Developing Countries Dilemma : Labor Intensive Technology or Capital Intensive Technology ?

Muhammad Tasrif
Center for Research on Energy ITB
(Pusat Penelitian Energi ITB)
Jl. Ganesha 10 Bandung 40132 Indonesia

It is an accepted view that technological progress is an extremely important - perhaps the most important - determinant in the growth in output per man. In the discussions of the role of technological change in the economy, one of some important questions naturally arise is how does technological change affect different factors. Traditionally, some technological changes are thought of as "labor intensive", and some as "capital intensive". Whether the technological change is capital intensive or labor intensive, the most important question for developing countries is how the technological change can be expected to improve their national productivity considerably and continuously. Their economies generally depend on foreign exchange earnings from loan and exports, and from now on, they are facing some constraints in the international market.

A system dynamics model based on an integration of micro-and macroeconomics theories is constructed and used firstly as an analytical instrument in trying to address the question of the way technological changes may affect national productivity. Secondly, long-run growth patterns resulting from various intuitively appealing development policies are analyzed, and an attempt is made to identify the best policy set for attaining a sustainable improvement in national productivity.

The study shows that the appropriate technology to be adopted by a developing nation should not depend on existing labor availability but should take into account the growth pattern desired. When the technology mix is allowed to change adaptively following the recognized (traditional) capital-labor ratio while aggregate demand is limited, the result shows that the productivity growth patterns decline in the long run. The economy in which a sustainable increase in capital intensity can be maintained in the long-run, can be expected to improve national productivity considerably. To prevent downward spiraling tendency of productivity, and therefore to chart out strategies for improved productivity, developing countries have to set an explicit effort to increase the capital-labor ratio of their economies; instead of the existing tradition, as a basis for determining appropriate factor proportions. When in the short-run the increase in capital intensity can be also adjusted with the existing labor availability, through an efficient market mechanism for determining wage rate in order to restore the balance between the workers and the unemployed, the issue of the increase in unemployment rate due to the functioning of the capital intensive technology is weak. The study shows that the long-run trend of the unemployment rate can decrease continuously and fluctuates at a lower level when an increase in aggregate demand can be realized in the market.

Theoretical framework

The studies of the 1950's indicated that technological progress was an extremely important - perhaps the most important - determinant in the growth in output per man. In the discussions of the role of technological change in the economy, four questions naturally arise (Stiglitz and Uzawa 1969).

1. How does technological change affect different factors ? Traditionally, some technological changes are thought of as "capital intensive", and some as "labor intensive".
2. What determines whether technological change is primarily "capital intensive" or primarily "labor intensive" ?
3. What determines the rate of technical change ?
4. How are changes in technique introduced into the economy ?

Hicks and Harrod among others, have proposed the different definitions of a neutral technical change. If the change in relative shares is used as the measure of bias of technological change, then the Hicks definition measures the bias along a constant capital-labor ratio while the Harrod definition measures the bias along a constant capital-output ratio. In the growth literature, Harrod neutrality has played a more central role. It has often been alleged that technological change in fact is Harrod neutral. Stiglitz and Uzawa observed an "almost constant capital-output ratio with an almost constant rate of interest" (Stiglitz and Uzawa 1969). Bach (Bach 1968) has showed the validity of their observations. It is based on the patterns of the economic growth in the US that showed the capital-output ratio and the interest rate were roughly flat in trend between 1900 - 1965. On the other hand, the capital-labor ratio was steadily increase in trend. The fact of the increase in capital-labor ratio can be observed also in the discussions of the relationship between labor productivity and capital-labor ratio (Sumanth 1985).

Whether the technological change is capital intensive or labor intensive, the most important question for developing countries is how the technological changes can be expected to improve their national productivity considerably and continuously. Developing countries are, among others, characterized by limited capability and capacity of their human resources in technological affairs, as reflected (among others) by the high imports of capital and other manufactured goods. Their economies generally depend on foreign exchange earnings from loan and exports of commodities (mostly in the form of raw materials or products exploited from natural resources). From now on, they are facing some constraints in the international market, i.e. export competition, loan availability, currency realignment, and unbalanced increase between the level of export price and the level of import price.

