DISCUSSION PAPER

Report No.: UDD 22

PUBLIC POLICY, URBANIZATION AND DEVELOPMENT:
AN INTRODUCTION TO
A COMPUTABLE GENERAL EQUILIBRIUM SIMULATION MODEL
OF THE INDIAN ECONOMY

by

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June, 1983

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The views presented here are those of the authors, and they should not be interpreted as reflecting those of the World Bank.
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Research Project 672-64
Indian Urban Development Research Project

The authors are grateful to Perry Beider for computer programming and to Koichi Nakajima for research aid. Both have provided excellent assistance.
ABSTRACT

This paper presents an outline of the BMW (Becker-Mills-Williamson) model which is being developed to simulate urban development in India in the context of general development of the national economy. The technique used is that of computable general equilibrium (CGE) which has been developed over the past decade. The model is aimed at providing a consistent explanation of India's city growth experience and, at the same time, undertaking counterfactual public policy experiments.

The BMW model is largely a refined and India-specific successor to Allen C. Kelley and Jeffrey G. Williamson's dynamic eight-sector urbanization model of a "representative developing country". Both models contain many common facets distinct from other CGE models, including detailed presentations of housing and service sectors, along with similar production, factor and demand structure. Among the differences, the most striking difference between them is BMW's more detailed government sector. BMW distinguishes urban public services from other capital-intensive urban services, and separates rural public services from rural services and other non-agricultural activities. Government spending allocation is also more complex in BMW.

The model is able to undertake public policy experiments with respect to (1) public investment allocation policy, (2) public expenditure policy, (3) public revenue allocation policy, (4) urban land and squatter policy, (5) wage policy, (6) education policy, (7) fiscal policy, and others.
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Introduction

Recent trends in Indian development reveal only moderate growth, well below the Asian average. Despite a major rise in the net savings rate during the past three decades, the economy grew so slowly that per capita NNP in constant prices rose only 50 percent. Urbanization rates have also fallen below that experienced by other countries, although the urban share of the population has risen steadily. Despite the increasingly urban character of India's population, however, the share in NNP of traditionally urban sectors has not risen greatly in the postwar era.

Our goal in constructing the "BMW" (Becker-Mills-Williamson) simulation model is to provide a consistent explanation of India's city growth experience. Indian policy-makers clearly view their city growth with alarm, particularly in the absence of either rapid output growth or large shifts in the economy's structure. Yet explanations of urban growth have been incomplete in the sense that many factors believed to affect urbanization have received limited econometric study, and have been completely omitted from economy-wide general equilibrium studies.

Given the enormous accumulation of third world experience with computable general equilibrium models (CGEs) over the past decade, the time is ripe to consider a similar application to India. Previous models of India have either concentrated on planning and inter-industry consistency, or have been highly simplified structures. We expand these models to capture critical parts of India's complexity, placing particular emphasis on its large and varied tertiary sector.

In that spirit, BMW offers a dynamic, general equilibrium simulation model of the Indian economy. It is oriented in particular to analyzing those variables perceived to strongly influence urbanization
that have been omitted from previous models of India and other
countries. The model's framework is predominantly neoclassical:
households maximize utility, producers maximize profits. Optimizing
behavior, however, faces constraints: households have limited endowments
and incur moving costs when they migrate. Producers must bid
competitively for factors in markets that, in the case of capital, are
not perfectly competitive across the entire economy. We recognize that
the Indian capital market is not fully developed, and thus treat it as being
divided into several isolated fragments. Within these submarkets,
though, behavior remains competitive.

There are several areas in which a medium-scale simulation model
of India, and in particular of Indian urban growth, will fruitfully
differ in structure from previous CGE simulation models of
underdeveloped countries. Most of these differences involve the role of
government in a poor, mixed enterprise economy. Many dynamic CGE's
minimize government's role, assuming that its investment behavior is
similar to that of the private sector. But the BMW model explicitly
confronts the effects of government investment allocation. Government
investment behavior is distinct from private investment activity, and
need not be allocated to equalize returns across sectors. Furthermore,
previous models typically ignore mixed enterprise activity, allowing
governments only to save or consume out of revenue from taxes and
foreign aid. BMW does not ignore central government relationships with
public enterprises in its fiscal system. In addition, the BMW model
also recognizes the critical role of public services as an intermediate
input, and thus provides a direct role for government in the production
process. As in reality, provision of these services is biased towards urban industries and wealthy households.

