. Hypothetical population developments, 1962-2022.

	Total population (1000)	School population (1000)	Labor force (1000)	Labor force (%)	Well-educated (%)	Elderly population (%)
1962	687	280	191	28	22	4
Observed development scenario:						
1977	902	298	286	32	39	6
1992	1081	316	404	37	53	7
2007	1222	308	509	42	63	8
2022	1291	290	546	42	69	14
Constant development scenario:						
1977	1029	369	283	28	31	5
1992	1652	616	430	26	31	4
2007	2725	1030	719	26	30	3
2022	4538	1702	1194	26	29	4
No fertility decline scenario:						
1977	1013	408	286	28	39	5
1992	1553	678	456	29	54	5
2007	2338	963	787	34	65	4
2022	3463	1380	1232	36	69	5
Delayed development scenario:						
1977	1029	369	283	28	31	5
1992	1421	495	432	30	40	5
2007	1741	511	663	38	54	6
2022	1999	505	833	42	65	9
Social stagnation scenario:						
1977	917	254	284	31	31	6
1992	1146	267	386	34	32	7
2007	1372	295	479	35	29	7
2022	1566	314	525	34	27	12

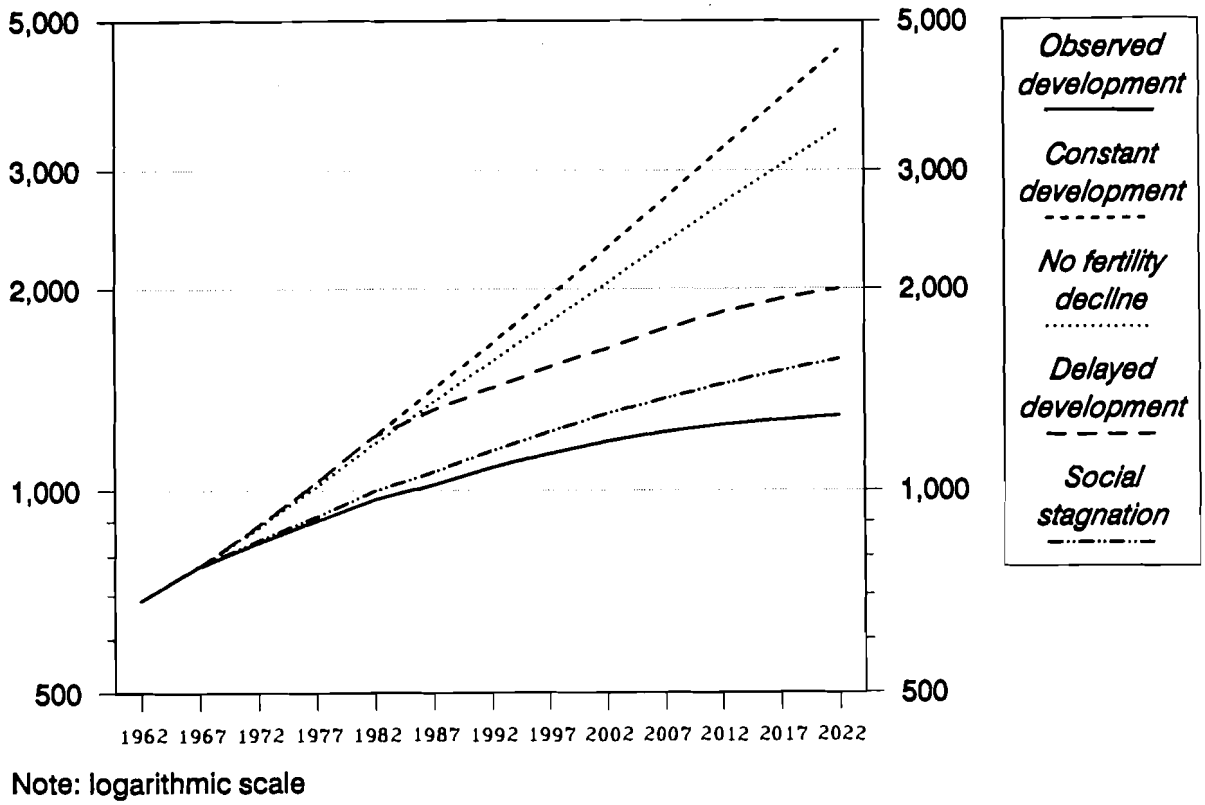

Figure 1. Projected population size, 1962-2022, in 1000 people.

Figure 1 has a logarithmic scale to accentuate changes in the historical period 1962-1987 and to put less emphasis on the future. The figure shows that the Mauritian population grew from almost 700,000 inhabitants in 1962 to about one million in 1987 and would grow to 1.3 million by 2022 under the observed development scenario. If the demographic transition could not have been completed (constant development scenario), population size would have increased exponentially (see the straight line in the logarithmic scaled figure) and would thus have doubled already by 1987. It would have reached more than 4.5 million by 2022. The significantly lower population size in the no fertility decline scenario is due to the educational structure of the female population, that is, the higher proportion of well-educated women leads to a lower overall fertility rate. Delaying the socio-demographic transition by only 15 years (delayed development scenario) would have brought population size to 2 million by the year 2022; i.e. in Mauritius, delaying the transition by 15 years would have led to a 70 per cent increase in the number of inhabitants in the long run.

The school population size behaves similar to the total population size, with scenario differences being even more pronounced. With respect to the size of the labor force very interesting results are obtained. By 1987, the total labor force would have been around 365,000 under both the constant development and the observed development scenario (see Table 2). This has two reasons: first, the labor force of the year 1987 is only to a smaller extent affected by fertility changes during the period 1962-1987. Second, until 1987 the increase in labor force participation rates of women since 1962 could actually

offset the decline in fertility during the 1960s and 1970s. The difference between the two scenarios is that in 1987 in the observed development scenario 36% of the population is part of the labor force, while under the constant development scenario the respective figure is only 26%. By the year 2022, observed development results in a labor force equal to 46% of the size of the labor force under constant development, while total population size is only 28% of the respective size under constant development. Without the increase in labor force participation rates and in school enrollment ratios, i.e. under social stagnation assumptions the labor force would be lower by 7% by 1992 and by 15% by 2022, under otherwise identical fertility and mortality assumptions (compare scenarios 1 and 5). The remarkable impact of increased economic activity of women is also demonstrated by the fact that by the year 2002 delayed development gives the same size of the labor force when compared to constant development, with only 70% of the respective total population size.