A system dynamics model based on an integration of micro-and macroeconomics theories is constructed and used firstly as an analytical instrument in trying to address the question of the way technological changes may affect national productivity. Secondly, long-run growth patterns resulting from various intuitively appealing development policies (facing the constraints mentioned above) are analyzed, and an attempt is made to identify the best policy set for attaining a sustainable improvement in national productivity.

Model description

Using the Harrod definition of technological change, the technological changes can be represented with the changes in the capital-labor ratio (called as technology mix) of the economy. Therefore, the main focus of the model is the mechanism of changes in the technology mix that may affect national productivity.

There are two submodels, namely the productivity growth submodel and the foreign exchange reserves submodel.

Productivity growth submodel

A simple generic dynamic model of productivity growth is formulated from a familiar theoretical model, the multiplier-accelerator model of Samuelson (Samuelson 1939). This submodel consists of a single-sector two-factors production system that incorporates national income accounting at an aggregate level and mechanisms to determine wage rate and technology mix (Figure 1).

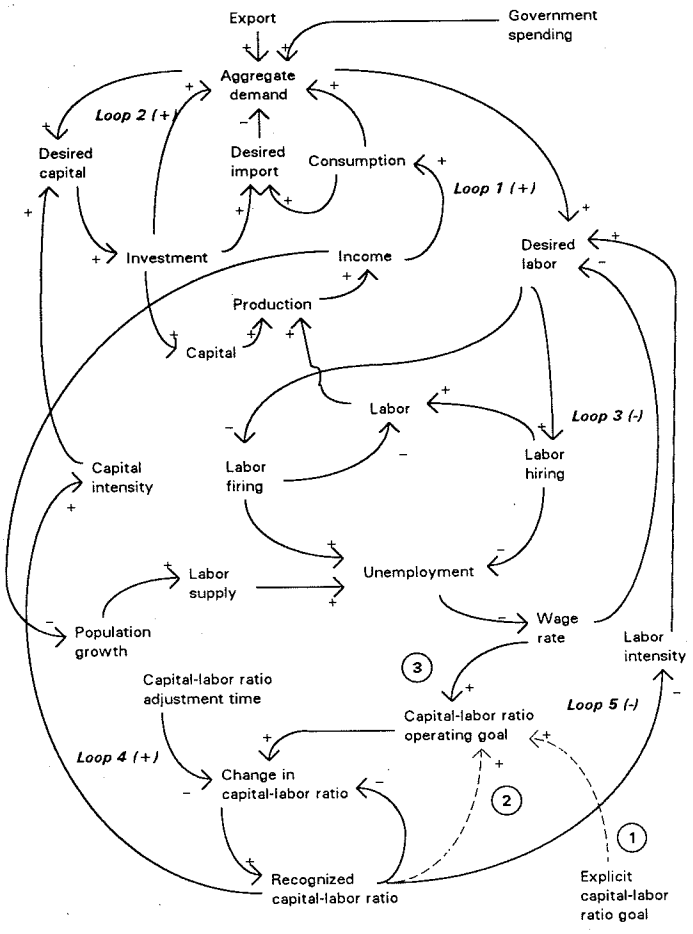

Figure 1. Productivity growth submodel

The growth mechanisms are embodied in the positive feedback loop 1 and the positive feedback loop 2 (see Figure 1.) representing the multiplier and accelerator principle respectively. However, instead of assuming the presence of a market equilibrium all along the growth path, the model incorporates the micro level responses of producers and consumers to changes in market conditions.

Two market-clearing mechanisms are built into the model. These are wage rate and technology mix. Wage rate clears the labor market. An increase in the unemployment rate depresses wage rate. A depressed wage rate, in turn, will increase the demand of workers. Subsequent hiring of workers restores the balance between workers and the unemployed. Through this mechanism the model is equipped with a negative feedback loop, i.e. loop 3 in Figure 1.

