Simulating Flows of Labor in the Middle East and North Africa

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WORLD BANK STAFF WORKING PAPERS
Number 736
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The World Bank
Washington, D.C., U.S.A.
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Library of Congress Cataloging-in-Publication Data
Abstract

This paper is part of a continuing effort by the World Bank to analyze labor migration in the Middle East and North Africa. It sets forth an approach to simulating the flows of labor between nineteen countries in this region. The methodology, however, could certainly have wider application in other regions of the world.

The proposed systemic approach is similar in many ways to the well-known RAS approach for updating biproportional matrices. It differs from the RAS approach in that it is capable of greater interpretability and manipulability for policy purposes. The systemic approach also sets forth the possibility of defining certain parameters or movements in a behavioral fashion, relating economic variables to the modeling effort. In so doing, this modeling effort represents a distinct improvement over the previous models developed under the international labor migration in Middle East and North Africa research projects in the Bank (see Staff Working Papers 587-590), which were primarily of an accounting nature.

The allocation mechanism described in this paper is soluble. Nevertheless, it is not clear at present whether it necessarily has a unique solution, and further proof may be required in this area. Its applicability should not be decreased, however, since many well-known simulation models do not necessarily have unique solutions.

The paper also suggests other avenues for further study.
Preface

The authors wish to record their deep appreciation for all those who have supported this research work during many months of contentious intellectual discussion. First and foremost, Robert Picciotto, Director of Projects, EMENA, whose unflagging support for further improvements in the migration research design was deeply appreciated. Messrs. Vinod Dubey, then Chief Economist, EMENA, and Jack Duloy, Research Advisor, were also actively involved in this pursuit of a better allocation mechanism. Per Ljung, then Senior Economist in the EMENA Projects Department, reviewed and, on several occasions, made substantive contributions, to our thinking. Messrs. John J. Stewart, Assistant Director, Roy Prosser, Division Chief, Education, and Abdallah El Maroufi, Division Chief, TASS, all of the EMENA Projects Department, also supported this research.

Sincere intellectual debt is owed to Richard Ekaus and Tim Kehoe of MIT and Messrs. Arne Drud of DRD, as well as Benoit Morin and Noboru Kawai of the Western Africa Programs II Department. Mr. Mohsen Youssef, consultant to the EMENA Projects Department, also participated in this endeavor.

To all of the above, we extend our thanks and appreciation. Any errors of omission or commission that are found in this paper are purely our own.
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I. BACKGROUND

The World Bank's currently operating International Labor Migration Model, called the Compound Model, has been described in detail in Bank Staff Working Papers 587 and 590. The following discussion therefore focuses on the intended improvements in the Model. Specifically, the focus of the discussion is on the allocation mechanism that can be used when updating/forecasting the migration flow matrix at the heart of the Model.

The data base consists of a detailed matrix of movements of persons among countries of the Middle East and North Africa regions, with classifications by occupations and by industries, which have been estimated for some previous (base) period. The quantitative, empirical data describing the social, political and economic environment which has contributed to these flows are limited. The labor market is known to be segmented and imperfect.

Furthermore, there is limited information on relative wages, savings, consumer price indices and other relevant variables which would ordinarily be used to generate a traditional economic formulation to model such migration, even if

1/ This discussion draws heavily on the ideas of many, especially Bob Li of the World Bank and of Professors R.S. Ekaus and T. Kehoe of MIT, and Mohsen Youssef, World Bank Consultant. Nevertheless, any errors or shortcomings in the material presented here are our own.


it were appropriate to do so. Also, it is expected that it would not be possible to carry out detailed field work and econometric studies which could be used to predict migration flows among countries in response to economic and other social variables. However, there is sufficient intimacy between Bank staff and the situation in these countries to produce very sound judgements as to the likely actual and potential migration flows in the form of lower and upper limits on particular flows, desired ratios and migrants from different countries, probable turnover coefficients in migrant populations, etc., for different countries.