Since a strong increase in school enrollment ratios took place already before 1962, the educational distribution changes even under constant development assumptions. The proportion of the labor force with at least some secondary education would have increased from 22% in 1962 to 32% in 1987 (see Table 2, column 5 "well-educated"). With observed socio-demographic development, the respective increase would be or was much stronger: to more than 50% of the labor force by 1992, and even up to 70% in the long run. With delayed development assumptions the respective proportion would be some 10 percentage points lower during most of the period but would converge to 70% in the long run.

A phenomenon that can be observed in any country that has completed its demographic transition, and thus also in Mauritius, is the remarkable aging of the population. Even without additional mortality improvements after 1987, the proportion of the population aged 60 years and over would increase from currently 7% to 14% by 2022 (Table 2, observed development scenario). With constant 1962 development--without completion of the demographic transition--no aging would have taken place. A 15-year delay in transition would directly have translated into a 15-year delay in the aging process.

3.3. Socio-Demographic Dependency Ratios

As in Chapters 12 and 16, emphasis should be put on the development of the Socio-Demographic Dependency Ratio (SDDR). This ratio measures the burden of the labor force considering its educational distribution and the status, i.e. age of the dependents. As can be seen from Figure 2, the SDDR declined from 376 in 1962 to 225 in 1987 and it would continue to decline to 162 by the year 2012 under constant 1987 assumptions (compare observed development scenario).

With constant 1962 development, the Socio-Demographic Dependency Ratio would have fluctuated around 370-390 throughout the projection period. Assuming a certain correlation between the development of the economy and the SDDR, significant economic development would probably not have taken place. Delaying the demographic transition and the socio-demographic development by 15 years would have delayed the decline of the SDDR and thus possibly the economic boom some 15 years.

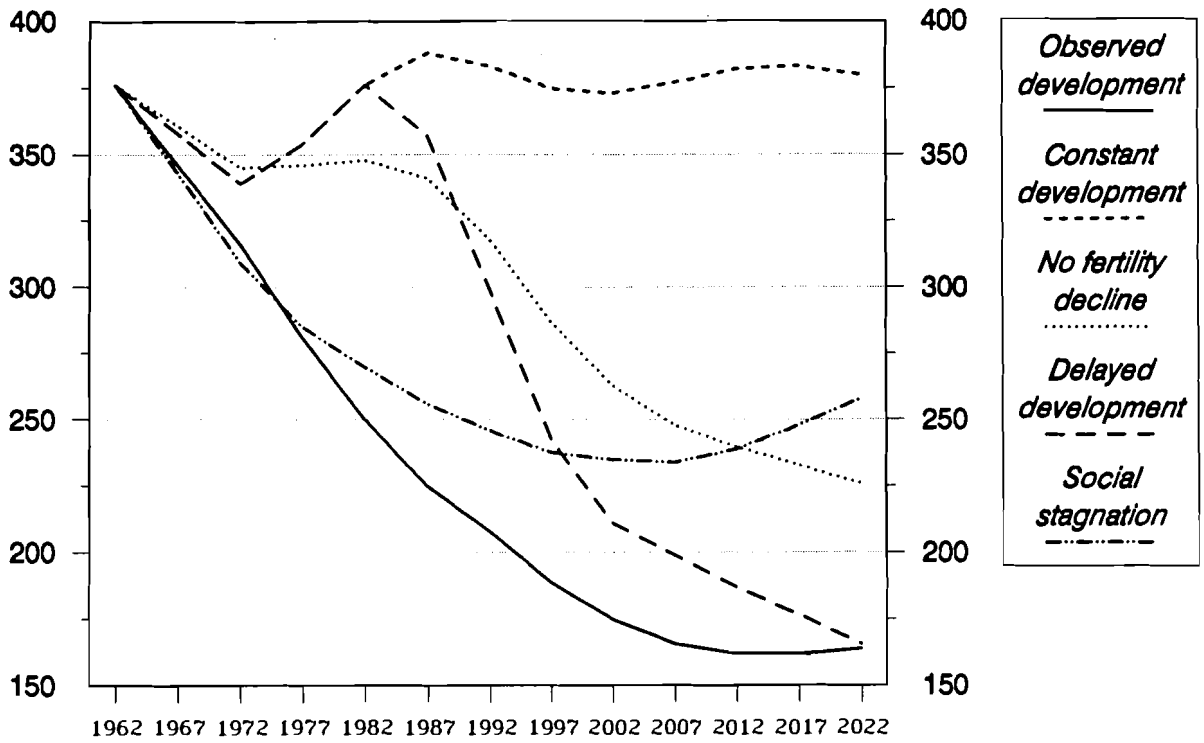

Figure 2. Projected socio-demographic dependency ratio, 1962-2022, which measures dependent equivalents per 100 active equivalents.

Looking at the results for the social stagnation scenario, which combines the observed demographic transition with social stagnation, i.e. no change in schooling and economic activity, one can conclude that during the period 1962-1977 the Socio-Demographic Dependency Ratio was dominated by changes in the age structure of the population, while after 1982 socio-economic changes started to prevail. Comparing observed development with social stagnation, the Socio-Demographic Dependency Ratio would have been 18% higher by 1992 and even 57% higher by 2022 without changes in labor force participation rates and school enrollment ratios. As can be seen in Figure 2, in the long run social stagnation gives a SDDR that is even higher than under the no fertility decline scenario, while by 1992 clearly the opposite conclusion holds.

Whether alternative developments of the Socio-Demographic Dependency Ratio hinder or favor economic development can be tested by the full population-development-environment model. A general conclusion will be difficult since the relation depends on the economic strategy adopted. The full model will also be able to trigger the effects of alternative population developments on the environment, again mainly via economic development. To be able to identify the impact of population changes, like extreme aging or excessive growth, on both economic development and environmental degradation is one of the features of the model; answers to those questions will be given in the following section.

4. POPULATION-DEVELOPMENT-ENVIRONMENT HISTORIES

When running the full PDE model one is confronted with a complex scenario design. Hundreds of parameters can be manipulated and specified but to make the comparison of different scenarios understandable one has to concentrate on a few major parameters. If we change only one or two values we can more easily grasp what is going to happen to the population, to the economy, and to the environment. The analysis that makes use of the full PDE model is only carried out for the period 1962-2002, since it does not sound reasonable to keep economic parameters constant over a long period of time. On the other hand, by projecting until 2002 instead of 1987 one can get an idea of what could have happened in the future under alternative historical pathways.

4.1. Scenario Specification

As in Section 3, a first step in the analysis is the detailed description of the scenarios to be investigated. After careful consideration, nine scenarios were specified.

1. *Observed development* scenario: assuming observed development in all areas between 1962 and 1987, i.e. assumptions for this period correspond to the assumptions in Sections 2.1 to 2.4, and keeping all parameters constant after 1987.