Production is determined by the stocks of labor and capital according to a Cobb-Douglas production function

$$Q = AK^{\alpha}L^{\beta} \tag{1}$$

where Q is production, K is capital stock, L is labor stock, α is exponent on capital, β ($= 1 - \alpha$) is exponent on labor, and A is a constant. Based on the standard neoclassical assumption of profit-maximizing behavior in the acquisition of production factors, the formulas for desired capital ($= D_k$) and desired labor ($=D_l$) can be derived as

$$D_k = \alpha \frac{P}{(1/t + i)} \tag{2}$$

$$D_l = \beta \frac{P}{W} \tag{3}$$

where P is aggregate demand, t is average life of capital, i is real interest rate, and W is real wage rate. Looking at those equation 2 and equation 3, the exponents α and β are also called as capital intensity and labor intensity respectively, as seen in Figure 1. Through equation 1, the capital intensity α can be derived as

$$\alpha = 1 - \frac{\ln (A) + \ln (KOR)}{\ln (KLR)} \tag{4}$$

where ln is natural logarithmic, KOR is capital-output ratio, and KLR is capital-labor ratio. In the model, the capital-output ratio KOR is assumed to be constant.

It is assumed that, in the long run, the technology mix (the capital-labor ratio) is allowed to adjust towards its operating goal, although this process may be quite slow. The adjustment time of technology mix depends on time needed to develop human resources and technology. As indicated in Figure 1., the operating goal of technology mix can be an explicit goal determined by government (the dashed arrow 1 in Figure

1.). Or, at the other extreme, the goal can be the recognized (traditional or attainable) capital-labor ratio (the dashed arrow 2 in Figure 1.). It is also assumed that, in the short run, the technology mix operating goal is influenced by the level of wage rate. The goal will rise when the real wage is higher than the average value of the marginal productivity of workers (arrow 3 in Figure 1.).

The formula for the change in the capital-labor ratio (technology mix) is modeled as

$$\frac{d\,(KLR)}{dt} = \frac{G_t - (KLR)}{T} \qquad (5)$$

where G_t is capital-labor ratio operating goal and T is technology mix adjustment time.

When the capital-labor ratio is allowed to vary, based on equation 4, an increase in this ratio will raise the capital intensity α (on the contrary it will reduce the labor intensity β). In other words, the economy adopts capital intensive technology. Change in these intensities, as seen in Figure 1., will augment the multiplier-accelerator mechanism with two important feedback loops, i.e. positive feedback loop 4 and negative feedback loop 5. This additional positive feedback loop will create bigger acceleration and also raise subsequent multiplier effects.

Foreign exchange reserves submodel

To incorporate the characteristics of developing countries and the constraints in the international market faced by developing countries, a foreign exchange reserves model is considered in order to determine foreign exchange reserves availability. As seen in Figure 2., this availability will influence imports. When the availability is low, the imports will be less than its desired level. In addition, these imports will affect the productivity growth submodel.

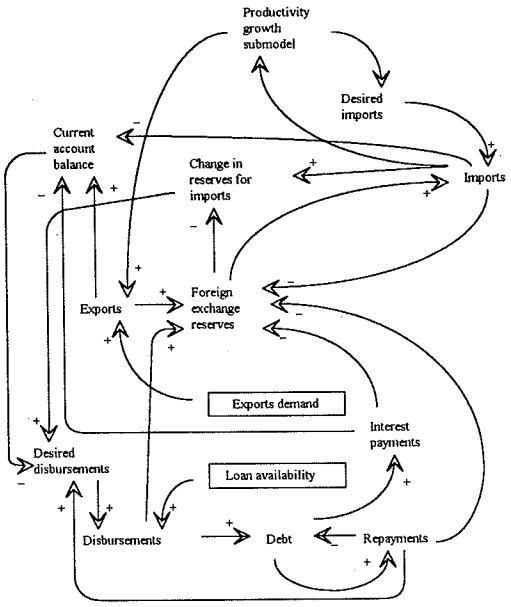

Figure 2. Foreign exchange reserves submodel

The external factors, those are considered in the model, are exports demand, loan availability, and general price level of exports and imports. The latter is not expressed is Figure 2. As indicated in Figure 2., exports demand will limit the exports and loan availability will limit the disbursements of loan. Then, the exports and the disbursements will affect foreign exchange reserves.