The explanation we provide of India's urbanization and development must be consistent with the essential institutional characteristics of the private sector of the economy as well. These characteristics include highly fragmented capital markets along with a "partially segmented" labor market. Earnings differ by skill classes in BMW, and since labor of various skills are not close substitutes, skilled and unskilled labor markets are quite distinct from one another. Yet, unskilled and skilled labor are both present in traditional and rural as well as "modern" and urban sectors. Furthermore, neither capital nor rental income accrue exclusively to one class, as many models assume. These characteristics, combined with the expanded role of government, serve to delineate the BMW model sharply from other computable general equilibrium models of less developed countries.

1. Overview of the Model

Given our goal, coupled with the need to capture the essential characteristics of the Indian economy, a multi-sector, multi-factor, multi-region simulation model is required. But how large should it be to ensure that counterfactual policy analysis is relevant to help guide policymakers? We suppress much regional, household and production detail that seems unlikely to influence greatly the overall determinants of city growth, including government policy. Much institutional detail is omitted on the same grounds. In making simplifications, we reduce data requirements and limit the extent to which simulation exercises appear to emerge from "black boxes." With a moderate-sized model we are
thus able to employ sensitivity analysis to gain crucial insight into those forces driving India's city growth.

In view of our desire to understand Indian city growth while minimizing complexity, we have chosen to build a ten sector model with four factors of production. The model includes the usual agriculture and manufacturing sectors, which absorb the majority of the labor force. As with the Kelley-Williamson CGE model of a "representative developing country," \(^1\) BMW admits both rural and urban informal service sectors, along with a capital-intensive "formal sector" service sector. Corresponding to each service sector is a housing sector, again following Kelley-Williamson. Finally, the model distinguishes urban public services (power, other utilities, some transport) and rural public services (largely public irrigation) from other services. Although these public sectors are not large employers, they do consume large portions of the nation's capital stock and provide essential intermediate goods to other sectors. The four factors in BMW are capital, skilled labor, unskilled labor, and land. Skilled and unskilled labor both appear in all non-housing sectors. BMW is thus able to distinguish between different types of rural-urban migration, and in contrast with other models, is able to capture the relatively high rural to urban migration propensity for skilled labor.

Most critical variables are determined endogenously in BMW: output, factor employment, factor prices, and product prices. The economy is essentially neoclassical subject to constraints imposed by market fragmentation. Agents are all constrained welfare maximizers. Welfare and profit maximization generates a static equilibrium in which returns are maximized, subject to mobility constraints.
Markets are predominantly competitive in BMW. Uniform prices received by producers prevail in product markets, although location-specific sales taxes are present. Real household wage incomes are equated to clear labor markets. Only in the land and capital markets does there appear to be a sizable degree of fragmentation. While the urban rental market operates to allocate land between high quality "pucca" and low quality housing, rental rates on farmland and urban land on the fringes of cities are not explicitly equated. BMW instead exogenously specifies the proportion of land stock devoted to urban uses. In the capital market, government investment funds are allocated independently of private savings in a manner that does not equate rates of return. We further assume that a portion of capital income is automatically reinvested in the generating sector for replacement of depreciated stock. Finally, different sectors in BMW have access to different savings pools. This differentiation effectively divides the capital market into three components: a rural sector, an urban informal sector, and an urban modern sector. Within each of these divisions, however, return differentials are minimized by private investors.

The model distinguishes between tradeable and nontradeable goods, and some consumption is therefore location-specific. World markets and government trade policy determine prices of energy inputs, while they interact with domestic supply and demand to determine domestic prices of agricultural outputs and manufactures. All other prices are fully endogenous.

Nontradeable, immobile goods include services and housing. The economy is divided spatially into rural and urban production and
households. While rural and urban households consume similar goods, prices they face need not be identical. In the case of traded goods, location-specific taxes may differentiate prices. Non-traded services experience differing production processes and factor costs. In particular, urban land scarcity generates an urban price index greater than the rural price index. Such cost-of-living differentials do exist throughout the third world, and are viewed here as resulting from higher urban food prices, congestion and higher rents.

The BMW model explicitly confronts the issue of government expenditure allocation. Government has the option of consuming goods and services (for army and bureaucracy), providing transfers, public services or investment funds to government enterprises. This set of options is similar to that actually faced by the Indian public sector. The innovative aspect here lies in the inclusion of public services, which comprise the major components of infrastructure: roads, some transport, power, water, and some health services. We treat these as private goods used as intermediate products in the production of final goods. Government produces these goods itself, and may subsidize them by providing an amount of capital for their production that generates a rate of return below that found in other sectors.