2. *Constant development* scenario: keeping all parameters in all areas constant at their 1962 level throughout the whole period 1962-2002, thus evaluating what would have happened until today if nothing would have changed since 1962 or, alternatively, what would have happened without any economic and socio-demographic development.

3. *No fertility decline* scenario: assuming constant 1962 fertility throughout the whole projection period, everything else being equal to the observed development scenario, thus isolating the economic and environmental effect of the rapid fertility decline.

4. *Socio-demographic stagnation* scenario: combining observed development in all economic and environmental parameters with socio-demographic stagnation (i.e. fertility, mortality, migration, education and economic activity constant as of 1962 throughout the whole projection period), evaluating the impact of high fertility and mortality rates and low school enrollment ratios and labor force participation rates on the economy and the environment. Government education and health expenditure was reduced in order to reflect higher mortality and lower schooling.

5. *Economic stagnation* scenario: combining observed development in all population related parameters with economic stagnation (i.e. stage of the economy constant as of 1962 throughout the whole projection period), thus evaluating the impact of economic underdevelopment together with rapid socio-demographic development.

6. *Sugar drop* scenario: assuming that the sugar protocol of the Lomé convention was not signed in 1970 and thus sugar exports were reduced to one-third of their actual level throughout the period 1972-2002, everything else being equal to the observed

development scenario, thus isolating the contribution of sugar exports to the actual economic development and environmental degradation.

7. *Tourism stagnation* scenario: assuming that the tourism industry was not further developed after 1962, everything else being equal to the observed development scenario, thus isolating the contribution of tourism to the actual economic development and environmental degradation.

8. *No EPZ exports* scenario: assuming that the EPZ textile and EPZ electronics&other sectors were not introduced, everything else being equal to the observed development scenario, thus isolating the contribution of the successful EPZ industries to the actual economic development and environmental degradation.

9. *EPZ export boom* scenario: assuming that EPZ textile and EPZ electronics&other exports would have been twice the observed amount of exports, everything else being equal to the observed development scenario, thus isolating the effect of even faster growth in the successful EPZ industries. In order to make this assumption possible labor force participation behavior of secondary educated women had to be raised to that of tertiary educated women.

Scenarios 2 to 5 were designed to answer some general questions within the population-development-environment debate. For example, "What was the contribution of population development to the development of Mauritius on the one hand and to environmental degradation on the other hand, as opposed to developments in the economy?" or, "What was the contribution of fertility decline as opposed to socio-demographic development?" Scenarios 6 to 9 were thought of answering some specific economic questions concerning development strategies, in particular specifying the impact of sugar cane growing and milling, of the tourism industry and of the EPZ industries.

Scenarios 2 to 8 are lower economic growth alternatives reflecting the belief that observed development was already extremely rapid; only scenario 9 investigates whether and under what circumstances even more rapid growth would have been possible.

In the following we first discuss some of the main output variables before comprehensive conclusions are drawn for each of the alternative scenarios.

4.2. Selected Results

Six major areas are discussed below: economic growth, i.e. GNP per capita; employment and unemployment; imports, exports and foreign-trade balance; government expenditure, taxes and budget balance; production and land use of sugar; and water requirement and (lagoon) water pollution. Population related results are discussed in detail in Section 3, and are not repeated below.

4.2.1. Economic Growth

Figure 3a gives GNP per capita for scenarios 1 to 5. The observed development scenario shows a steep increase from US$ 440 in 1962 to almost US$ 1700 in 1987. In the case of constant 1962 development, GNP per capita would have declined continuously parallel to population growth to only US$ 170 by 2002. Would the population have developed as actually observed, including a strong decline in fertility and an increase in schooling and economic activity of women, gains in terms of economic growth would only have been marginal: GNP per capita would still have declined more or less continuously (compare the economic stagnation scenario). On the other hand, if only the economy but not the population would have developed further (socio-demographic stagnation scenario) quite rapid economic growth would have taken place. By 1987, GNP per capita would have reached US$ 1170, a level some 30% below the level under observed development. However, due to the momentum of population growth a rapid decline in GNP per capita would take place in the future with no further development after 1987. GNP per capita would be back to the level of 1962 by 2022.

Taking into account the no fertility decline scenario we can conclude that roughly half of the drop in economic growth resulting from the socio-demographic stagnation scenario is due to high fertility while the other half is due to the lower educational level. The main conclusions from Figure 3a are first that changes in the economy are far more important for development than population changes, in particular in the short and medium term, and second that education is as important for development as fertility.