Simulation results and analysis

The model is initialized in the full equilibrium. In this equilibrium the population growth rate is equal to zero, exports equal imports, export price is equal to import price, debt equals zero, and the constant fraction of government spending to production is greater than the constant fraction of tax rate to production (deficit budget). The model is simulated for 200 years from 1900 to 2100. A non zero population growth rate is assumed as the only source of growth in the model.

Technology mix and national productivity

In trying to address the question of the way technology mix may affect national productivity, three scenarios were developed. The first, designated as 'fixed scenario', describes the behavior of the growth of productivity in response to population growth with a fixed technology mix assumption (the capital-labor ratio is constant). For the second scenario, designated as 'market scenario', the capital-labor ratio is allowed to change adaptively, where the recognized capital-labor ratio is used to determine the capital-labor ratio operating goal. In the third scenario, designated as 'targeted scenario', the operational goal is set externally which is increasing gradually. For these three scenarios, the export and import prices increase with the same growth rate.

The results show differences in production per capita patterns (Figure 3.), unemployment rate (Figure 4.), real wage rate (Figure 5.), capital-labor ratio (Figure 6.), capital intensity (Figure 7.), and debt-service ratio (Figure 8.). An analysis of the three scenarios reveals that the productivity growth rate (production per capita and real wage rate) resulted by the model in the targeted scenario surpasses that in the two other scenarios. Under the fixed technology mix assumption, the production per capita and the real wage rate, though fluctuating with relatively constant cycle, tend to be flat. This shows that production growth rate and population growth rate are at equal levels. Interestingly, in the market scenario those trends decline in the long run. Apparently, in this second scenario the rise in population raises the pool of the unemployed, which depresses real wage rate, and the consequent decrease in capital-labor ratio. The lower level of capital-labor ratio does not encourage further investment. This limits acceleration and subsequently the multiplier effects, leading to a downward spiral.

Unemployment rate in the targeted scenario, in the long run, performs better than the other two scenarios (Figure 4.). However, this better performance has to be supported by an increase in external loan, as seen in Figure 8 (debt-service ratio).

The analysis indicates that to prevent downward spiraling tendency of productivity, and therefore to chart out strategies for improved productivity, developing countries have to set an explicit effort to increase the capital-labor ratio of their economies. It is