In the BMW model of India, then, urban growth may result from a variety of forces, which may or may not be self-limiting. Rising land rents due to urban land scarcity increase relative factor costs and discourage growth of urban production. However, growth of government may have the reverse effect. Government purchases predominantly urban goods and services, while its public service subsidy is concentrated in the urban sector. Such a subsidy lowers the cost of living and raises
production in urban areas, while government's consumption patterns increase demand for urban products.

Government expenditures are determined in the basic BMW model by estimates of fiscal behavior from regression analysis. For purposes of counterfactual policy simulation, however, government may follow different behavioral rules. A government behavior modification of particular interest involves minimizing return differentials on its various investments. Counterfactual and actual growth paths may then be compared. Government revenue is also endogenously determined in the model, although tax rates are fixed. In addition to foreign aid, government earns capital income from its productive enterprises and public services; it also receives revenue from product, capital and skilled labor taxes.

As constructed, the model permits enhancement of labor productivity in many ways. Capital accumulation is an endogenous process that raises labor productivity. New capital can be allocated directly to industries producing final goods and services, or it can be used by the government to provide intermediate public services. Inputs per worker increase in either case, so that productivity rises. Although the costs are not directly modelled, human capital accumulation through apprenticeships and education also transforms annually a proportion of unskilled workers into skilled workers. The BMW model further assumes exogenous rates of capital and labor augmenting technological progress, with these rates potentially differing across sectors.

Asset formation is determined by aggregate savings in BMW. Saving, though, is not a simple fraction of income. Household saving
depends on saving propensities and on the distribution of income, and combines with corporate savings, government savings and foreign aid to form a potential investment pool. However, some of this potential investment pool that has been accumulated will be "diverted" into uses that are not directly productive. Household savings are used to invest in housing as well as in private industry. Thus, the housing sector absorbs part of the investment pool both directly and indirectly through consumption of public services.

The moderate-sized model just described appears to adequately portray the structure of the Indian economy. Government receives detailed attention. The service sectors permit BMW to distinguish modern and informal urban sectors, as well as to explore the importance of rural non-agricultural employment. Recent evidence suggests that earlier neglect of the rural non-agricultural sector has been an undesirable oversight. The housing and public service sectors are both essential for understanding the nature and extent of the implicit urban bias in government policy; the housing sector is also important in capturing urban/rural cost of living differentials.

The sectoral choice employed by BMW thus divides the economy into sectors that differ by output type, and at the same time permits locational and formal/informal sector distinctions useful for performing policy experiments aimed at particular parts of the economy (particularly the urban, formal sector). The division of labor into skilled and unskilled labor permits us to model the relative complementary between skilled labor and capital that seems likely to underlie the rapid growth of the class of skilled urban workers. This
division, along with generation of returns to land and capital, also enable the model to analyze factor income distribution trends.

The BMW model is to a large extent "India specific." Yet its structure may also describe other mixed economies with large public sectors and fairly integrated labor markets. For all these economies, the model is designed to offer an explanation of the basic phenomena accompanying gradual development. The model generates growth and urbanization given factor accumulation and technological progress; it analyzes the spatial effects of these catalysts on production and consumption patterns, on factor incomes, and on future rates of accumulation themselves. The model also describes the impact of development on city in-migration and on the relative cost of living differential. We believe that there is substantial similarity in the forces driving these trends in India and in some other LDCs. Several North African, Middle Eastern and South Asian economies maintain structural characteristics in varying degrees compatible with the India model described above. In sum, the conclusions derived from the simulation exercises may also have relevance for countries other than India.

2. The BMW Model of Indian Urbanization and Other CGE Models

While BMW differs in significant respects from earlier CGEs, it has evolved directly from a few of these models. The BMW model is largely a refined and India-specific successor to Allen C. Kelley and Jeffrey G. Williamson's dynamic eight-sector urbanization model of a "representative developing country." Both models contain many common facets distinct from other CGE models, including detailed presentations of housing and service sectors, along with similar production, factor
and demand structures. The BMW model is also related to Rakesh Mohan's earlier three-sector CGE model of India. Mohan concentrates on introducing a single service sector to accompany agriculture and industry. BMW further disaggregates the large Indian service sector, and presents more explicit descriptions of government's role and Indian factor market imperfections.