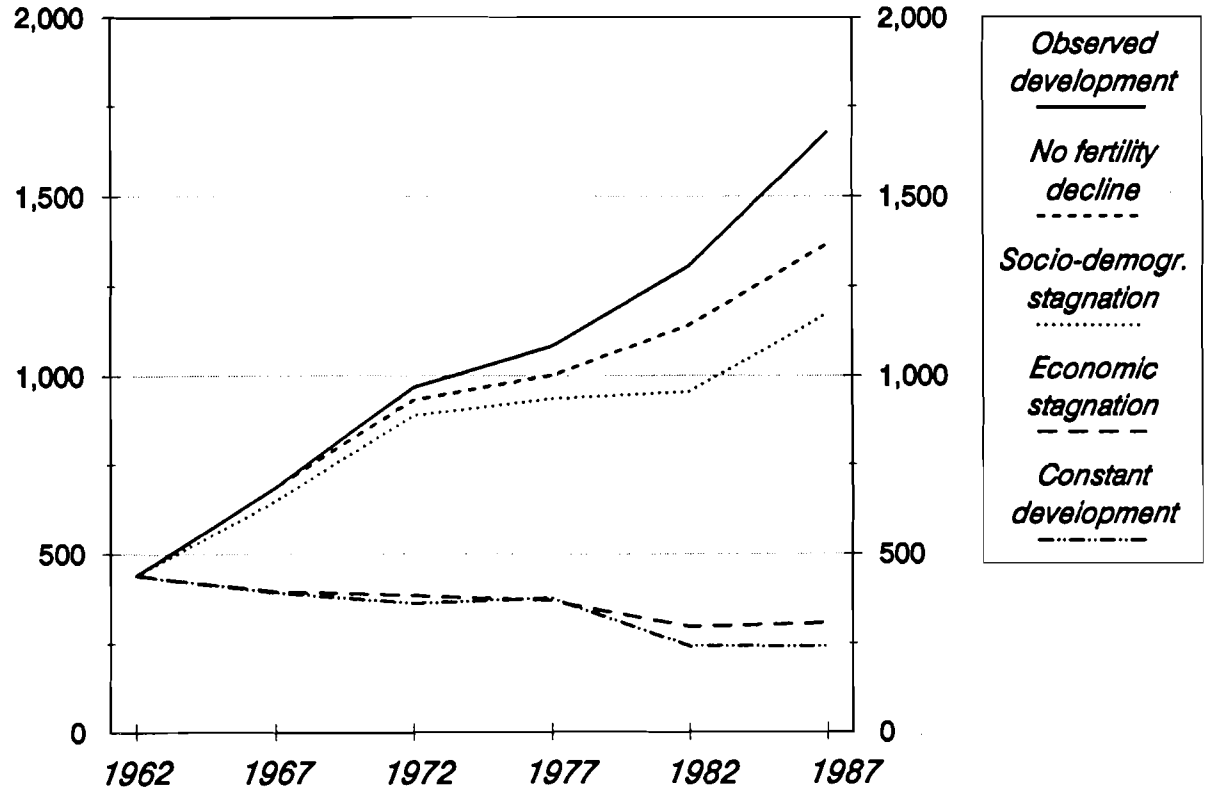

Figure 3a. Projected GNP per capita, 1962-1987, in US$.

Figure 3b gives GNP per capita for scenario 1 and scenarios 6 to 9. In any of the purely economic scenarios economic growth would have been rapid and would have gone beyond the level we would have reached under the socio-demographic stagnation scenario. In that respect population changes turn out to be more important for development than any single economic measure.

Interestingly, both under the assumption of a drop in sugar exports to only one-third of the observed level and under the assumption that no EPZ industry would have developed, GNP per capita would have reached US$ 1330 by 1987, a level some 20% below observed development, with insignificantly different development paths. Sugar and EPZ exports were equally important for Mauritius' rapid development. The marginal contribution of tourism to economic growth is also shown in Figure 3b.

Comparing the observed development with the EPZ export boom scenario shows that in theory even faster development of the economy would have been possible. However, in practice this development path would not have been feasible. It would have lacked the required labor force and could only have been realized if labor force participation rates of secondary educated women would have been equal to those of tertiary educated women, i.e. around 90%.

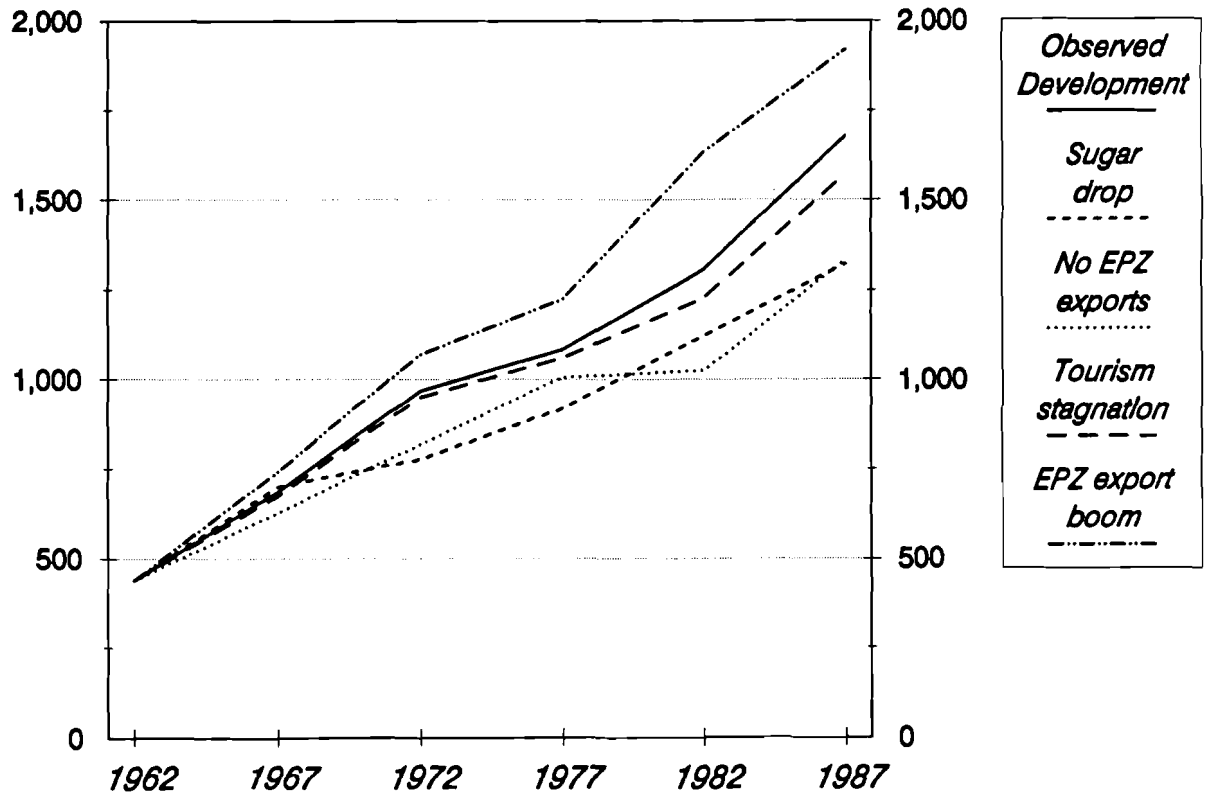

Figure 3b. Projected GNP per capita, 1962-1987, in US$.

4.2.2. Employment and Unemployment

Figure 4a gives the unemployment rate for scenarios 1 to 5. According to the observed development scenario, unemployment was high in the late 1970s and early 1980s and around 4% in 1987. With no further development unemployment would increase steeply and reach some 25% by 2002. Notwithstanding the larger size of the population and thus also of the labor force, during the period 1962-87 population changes alone (no fertility decline and socio-demographic stagnation scenarios) would hardly have affected the unemployment rate. In the no fertility decline scenario, for example, unemployment would even have been lower in 1977 and 1982, since the larger number of well-educated people in the labor force would even have accentuated the productivity of urban activities and could easily have been employed by the economy. Only in the long run the continuously increasing population would have had to struggle with over-proportionally increasing unemployment.

Constant 1962 development would have led to continuously rising unemployment up to one-third of the labor force by 1987. Employment would have been only at 70% of the observed level by 1987 and would reach the same level by 2002, however, with somewhat higher unemployment due to the larger size of the labor force. Much lower employment and much higher unemployment rates would have been realized under the economic stagnation scenario. Together with economic stagnation the low size of the labor force stemming from population development hinders the development of the industrial sectors and thus increases unemployment.