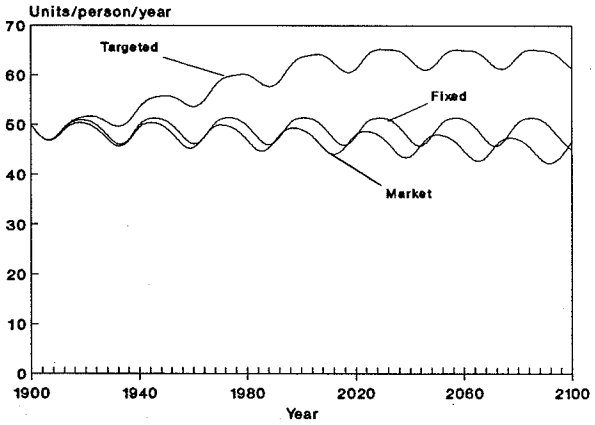

Figure 3. Production per capita

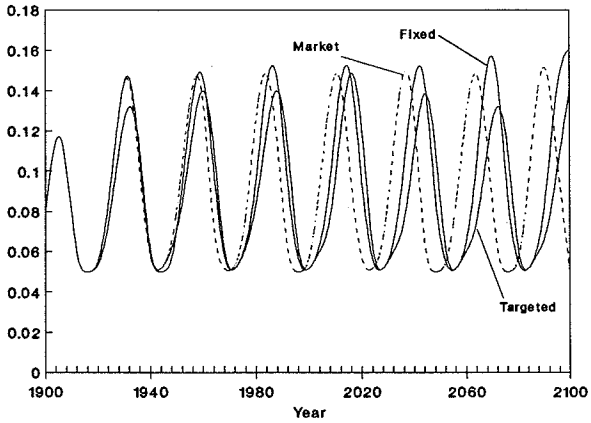

Figure 4. Unemployment rate

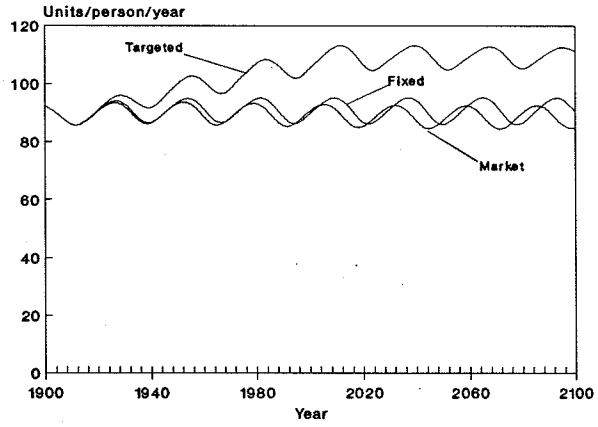

Figure 5. Real wage rate

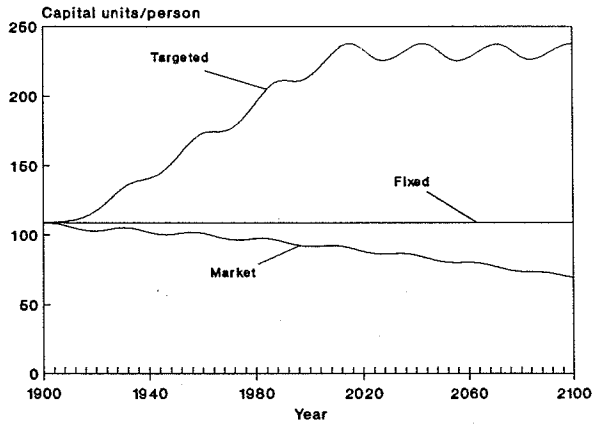

Figure 6. Capital-labor ratio

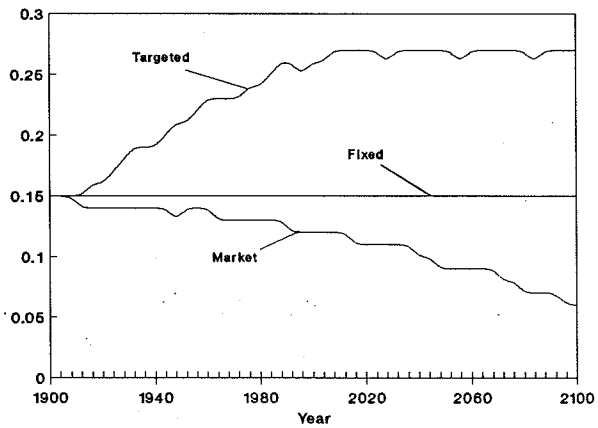

Figure 7. Capital intensity

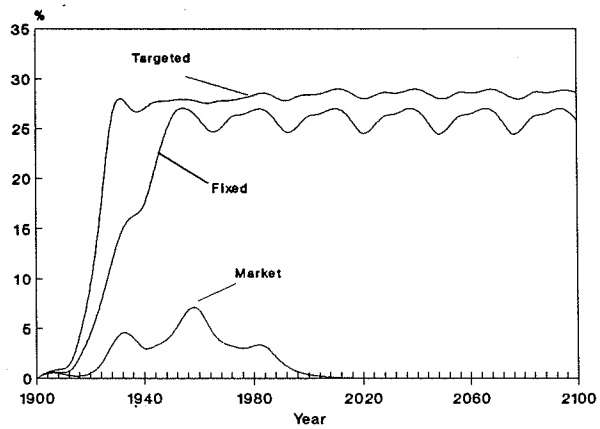

Figure 8. Debt-service ratio

also important to develop policies to establish more efficient labor market. Such strategy is shown to have two positive effects, namely the long term tendency for improved productivity and a corresponding higher employment level.