It will help in discussing the problems of updating to be able to refer to a particular matrix. The one which follows is intended to serve as an example of accounting for flows for a particular occupation which has been estimated for some past period:

<table>
<thead>
<tr>
<th>Sending Country</th>
<th>Receiving Country</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>M_{11}</td>
<td>M_{12}</td>
</tr>
<tr>
<td>2</td>
<td>M_{21}</td>
<td>M_{22}</td>
</tr>
<tr>
<td>\vdots</td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>M_{n1}</td>
<td>M_{n2}</td>
</tr>
<tr>
<td>Total</td>
<td>M_{*1}</td>
<td>M_{*2}</td>
</tr>
</tbody>
</table>

It may be noted that, by including the diagonal elements, the matrix is not simply one of migration flows but also accounts for the active labor force in each country in that particular occupation. If the diagonals are omitted, only migrants are counted. If all the components of the labor force
were alike, the matrix would be expected to be triangular. There would be no reason for identical migrants to move out of and into a country. Non-triangularity reflects differences among workers in the skills and, perhaps, in their preferences as to where they work, at home or abroad. The row sums are the total labor availabilities from a country. The column sums are total labor demand within a country. The row and column sums would not be expected to be equal.

II. THE CHOICE OF APPROACH

A. Introduction

Two fundamentally different approaches, referred to as the programming approach and the systemic approach, could give us an estimate of the updated matrix M with elements \((M_{ij})\).

Nevertheless, given the limits and requirements of the programming approach, the principles of which are described below, the systemic approach seemed more adapted to the present Model and is therefore developed and analyzed extensively in Sections III and IV.

B. The Programming Approach

The programming approach relies basically on the specification of behavioral relationships that link, or explain, the number of migrants from i to j \((M_{ij})\) to the other flows and to exogenous socio-economic variables or given environmental signals that influence migration.

The optimization of an objective function, taking these relationships as constraints, should then give a "best possible" distribution of labor between countries and skill categories.
To make this process simpler, it could be done in two steps: first, assuming that the future total demands by receiving country \((M_{xj})\) and total supplies by sending country \((M_{ij}^*)\) have been estimated from other sources and can be considered given marginals, we estimate the future intercountry cells \((M_{ij})\) on the basis that the changes affecting the future migration are minor ones. Secondly, the optimization of the distribution of these marginals according to a specific political or technical criterion would give a "best possible" solution.

As for the first step, adjusting an old matrix on new marginals can be done under appropriate biproportional constraints by the RAS technique but the difficulty of interpreting the coefficients that are derived for this updating problem has been widely discussed.\(^4\)

An alternative, that could employ additional information, would utilize the minimization of a loss function, such as a distance between the new and the previously estimated matrices, under certain linear constraints. A loss function such as the sum of the squared deviations of the new cells from the old cells values would lead to a quadratic program difficult to handle. Taking the sum of the absolute values of the deviations as the minimized distance could enable linear programming, providing that every constraint is linear.

The constraints insuring that the sums of new rows and columns match the assumed marginals are obviously linear. Some more information based on knowledge of new national or international policies could be added as linear constraints. For instance, limits or quotas imposed on the maximum or minimum

allowable intercountry flows could appear as upper or lower bounds. Stipulated ratios of country flows could also be introduced. Econometric equations linking migrations to exogenously estimated wage differentials or other exogenous variables would also be conceivable.

Still, it should be emphasized that the purpose of this first step would be to simulate future flows $M_{ij}$ on the assumption that the future will be like the past, except in the few specific ways in which major differences could be made explicit in the form of linear constraints.

The second step could take the intercountry flow matrix coefficients (cell/marginal) as given and try to project a set of flows, which would satisfy some criterion of optimality, or at least improvement, that could be achieved through national policies and/or bilateral or multilateral cooperation.

For instance, costs might be associated with particular inter-country flows and thus be minimized, subject to constraints that the total flow requirements are satisfied and certain minimum and maximum limits are observed when known. An estimated reduction of the GNP of the sending country, specified as a multiple of the labor productivity, could also be included as a cost in the objective function. Total net benefits for the receiving country could be maximized by labor category, again using labor productivity coefficients or preestimated labor input-output relations (or elasticities) for each sending country.