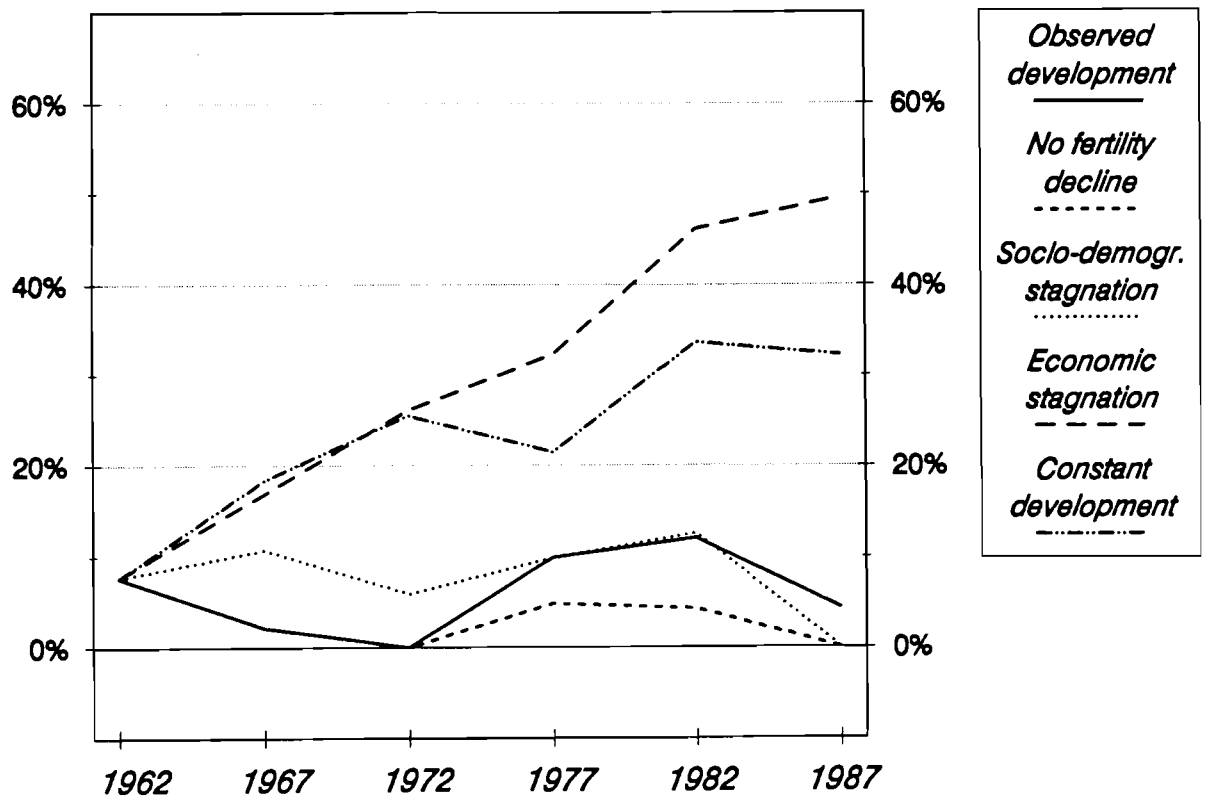

Figure 4a. Projected unemployment, 1962-1987, in % of the labor force.

Figure 4b again gives the unemployment rate for scenario 1 and scenarios 6 to 9. Both the sugar drop and the no EPZ exports scenarios result in high unemployment rates over the whole period. In accordance with the scenario assumption, the sugar drop scenario leads to a sudden increase in unemployment by 1972, while it remains around 20% until 1992. Without the successful introduction of the EPZ industries, unemployment would have risen more or less continuously to some 32% by 1987, a figure as high as under the constant development scenario.

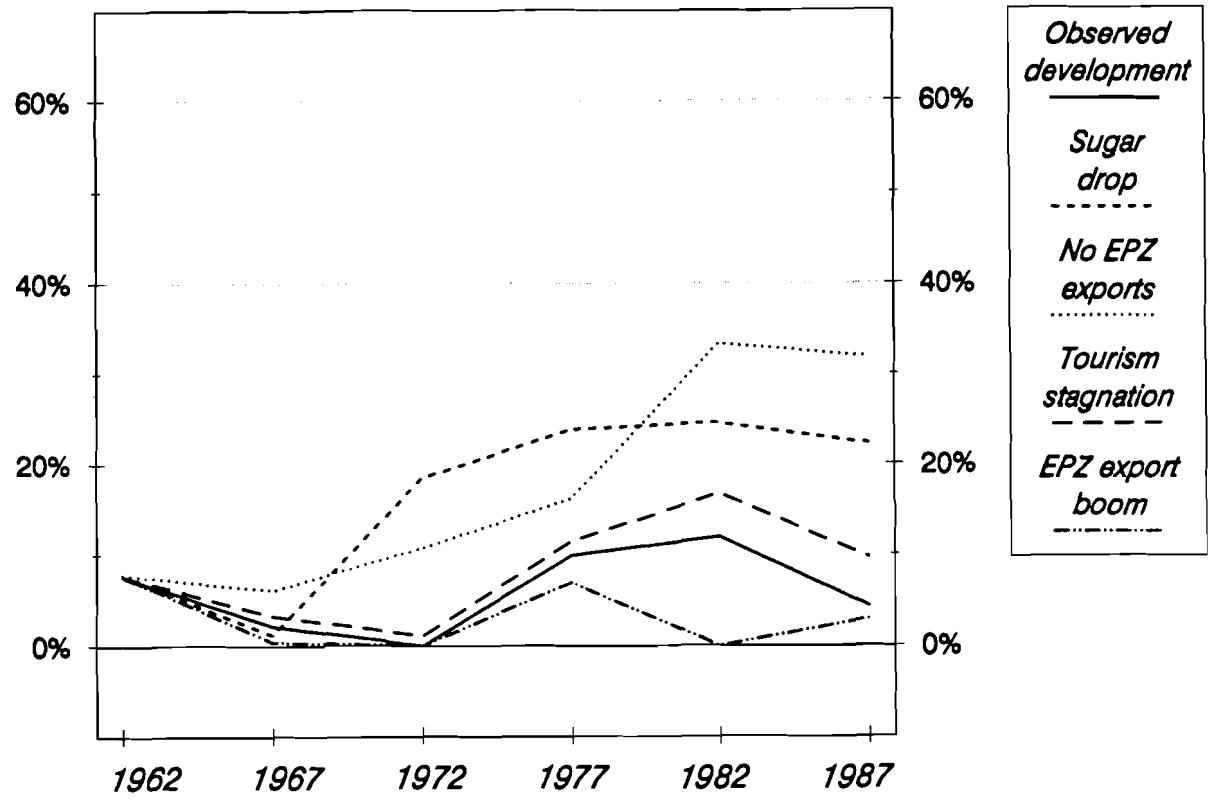

Figure 4b. Projected unemployment, 1962-1987, in % of the labor force.