Facing constraints in the international market

The flexibility of technology mix is tested in facing the constraints in the international market. To those three scenarios (fixed, market, and targeted), change of the model parameters is introduced in simulating the model representing three main constraints in the international market. The first, the loan availability is set equal to 0.5 for all simulation periods. This means that the only half of the desired disbursements of loan can be realized. In the second experiment, it is assumed that in the periods of 2000 to 2050 the import price is higher than the export price, representing the unbalanced increase in the export and import prices. In the third experiment, from 2000 to 2020, it is assumed that the actual repayment is higher that the recorded repayment due to the currency realignment.

An analysis of these three experiments reveals that the trend of productivity growth rate resulted by the model in the targeted scenario is still better than in the two other scenarios. The targeted scenario can prevent downward spiraling tendency of productivity, although this better performance has to be supported by an increase in external loan.

Raising exports and increasing taxes

To those three scenarios, two experiments of raising exports and increasing taxes are simulated using the model to see the response of productivity growth of the model in facing an increase and a decrease in aggregate demand of the economy respectively.

The results show that the trend of productivity growth rate produced by the model in the targeted scenario is still better that in the two other scenarios.

When the increase in aggregate demand can be realized in the market, while developing countries are facing the constraints in the international market and policy to increase tax rate in order to reduce deficit budget, the simulation results of this experiment are shown in Figure 9. (production per capita), Figure 10. (unemployment rate), Figure 11. (real wage rate), Figure 12. (capital intensity), Figure 13. (debt-service ratio), and Figure 14. (government deficit). The results show that the targeted scenario can be expected to improve the productivity considerably and continuously in the long run as seen in Figure 9 and Figure 11 respectively. This better performance my be achieved without external loan and government deficit as seen in Figure 13 and Figure 14 respectively.

Concluding remarks

This study investigates the dynamic effects of technological changes on the growth of productivity of developing countries. Using the changes in capital-labor ratio as a representation of technological changes, three growth scenarios under the flexibility of the capital-labor ratio are simulated. These three scenarios are also tested with some constraints those have been experienced by developing countries.