Both Kelley-Williamson ("KW") and BMW enjoy several characteristics in common with other "state of the art" CGE models. These include nested constant elasticity of substitution production functions, extended linear expenditure systems of consumer demands, substitution in the use of intermediate inputs, and factor-specific technological progress. As with other recent CGE models, KW and BMW present far more elaborate production and consumption systems, labor demands and capital allocation structures than earlier models.

Most importantly, the sectoral composition of the two models offers striking similarities. Both models contain a rich description of the tertiary sector, combined with simpler representations of the primary and secondary sectors. Both models are distinct from other development CGE models in identifying rural non-agricultural industries. Finally, the models share a concern for the provision of housing, including detailed analysis of industries ignored by other models.

Given these similarities, one may ask whether a plausible model of India would merely involve making a few minor changes and adjusting parameter values in the KW prototype model. We felt this was not possible, although a part of our research will involve the comparison of simulation results from BMW with those from KW using Indian parameters. Our efforts to describe the critical features of the Indian economy
induced us to employ several substantive changes to KW, along with a variety of minor ones.

The most striking difference between BMW and KW is the former's more detailed government sector. BMW distinguishes urban public services from other capital-intensive urban services, and separates rural public services from rural services and other non-agricultural activities. Identification of these sectors causes BMW to have ten productive sectors, compared to eight in KW. Creation of public service sectors enables the Indian government to directly alter production conditions in various private industries, since public services are used exclusively as intermediate inputs by the other sectors.

Government spending allocation is also more complex in BMW. In addition to allocating part of its budget to capital investments in rural and urban public services, the government budget funds capital formation by public enterprises as well as government recurrent expenditures. Since BMW models public service expenditures as responding indirectly to household demands, any crowding out effects on government funds available for directly productive investment due to rapid urbanization will be captured. Government tax revenues are also fully endogenous in BMW; they are not in KW.

A second sphere of distinctions involves the extent to which factor markets are competitive. Real earnings for skilled and unskilled workers do not vary by sector in BMW, nor do they vary by rural or urban location. By contrast, unskilled wages in urban industries exceed those in rural sectors in KW. KW also restricts skilled labor to urban industries; BMW does not impose this restriction. Policies that stretch
urban wage differentials will thus stretch rural labor income
differentials as well in BMW.

While Indian labor markets appear to be described well by a
competitive paradigm within each skill level, capital markets are
modelled as being highly fragmented. This fragmentation captures one of
the essential stylized facts of India's economic structure. BMW does
not integrate formal sector urban, informal sector urban and rural
private capital markets. Private and public investment decisions are
also largely segregated in BMW. By contrast, investment allocation
demonstrates much less fragmentation in KW. Government savings are also
combined with private savings in the KW capital market, where they seek
the highest rate of return.

Additional complexities have been added to BMW to make it more
closely resemble the Indian economy. BMW has a more complete
input/output matrix than does KW. Production function forms are also
less restrictive in BMW: all non-housing service sectors have nested CES
production functions, while housing service sectors employ a
Cobb-Douglas technology. BMW distributes capital income to all
household classes, while KW limits its distribution to one "capitalist"
class. This more elaborate specification in BMW is necessitated by the
model's fragmented capital market structure; it also contributes
additional realism to the model.

Further, BMW has chosen to diverge from KW by treating domestic
and foreign agricultural goods and manufactures as imperfect substitutes
(see footnote 2). This specification enables us to determine gross
trade flows as well as net flows, and also makes endogenous both tax
receipts and all producer prices.
On the other hand, BMW does not employ the sophisticated labor training story contained in KW. We excluded this section of KW from BMW largely to limit the model's complexity. We were also unconvinced that a model of skilled labor creation based on profit-maximizing investments was appropriate for India. Determination of the skilled labor supply appears to be quite complex in India's case, and is best left exogenously specified in a CGE model. Furthermore, exogenous determination of the growth of the skilled labor force enables us to avoid choosing between neoclassical and "segmentation" theories of the labor market. BMW's construction is consistent with a labor market model containing non-competing components in which individual mobility between subgroups is constrained, while the markets are competitive within each subgroup. BMW is also consistent with more "perfectly competitive" theories of labor market behavior.