The tourism industry makes a more significant contribution to total employment. By 1987, the unemployment rate would have been close to 10% with the tourism industry not developed further after 1962. The unrealistic EPZ export boom scenario would have resulted in virtually zero unemployment over the period 1962 to 1992.

Interestingly, the correlation between GNP per capita and unemployment is very high. Scenarios that result in lower economic growth at the same time result in higher unemployment and vice versa.

4.2.3. Foreign-Trade Balance

Figure 5 gives the foreign-trade balance for scenarios 1 to 5. Under the observed development paths, the foreign-trade balance was positive over the whole period. Exports exceeded imports by some 20% with an unexpected peak in 1982. The economic scenarios 6-9 do not significantly deviate from that pattern. Economic stagnation would

have led to increasingly higher imports as opposed to exports making the trade balance deteriorate to minus 20% by 1987. Due to the increasing size of the population, socio-demographic stagnation on top of economic stagnation, i.e. constant development, would even have accentuated the increase in imports and worsened the foreign-trade balance (-33% by 1987).

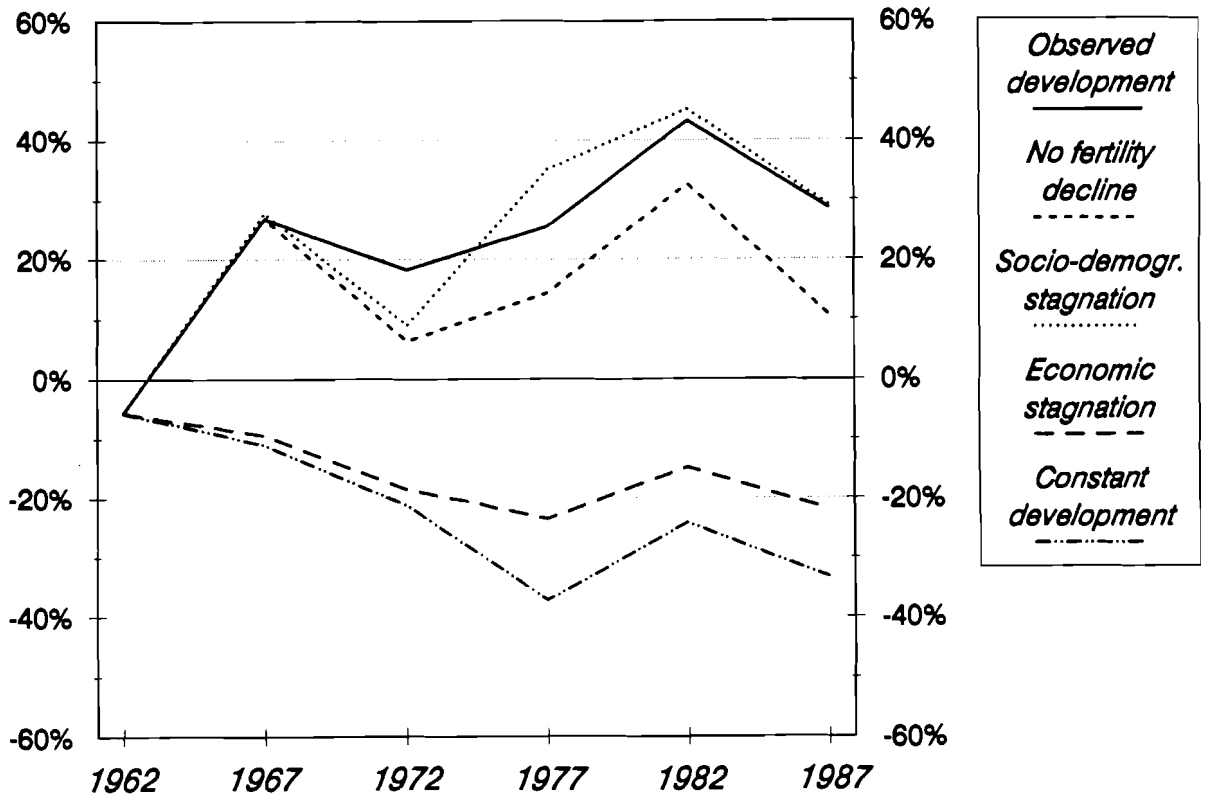

Figure 5. Projected foreign-trade balance, 1962-1987, in per cent.

Socio-demographic stagnation alone, however, would not have affected the trade balance. At least up until 1987, the higher demand from the larger population would have been compensated by the lower education and thus lower per capita demand of that population. In the case of the no fertility decline scenario the trade balance would have been somewhat worse as the large number of highly educated people would have demanded more expensive goods and would thus have increased imports, without any compensating effects.

4.2.4. Budget Balance

Government expenditure is a function of the size, the age structure and the educational structure of the population on the one hand and of the per capita expenditure on the other. Under the observed development scenario total government expenditure, including the groups education, health and other expenditure, increased from around 800 million Rupees in 1962 to around 2,900 million by 1992. Under the no fertility decline scenario, with its large size and well-educated population, this increase would have been much larger (4,500 million by 1992) and would be especially large in the long run. On the

other extreme we find the economic stagnation scenario. Government expenditure would only have increased to around 1,300 million by 1992 under this scenario due to the low size of the population and the lower, constant 1962, per capita expenditure.

Taxes are somewhat artificial in Mauritius since the large producers, the EPZ industries, are exempted from paying taxes. As a consequence, the budget balance is slightly (10% to 15%) negative during the whole period not only under the observed development scenario but also under the EPZ scenarios. Assumptions of the sugar drop scenario would have reduced taxes and thus would have worsened the budget balance to around minus 30% between 1972 and 2002. A similar budget deficit results from the economic stagnation scenario, while population stagnation scenarios all lead to significantly higher budget deficits especially in the long run, for example -60% by 2002 under the constant development alternative.

4.2.5. Sugar Production

Figure 6 gives total production of sugar measured in 1000 tons. Due to the increase in land and labor productivity, the amount of sugar produced almost doubled from 3,400 thousand tons in 1962 to more than 6,600 by 1987. At the same time the amount of land needed to produce this sugar declined from 88% to only 67% of total arable land. With constant development, both the amount of sugar produced and the land required to produce it would almost have remained on its 1962 levels.