Certain marginal values could be regarded as fixed or imposed-dependent on exogenous variables or bounded by receiving or sending countries.

As one can see, the cell by cell programming approach is basically introducing slight amendments to the allocation mechanism of the present Model. It suffers from the same key shortcomings.
C. Strengths and Weaknesses

The programming approach appears immediately attractive to the analytical mind because of its relatively natural and intuitive cell-by-cell information process, and its great flexibility. But this strength is also its weakness.

Many assumptions and individual judgements must be made about individual cells in order to formalize the relationships without which the programming approach would lose its wealth and attractiveness.

To estimate and project the refined—but most of the time assumed—cell-by-cell relationships, the data requirements would be horrendous in what is, by any account, a large if not enormous system in our case. More precisely, it would be particularly difficult to quantify such non-economic influences as the relative quality of life between countries or the relative discomforts imposed on social life by political or cultural habits; both factors that can be determinant in the decision-making process of a migrant in the Middle East and North Africa regions.

Finally, it is not clear that the objective function to be optimized would necessarily reflect the wishes and preoccupations of the concerned government, factors that might well prove impossible to model. The introduction of the socio-political variables would be difficult, judgemental and extremely time-consuming on a cell-by-cell approach.

D. The Systemic Approach: a Choice

The systemic approach holds more promise but is also technically challenging. It tries to look at the system in its entirety by manipulating key variables, that could be considered as policy tools, to define flow
patterns. It requires few policy or environmental judgements.

Some aspects of the systemic approach could also lend themselves to an optimizing framework, but that would be the core of further research.

It is described below in further details to allow the reader a better understanding of this method, familiar in movement analysis, but not widely discussed in economic literature.

III. THE SYSTEMIC ALLOCATION MODEL

A. Introduction

The procedure outlined below is designed to allocate workers of a given skill level and national origin from within the region to the industrial sectors in the nations of the region, and to estimate the number of workers from outside the region of that skill level which will need to be recruited to fill the shortages by each industry in each nation.

This allocation procedure takes as its point of departure the current inventory, which has been developed by the Bank, of workers by skill and national origin as distributed by sector and nation. It links an analysis of this distribution with Bank projections of future labor supply and demand in the region to permit estimation of future labor flows. These future labor flows, in the simplest case, may be projections under a basic "no change" assumption; they may also be projections which incorporate other information (such as judgements of preferences or policies by sending or receiving countries) or conditional scenarios under particular optimizing models.

The general procedure draws on a more general theory of movements or transitions, the principles of which are outlined in one of the authors'
previous work, "A Theory of Movements." The next subsection (III-B) is a synoptic exposition of this work. It leads to a discussion of how it is adapted for the Bank's Model of regional labor flow in the Middle East and North Africa (Section III-C).

The reason for adapting the general theory for modeling the labor flow in this region is that the resultant procedure has four main advantages: (i) it is based on a very general approach and therefore, in spite of some of its apparent complexity, makes a minimum of arbitrary assumptions; (ii) it makes full use of the information now being gathered by the Bank on current distribution of the labor force and future plans or forecasts of the demand and supply of labor; (iii) it yields certain values which are interpretable and may assist in the diagnosis of the situation; and (iv) it permits judgemental modification of certain parameters to incorporate knowledge of expectations not included in the data on which the model is calibrated, or to reflect policy preferences. It is noteworthy that advantages (i) and (ii) are shared with the RAS technique, but advantages (iii) and (iv) are particularly easy to realize in the systemic approach.

After presenting the model, we present the algorithm for estimating the parameters of the model in III-D and its use for projection in III-E. They will be illustrated by a numerical example in III-F. Then we discuss the relation of this approach to other approaches dealing with systems of movements or transition; in particular, we detail its close relation to the RAS approach to updating matrices in III-G. The rest of this section--III-H to III-K--is devoted to further policy use of the model.

B. The General Model from a Theory of Movements

Considering again the table of labor flows on page 2 and the symbols used there, let indexes i, j respectively denote the origin and destination of each flow.