It is apparent that BMW differs considerably even from its parent model, as well as from those more distantly related. In particular, it differs strikingly from previous models of India. With the exceptions of Mohan's three-sector model and the highly aggregated two-sector model of Kripalani and Tolley [1981], India has been described by several constant coefficient inter-industry models (for example, S. Mohammed [1981], A. S. Manne and S. Rudra [1965] and I. SaKong and G. V. L. Naresimiam [1974]) or short run disequilibrium macroeconomic models (for example, those of J. Rattso, H. Sarkar and L. Taylor [1981] and D. K. Srivastava [1981]). Given our detailed consideration of services and the role of government, coupled with our high degrees of aggregation in manufacturing and agriculture, and our emphasis on factor and product
substitutability in place of short run constraints and fixed coefficients, BMW has little in common with these other models.

BMW thus provides a contribution to the analysis of long term forces underlying Indian urbanization. It builds on the KW model, adding many components that add realism and adjust the model to the stylized facts of Indian development. The resulting product is one that differs from previous models most critically in its emphasis on the service sectors, on the varied roles of government, on the role of skilled labor in the migration process, and on a complex form of capital market imperfections.

While previous CGE models have neglected public services, we view the separate consideration of these sectors to be an important addition, particularly in the case of India. First, it should be noted that these sectors receive a large fraction of India's investment. By 1960, gross public investment absorbed roughly six to seven percent of net national income (Healey [1965]), while public net investment was decomposed in the following manner:

<table>
<thead>
<tr>
<th>TABLE 1: ALLOCATION OF PUBLIC NET INVESTMENT IN INDIA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Irrigation and Agriculture</td>
</tr>
<tr>
<td>Power</td>
</tr>
<tr>
<td>Transport &amp; Communications</td>
</tr>
<tr>
<td>Industry &amp; Mining</td>
</tr>
<tr>
<td>Public Buildings and Other</td>
</tr>
</tbody>
</table>

Government investment is thus a critical component in national income; it also accounts for about 60% of total investment. Its destination obviously differs considerably from those of private sector investments. Moreover, the characteristics of the locations of public sector investments also differ dramatically from the characteristics of other locations. For example, Wolf [1978] reports capital/output ratios for 1961 of 16.8 in electricity, 12.2 in railways, 6.5 in other transport, 3.7 in communications and 4.8 in public administration, compared to 3.0 in manufacturing and a national average of 1.94. Our own division appears in Table 2. Even allowing for BMW's high degree of aggregation, rural and, especially, urban public services are far more capital intensive than the remaining sectors. Output per worker, however, is not high relative to the other modern sectors (manufacturing and modern services). Consequently, our concern with distinguishing the role of public services in the investment process seems to be well founded.

3. Constructing the BMW Model for Simulation Experiments

Once the equations have been stated, the model remains to be programmed. The programming task has two major components: generating a consistent data set, and then running simulation experiments. Different programs are required for the two parts.

As stated, the BMW model contains a large number of parameters, exogenous and endogenous variables. Running simulation experiments involves solving for the endogenous variables, given specific values for the exogenous variables and function parameters. Our initial task is therefore to derive a set of exogenous variables and parameters for India. Our task would be greatly simplified if data on
<table>
<thead>
<tr>
<th>Sector</th>
<th>Capital Stock (Rs. Crores)</th>
<th>Net Output (Rs. Crores)</th>
<th>Employment (million)</th>
<th>Capital/Output (Rs.)</th>
<th>Labor Productivity (Output/Worker) (Rs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: agriculture</td>
<td>9,700</td>
<td>6,540</td>
<td>134.000</td>
<td>1.483</td>
<td>488</td>
</tr>
<tr>
<td></td>
<td>(36.4)</td>
<td>(47.5)</td>
<td>(71.2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RS: rural services, rural manufacturing</td>
<td>1,880</td>
<td>1,325</td>
<td>26.100</td>
<td>1.419</td>
<td>508</td>
</tr>
<tr>
<td></td>
<td>(7.1)</td>
<td>(9.6)</td>
<td>(13.9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>US: urban informal sector services</td>
<td>1,977</td>
<td>808</td>
<td>13.132</td>
<td>2.447</td>
<td>615</td>
</tr>
<tr>
<td></td>
<td>(7.4)</td>
<td>(5.9)</td>
<td>(7.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M: urban manufacturing</td>
<td>4,862</td>
<td>2,227</td>
<td>8.146</td>
<td>2.183</td>
<td>2,734</td>
</tr>
<tr>
<td></td>
<td>(18.2)</td>
<td>(16.2)</td>
<td>(4.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>KS: urban capital-intensive services,</td>
<td>2,310</td>
<td>1,897</td>
<td>2.949</td>
<td>1.218</td>
<td>6,433</td>
</tr>
<tr>
<td>including public administration</td>
<td>(8.7)</td>
<td>(13.8)</td>
<td>(1.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PSR: rural public services</td>
<td>1,526</td>
<td>360</td>
<td>1.900</td>
<td>4.239</td>
<td>1,894</td>
</tr>
<tr>
<td>(including rural public administration)</td>
<td>(5.7)</td>
<td>(2.6)</td>
<td>(1.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PSU: urban public services</td>
<td>4,399</td>
<td>617</td>
<td>2.073</td>
<td>7.130</td>
<td>2,976</td>
</tr>
<tr>
<td></td>
<td>(16.5)</td>
<td>(4.5)</td>
<td>(1.1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total, Non-housing</td>
<td>26,654</td>
<td>13,774</td>
<td>188.3</td>
<td>1.935</td>
<td>731</td>
</tr>
</tbody>
</table>