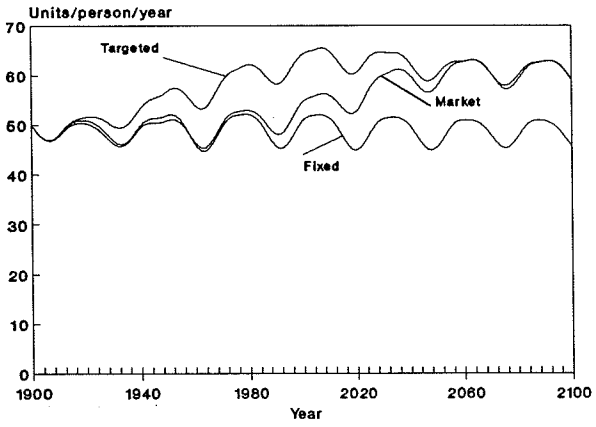

Figure 9. Production per capita

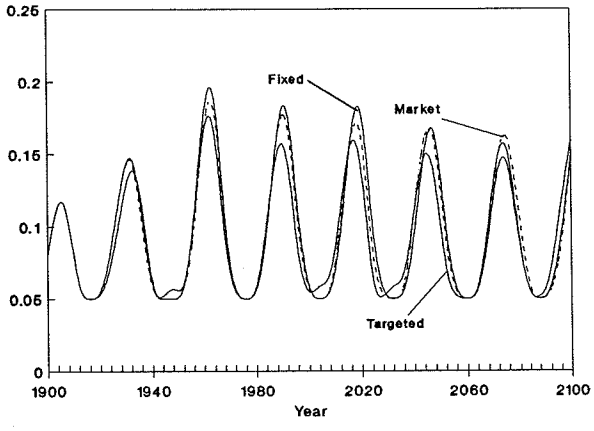

Figure 10. Unemployment rate

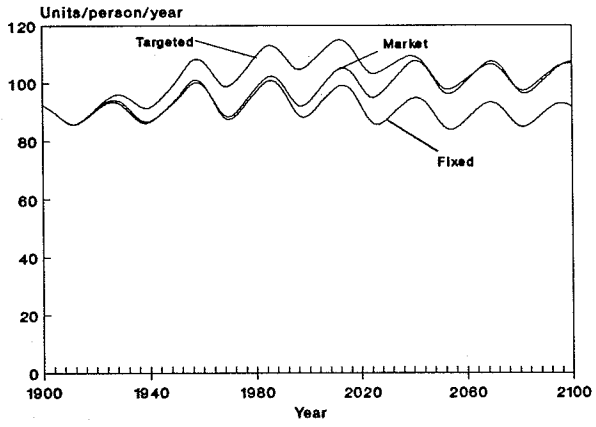

Figure 11. Real wage rate

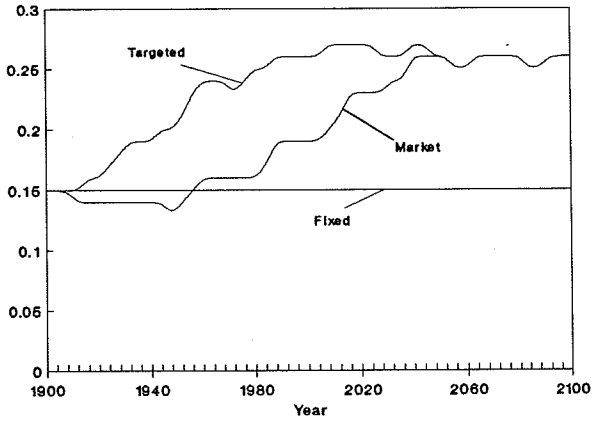

Figure 12. Capital intensity

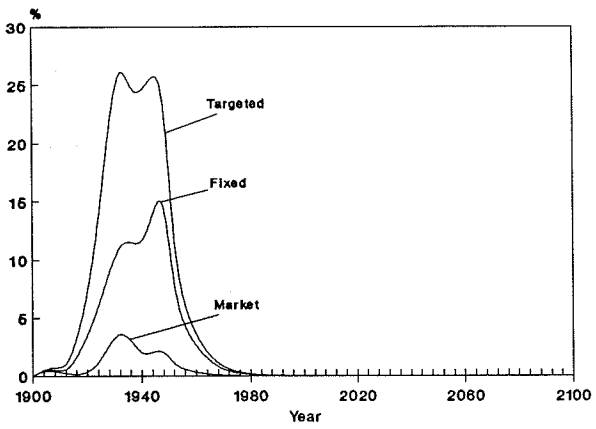

Figure 13. Debt-service ratio

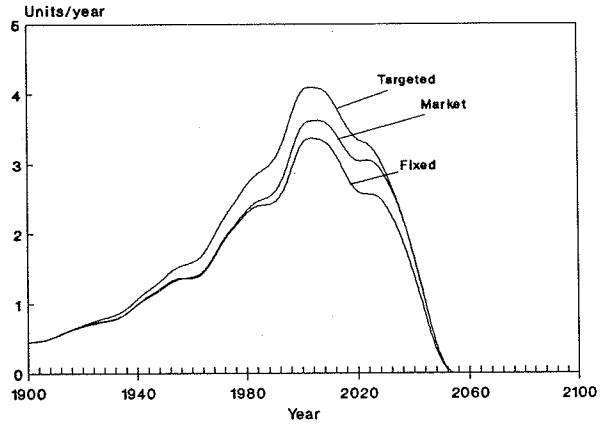

Figure 14. Government deficit

The study shows that the economy in which a sustainable increase in capital-labor ratio (capital intensity) can be maintained in the long run, can be expected to improve national productivity considerably and continuously. When in the short run the increase in capital intensity can be also adjusted with the existing labor availability, through developing policies to establish more efficient labor market, the issue of the increase in unemployment rate due to the functioning of the capital intensive technology is weak.

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