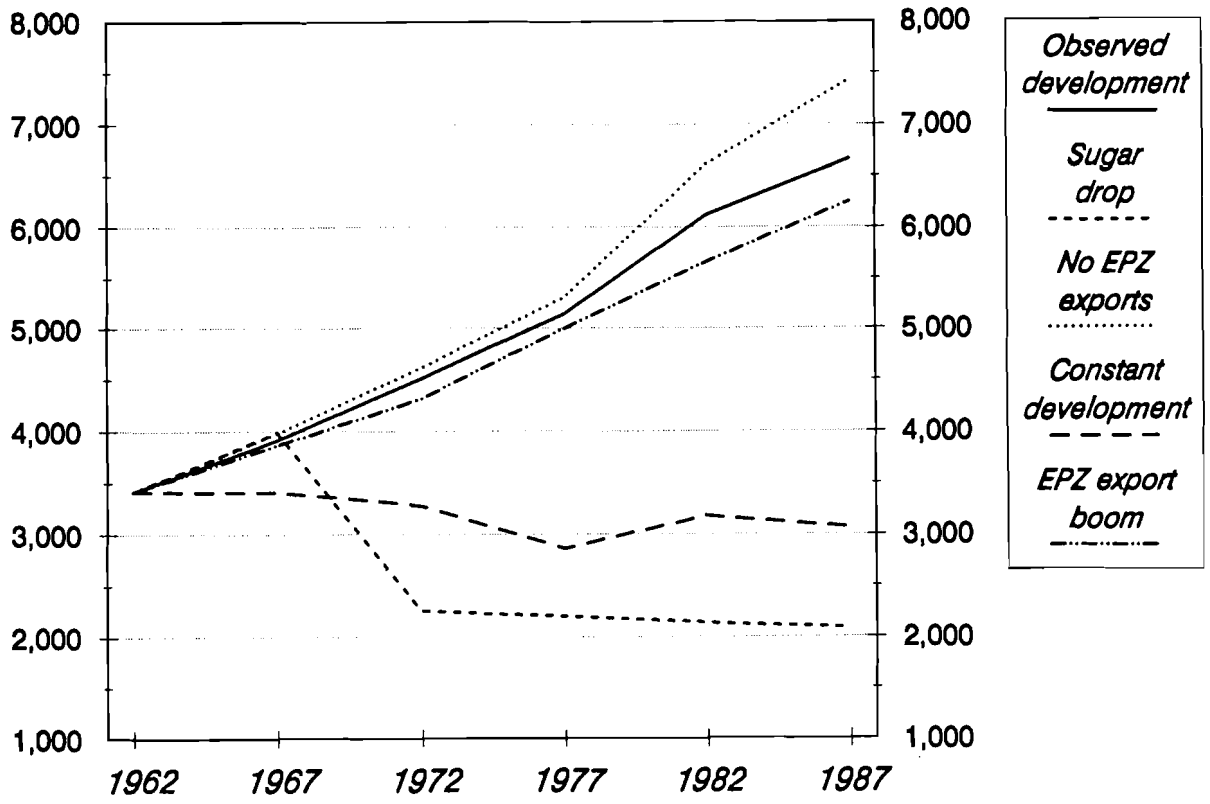

Figure 6. Projected production of sugar, 1962-1987, in 1000 tons.

Under the sugar drop scenario, sugar production would have gone down to only 2,000 thousand tons in 1972 and would have remained on that level. The amount of land needed to produce that sugar would have declined accordingly, thus freeing lots of land for urban activities. Under the no EPZ exports scenario, more land would have been available for sugar cane growing and milling and as a consequence sugar production would have been higher as was actually observed. The opposite would have happened under the EPZ export boom scenario.

4.2.6. Water Requirement and Pollution

The amount of water required, measured in million m^3 per day, by some of the development paths is shown in Figure 7. According to observed development, water requirement steeply increased from 6 million m^3 per day in 1962 to 12.3 million in 1987. Since the corresponding water supply, which was almost constant through the entire period, was calculated at 12.45 million m^3 (see Section 2.4 for details) almost all water resources were required in 1987 and would be required in the future without additional economic development after 1987. At the same time the concentration of organic waste in the lagoon water increased from 1% in 1962 to 5% by 1987.

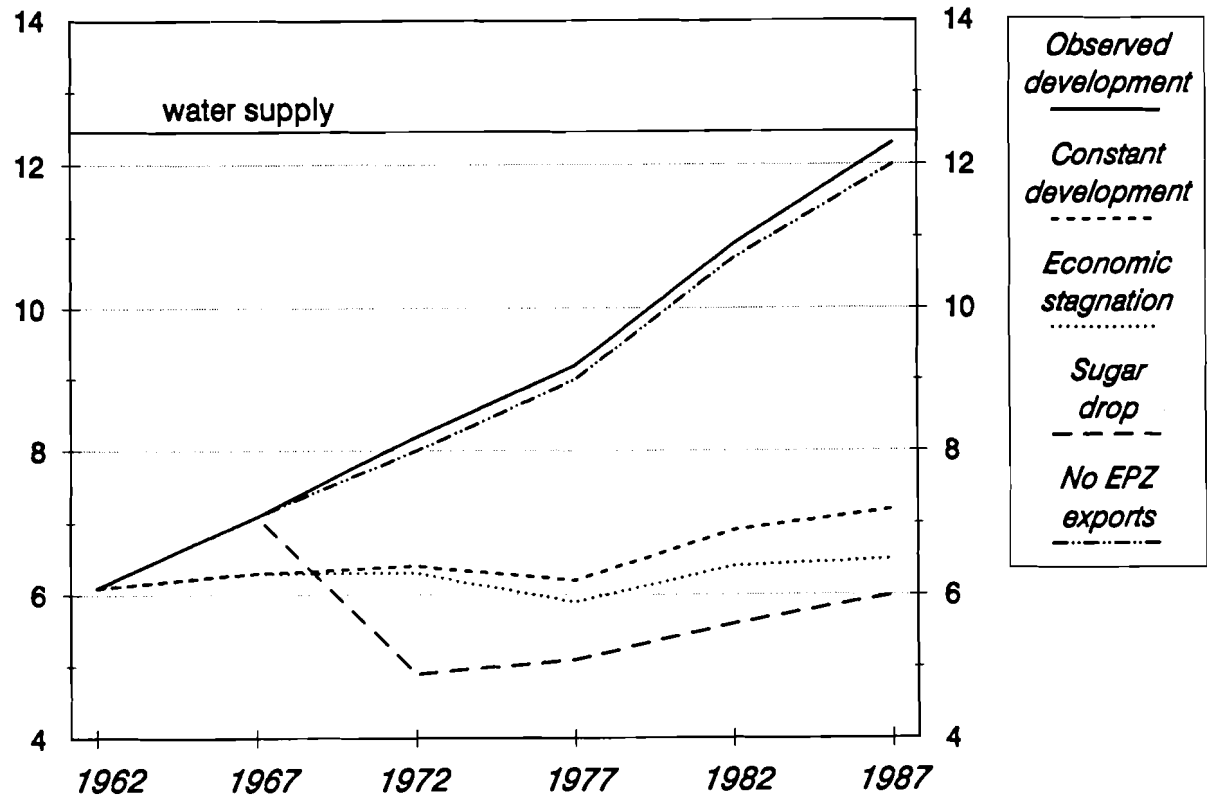

Figure 7. Projected water demand, 1962-1987, in million m^3 per day.