**SOURCE:** Nakajima, Becker, Mills and Williamson [in progress].

**NOTE:** The anomalously high US sector capital/output ratio largely reflects the presence of retail inventories held by small traders; it also reflects the scarcity of skilled labor in that sector. By contrast, the high labor productivity and low capital/output ratio in the KS sector reflect that sector's extreme skilled-labor intensity. See Nakajima et al. [in progress].
all these variables and parameters were available (preferably collected in a consistent fashion) for the same year.

Not surprisingly, such a data set does not exist, and we must therefore create it. To do this, we choose a "benchmark" year in which we assume the model perfectly describes India. In this exercise we compel the model to simulate an outcome that, given the benchmark year values of parameters and exogenous variables, will replicate endogenous variable data for that year. That is, we force our model's solution to replicate the national accounts and labor force data for the benchmark year. We have chosen 1960 to be the base year for BMW.

We then use the benchmark replicability restriction to determine values for parameters and exogenous variables that are not available from official Indian sources and from econometric studies. The initial conditions (IC) program uses available data from 1960 for both exogenous and endogenous variables to solve for unknown exogenous variables and parameters. The IC program thus solves the BMW model for 1960, but the solution variables, endogenous in this case, are parameters that will be treated as exogenous constants thereafter. The data set containing these "residually determined" parameters and exogenous variable estimates then guarantees that the solution to the BMW model for the properly endogenous variables will reproduce their observed 1960 values.

Once the base year exogenous variables and parameters are known, they can be systematically revised for succeeding time periods. For example, 1961 capital stock values will equal base year (1960) capital stock values, plus net investment during 1960, where net investment is determined endogenously. Other exogenous variables, such as population, are assumed to grow at constant rates. As discussed in section 4,
policy experiments will also be described by altering particular exogenous variables and parameter values. Exogenous variables with historic data available will also vary annually to reflect actual trends. For example, we will adjust the import prices of oil, manufactures and food to reflect exogenous changes in world prices.

Finally, there is a small set of parameter values (essentially productivity augmentation parameters) not restricted by the "static" IC program. We determine these values endogenously in a dynamic initial condition (DIC) program conceptually similar to the static IC program. We assume that India enjoyed a "benchmark equilibrium growth era" during the early 1960s. Given the static parameters and exogenous variables determined by IC solutions or taken from official sources and econometric estimates, a second computer program solves the BMW model for its endogenous variables as functions of the dynamic parameter values. The DIC program then determines the solution values to the dynamic parameters by minimizing a loss function based on the difference between the model's solutions to key endogenous macroeconomic variables and those actually observed for India in the early 1960s.

Once a consistent data set has been derived, we are ready to run the "computable equilibrium model" (CEM) program. CEM takes values of exogenous variables and parameters from Indian statistical sources, from econometric studies, and from output of the IC and DIC programs. Given these data and the structure of the Indian economy portrayed by the BMW model, it determines a solution vector of endogenous variables. Endogenous variables include factor allocation by sector, production, investment, trade flows, fiscal variables, factor rentals, household demands, product prices and rural-urban migration flows.
The manner in which we solve for the unknown parameter and exogenous variable values in the IC program using normally endogenous variables as inputs ensures that the CEM program will successfully "replicate" India for 1960. For later years, however, there is no guarantee that the CEM solution will provide endogenous variable values identical to those found in India's statistical accounts.

The raw data employed to construct the consistent data set via the IC and DIC programs come from a variety of sources, as detailed in Nakajima et al. [in progress]. We employ Indian national accounts data to determine aggregate outputs and trade. Excellent detailed estimates of capital stocks and interindustry flows are available for India, as is a recent survey of Indian housing by Devendra Gupta. Various studies by the National Council on Applied Economic Research (NCAER) and the National Sample Survey (NSS) provided us with labor force and other data.

Although considerable effort has been devoted to obtaining a consistent data set of high quality, numerous problems remain. Estimates from different sources frequently conflict: for example, there are several alternate capital stock figures. Secondly, we are frequently forced to make imputations when sectoral and skill classifications in data sources differ from those we distinguish in BMW. While we strive to base our imputations on assumptions consistent with available statistical studies, a degree of arbitrariness invariably remains.

Given our need to choose among conflicting data estimates and impose various assumptions, a critical part of our study deals with exogenous variable and parameter sensitivity analysis. This sensitivity
analysis has two components. First, we need to examine alternative imputation assumptions to determine their impact on data read into the IC and DIC models. We then assess the sensitivity of our model to these assumptions by comparing the resulting new parameter and exogenous variable values determined by the initial conditions models to the original values. Such sensitivity analysis indicates areas in which improved data series or econometric research would be valuable.

The first set of sensitivity analyses also provides the starting point for the second component. In addition, we need to assess the impact on the simulation exercise of those parameters particularly sensitive to differing assumptions in the raw data. That is, we need to determine how the simulated time series of India provided by successive runs of the CEM program will differ with varying data assumptions. It is necessary also to test the model's sensitivity to parameters taken directly from the econometric literature and not solved for in the initial conditions models. Most critical is our examination of the solution's sensitivity to various assumptions on the elasticities of substitution in different sectors. Since in a CES function elasticities of substitution and factor-augmenting technological change parameters combine to determine the extent a particular factor-using bias exists in a sector, such sensitivity analysis will provide insight into the importance of changes in labor- or capital-using biases in production technology.

Sensitivity analysis of the importance of critical parameter values such as the elasticity of substitution provides an indication of the model's robustness. If solutions to the CEM vary wildly with slight changes in parameter values well within their range of plausible values,
it is difficult to accept the model's results with confidence. In such a case, it would appear that the BMW model's complexity generates data requirements in excess of current availability. Such problems also indicate that the implicit assumptions of simpler models may be "building in" results to an extent greater than previously realized. It is also possible that sensitivity towards some parameters will be inconsequential; in such cases we need to examine whether a less complex model specification would be acceptable. In general, it is hoped that moderate sensitivity to parameter shifts will dominate, with greatest sensitivity exhibited for those parameters and exogenous variables generated by the most reliable data.

4. The BMW Model: Uses, Limitations and Extensions

Once properties of the model have been explored through sensitivity analysis, we must examine its ability to explain India's economic experience in recent decades. Given changes in exogenous variables such as import prices (especially petroleum) and tax rates, we must determine how accurately the variables solved for endogenously in the BMW simulation replicate observed variables. In particular, we must ascertain whether the model successfully generates urbanization rates and sectoral output shares similar to those actually observed in India during the period 1960-1980.

Having compared the simulated patterns of major variables to those recorded in the Indian census and national accounts, we may use the model to explain the sources of the observed shifts. In particular, we can perform counterfactual experiments to determine the impact of such factors as the OPEC price shocks and non-neutral biases in productivity gains on the rate of urbanization and on GNP composition.
Beyond replicating and "explaining" Indian history, the BMW model can be used to forecast future trends in Indian urbanization. We may compare various scenarios to a base of comparison simulation exercise in which demand, technological and demographic parameters, plus government policy exogenous variables are assumed to maintain their 1980 values for the entire forecasting period. Alternative scenarios involve declining fertility rates and shifts in the factor biases contained in technological advances. The largest set of counterfactual experiments, however, involve shifts in government policy.

Given the model's detailed public sector, the opportunities for conducting counterfactual public policy experiments are substantial. Major issues include:

1. **Public investment allocation policy.** In particular, we seek to examine the impact on urbanization and GNP growth of a policy that provides for public investment in the sectors of highest returns. Such a policy would represent a substantial move towards capital market integration.