Without changes in the economy (economic stagnation scenario) both water requirement and lagoon water pollution would almost have remained on their 1962 level. Adding socio-demographic stagnation (constant development) would have resulted in an increase in water requirement to 9 million m^3 per day by 2002, being a consequence of the rapid

population growth under that particular scenario. Water pollution would not have changed significantly.

Figure 7 also shows the almost insignificant water demand of the EPZ industries (compare the no EPZ exports scenario). Given the current level of economic activity, the big water user in Mauritius is clearly the sugar industry, mainly due to irrigation. Reducing sugar production to one-third of its actual level would, by 1987, have cut total water requirements in half. Both the sugar drop and the no EPZ exports scenarios would have had a slightly positive impact on water pollution, their contribution to lagoon water pollution being on the same level.

4.3. Comprehensive Conclusions

In this final section the major conclusions of the alternative historical development paths are summarized scenario by scenario.

1. *Observed development* scenario: the full PDE-Mauritius model was reasonably able to reconstruct the history of Mauritian development during the period 1962 to 1987. The economy grew with an amazing speed, quadrupling GNP per capita to US$ 1700. The educational level of the population increased remarkably, as did economic activity of women. Unemployment was brought down to a reasonable level, the foreign-trade balance was significantly positive and the budget deficit fluctuated at around -10%. Production of sugar doubled albeit using much less land to grow sugar, water demand increased to reach water supply by 1987.

2. *Constant development* scenario: would neither the population nor the economy have developed further after 1962, population size would have increased at a remarkable rate while the economy would have stagnated. As a consequence, GNP per capita would have fallen continuously to only US$ 100 in the long run. Mauritius would, by today, be a poor developing country. Unemployment would be tremendous (around 40% by 1992), the foreign-trade and the budget deficit would soon have reached unsustainable levels (both around -50% by 1997). Only the environment would have benefitted--due to economic stagnation--as both water requirement and water pollution would not have increased.

3. *No fertility decline* scenario: would Mauritian women still have more than five children on average, development would clearly have been much more difficult. Up until the 1990s still remarkable economic growth albeit on a significantly lower level would have occurred, but in the long run continued population growth would increasingly have made development difficult if not impossible. For some periods, unemployment rates would even have been lower than under observed development, while the foreign-trade and in particular the budget balance would have developed in an alarming manner. Due to the large number of well-educated people production and land use of sugar would have been lower and thus additional water demand from the larger size of the population could have been offset by reduced water demand from reduced sugar production and irrigation. By 1987, high fertility would not entirely have hindered development, but in the long run a reduction in fertility would have been necessary.

4. *Socio-demographic stagnation* scenario: adding socio-demographic stagnation to constant fertility would first and foremost have led to a completely different educational structure of the Mauritian population. As a consequence and also due to accentuated population growth, the development of the economy would again have been more difficult (as compared to the no fertility decline scenario) and GNP per capita would have developed with a slower speed. Also as a consequence of different education developments, both the foreign-trade balance (less educated people demand less expensive goods and reduce imports) and the budget balance (less people in school reduce education expenditures) would have developed significantly more favorable; in the short and medium term almost as satisfactory as under observed development. In the long run, however, no advancement in education would have put strong restrictions on possible development in Mauritius. Limitations already imposed by continued high fertility would have doubled by continued low education.

5. *Economic stagnation* scenario: economic stagnation combined with observed population developments would have resulted in an economic disaster almost as bad as under the constant development scenario. Unemployment would even have been worse, more than half of the population willing to work would have been concerned. Due to the lower population size, GNP per capita, the foreign-trade balance and the budget deficit would have developed more favorable, but still in an unsustainable manner. One should note that by assumption in this scenario benefits from the higher educational level of the population were not economically realized.

6. *Sugar drop* scenario: assuming that the sugar protocol of the Lomé convention had not been signed in 1970 clearly shows the important contribution of the sugar industry to development in Mauritius during the last three decades. GNP per capita would have been reduced by more than 20% (1987), while unemployment would have been high (some 20-30%) throughout the period. Both the foreign-trade balance (sugar exports hardly need any imports) and the budget deficit (the sugar industry is one of the main tax payers) would have developed very unfavorably. Interestingly, the large drop in land required for sugar cane growing could not have been used by any other agricultural, industrial or service activity; 50% of total usable land would not have been used under that scenario. Since sugar is the major water user in Mauritius--at least up until today--total water demand would not have increased since 1962 and water pollution increases would clearly have been lower.

7. *Tourism stagnation* scenario: in terms of output variables from the PDE model tourism had only a small share in overall development of Mauritius. GNP per capita would have been somewhat lower, unemployment some 2 to 5 percentage points higher. Budget deficit and particularly the foreign-trade balance would have developed more unfavorably. The ideal value of tourism, like for example making non-Mauritians familiar with the island in the Indian ocean and therefore making them interested in investing in Mauritius is not measured by the model but should not be disregarded.

8. *No EPZ exports* scenario: not having introduced EPZ industries would have lowered Mauritian development to a level comparable to the sugar drop scenario. Unemployment would have increased rapidly to levels that would have been observed under constant development, marking EPZ industries out as the main employer in Mauritius today. In contrast to the sugar drop scenario, the budget deficit (the EPZ industry is exempted from paying taxes), the foreign-trade balance and water demand would have developed very much like under observed development. Overall, not having introduced the EPZ industry turns out to be somewhat less harmful to Mauritian development as the sugar drop assumption, because some of the missing EPZ exports could have been compensated by additional sugar exports.

9. *EPZ export boom* scenario: even higher EPZ exports (+100%) would clearly have accentuated economic growth in Mauritius, accompanied by lower unemployment rates, and higher imports and exports. But, the high labor demand could only have been satisfied if economic activity of secondary educated women would have increased to the level of tertiary educated women, or, if labor productivity would have increased more rapidly. It seems justifiable to say that on the basis of the already very rapid observed socio-demographic development during the period 1962 to 1987 not much higher economic development would have been possible in Mauritius.