2. **Public expenditure policy.** Will a rising share of government expenditures in national income generate higher real growth for the Indian economy? While a larger tax bite reduces the private investible surplus, it will lead to greater public savings. Such a reallocation can have positive growth effects if public savings rates are sufficiently great, thus overcoming the lower efficiency of public investment.
iii. Public revenue allocation policies. To what extent does increased urbanization reflect a pro-urban bias in public service provision? How powerful an impact does increased government savings have on urbanization?

iv. Government policy towards squatter settlements, and interference in urban land markets. Indian governments have often both taken steps against squatters and interfered extensively in urban land markets. Many specific actions can be captured in BMW by altering particular exogenous variables that determine urban public services allocation and housing consumption.

v. Wage policy. Will the presence of a minimum wage in urban, formal sector, unskilled labor employment substantially reduce urban growth rates? As BMW is a full employment model with no "Harris-Todaro" effects, the impact effect of a minimum wage will be to decrease the unskilled formal sector labor force. If this decline is moderate and total labor incomes rise, however, increased demand for labor-intensive informal sector urban services may substantially mitigate the urban population decline.

vi. Education policy. How rapidly will India's cities grow in response to increases in the stock of skilled workers? What will be the impact of a rise in the skilled portion of the labor force on sectoral shares in GNP?

vii. Fiscal policies. A series of counterfactual simulations can be used to determine which taxes have the largest positive (and negative) impacts on urbanization and economic growth. In particular, we can examine sets of taxes and subsidies that discourage rapid urbanization but generate high levels of capital
formation. Income distribution effects of various fiscal packages can also be examined.

This list of policy issues to be addressed by counterfactual simulations is by no means exhaustive. Moreover, the initial impact effects of policies prior to capital stock adjustments may differ both in sign and in order of magnitude from long run effects.

It is also apparent that the questions raised by the forecasts and counterfactual experiments are directly relevant to the choices faced by Indian policymakers today. Much fiscal and development policy is currently formulated with regard only to partial equilibrium impacts. Since many policies have potentially far-reaching effects, it is important to examine the Indian economy's total response to policy changes.

While the model we have constructed is equipped to analyze a broad set of issues, there are some areas which the model is not designed to address. Foremost among these is the analysis of short run disequilibrium economic behavior. BMW is essentially a long term equilibrium model that does not concentrate on the adjustment process. We concentrate instead on issues involving urban and economic growth, capital and skills accumulation, productivity and demographic changes, and long term government policy shifts. A second important area not directly addressed by the model concerns shifts in the distribution of personal (as opposed to factor) income. Investigation of personal income distribution trends requires knowledge of inter-class mobility; at present, the data do not permit us to derive the appropriate transition probability matrices.
It is evident that a detailed study of the Indian economy through the BMW model will be quite lengthy. However, the model as presented is also amenable to various extensions, each of which may offer additional insight into the Indian urbanization process. Perhaps the most useful extension involves developing the model for a particular region within India and linking it via a simple trade and factor flow model to a similar model for the rest of India. It would be especially useful to isolate relatively dynamic and stagnant regions from the remainder of the Indian economy.

Models that complement BMW's general equilibrium framework could also be incorporated. For example, it might be possible to link our model to a more detailed linear programming model of the manufacturing sector, or to a more detailed model of Indian agriculture. BMW could also be linked with a model of city size distribution. Alternatively, the model might be applied to another economy structurally similar to India. In view of the wide range of simulation tasks currently awaiting the model, however, these extensions remain distant possibilities.
Footnotes


2 In BMW, agricultural and manufactured goods are produced domestically as well as being imported (and exported). While domestic producers' prices are highly influenced by world prices, internal prices are not completely determined by international price fluctuations. While imports and domestic products are virtually identical in the high level of aggregation offered by BMW, further disaggregation suggests that there are not domestically produced items which substitute perfectly for all imports. Institutional restrictions, information gaps and adjustment lags also deter free entry of imports. To prevent the domestic and imported components of manufactured and agricultural goods from being inappropriately modelled as perfect substitutes, and to restrict the possibility of implausibly large annual trade pattern shifts, we follow a state-of-the-art technique first proposed by Armington ("A Theory of Demand for Products Distinguished by Place of Production," IMF Staff Papers, vol. 16, 1969, pp. 159-178). We create "composite" manufactured (agricultural) goods. These composite goods then employ imported and domestic manufactures (agricultural products) as the sole inputs, and specify a high but finite elasticity of substitution between them.


8For a brief survey of these theories, see Lewis [1979].

9To some extent, as we explain in our following paper, the two competing theories can be tested in our model to see which more successfully explains Indian economic history.


12. An especially critical problem involves dealing with weather-related variability in agricultural production. As our following paper explains, we incorporate a weather-related factor-neutral augmentation parameter in agriculture to more closely approximate Indian economic history.

References