In a general situation, we not only have this matrix M of $M_{ij}$ together with its marginal totals:

\[ M_{i*} = \sum_j M_{ij} \]

and

\[ M_{*j} = \sum_i M_{ij} \]

but we may also have:

V : a vector of exogenous variables, $V_i$, which partially explain how $M_{i*}$ is generated (for example, $V_i$ may be the labor force of i or a composite index indicating the local supply condition);

and

W : a vector of exogenous variables, $W_j$, which partially explain how $M_{*j}$ is generated (for example, $W_j$ may be jobs at j or a composite index indicating the local demand condition).

Given this set of data $M_{ij}, V_i,$ and $W_j$, the five equations below represent a general and consistent systemic model whose meaning and uses are based upon the interpretations of endogenous variables and parameters which follow:

\[ (1A) \quad M_{i*} = V_i D_i^\alpha \]
where:

\( t_{ij} \) is a numerical statement of the transitivity from \( i \) to \( j \). It may be interpreted in various ways. In the context of labor movement, it may be interpreted as accessibility from \( i \) to \( j \), propensity of movement as a function of wage differential, cultural, religious or political compatibility, etc. Different application of the model may have different interpretation and different dimension of measurement.

\( D_i \) is the system pull at \( i \) or a pool of potential movers out of \( i \) per unit of \( V_i \). In the context of labor movement, it may be viewed as the job opportunities in the system (region) from the perspective of a person at \( i \), or as the regional demand for labor from \( i \).

\( C_j \) is the system push to \( j \) or a pool of potential movers into \( j \) per unit of \( W_j \). In the context of labor movement, it may be viewed as the workers available to each job at \( j \), or as the regional labor supply to \( j \).
\( \alpha, \beta \) are two elasticities respectively measuring the responsiveness of labor movement from \( i \) and into \( j \) to the system (regional) forces.

The five equations constitute a highly consistent system—consistent on both accounting and interpretation ground:

- On the **accounting** side, summing of Equation (1E), respectively over \( i \) an \( j \), and using Equations (1A) - (1D) yields \( \sum_j M_{ij} = M_i^* \) and \( \sum_i M_{ij} = M_j^* \). Few social models achieve this consistency along both directions of summation simultaneously.

- On the **interpretation** side: given a specific meaning of \( C_j \), Equation (1C) provides a derived meaning for \( D_i \) which corroborates the original meaning of \( C_j \) through Equation (1D); and the other way around too. For example, accept intuitively that \( C_j \) is the number of workers potentially competing for each job opening at \( j \), then \( D_i \) may be interpreted by Equation (1C) as follows. It is a measure of job opportunities from the perspective of a worker at \( i \): over the range of possible destination \( j \), it is the number of job openings \( (W_j) \), weighted positively for their accessibility or compatibility \( (t_{ij}) \), and inversely by the number of competing potential workers \( (C_j) \); i.e. weighted inversely by \( i \)'s chance of obtaining that job. Consistently, \( C_j \) can now be interpreted in terms of \( D_i \). It is the potential number of workers per job opening at \( j \), since, from equation (1D), it is the sum, over all possible origin \( i \), of the number of workers at each origin \( (V_i) \), weighted positively by accessibility or the ease of their recruitment \( (t_{ij}) \) and negatively by their alternative opportunities \( (D_i) \), i.e. weighted inversely by the chances of getting the worker.
The five equations can generate other equations or relationships. They are all consistent in meaning. In understanding this system, we should not insist on following the traditional mode of derivation which has a clear starting point of postulation and an end of derivation. Here the interpretations integrate with derivations and then a circle of relationships. One can enter the circle at any point that is theoretically convenient to the field of application, and then complete the logical derivations to exploit the consistency of the system.

Circular reasoning is not a necessary part of the derivation, particularly if the meaning of $t_{ij}$ is cast in more conventional terms of cost. If $1/t_{ij}$ is interpreted as generalized cost, then it is shown that $D_i$ is inversely proportional to the mean cost of moving out from $i$ and $C_j$ is inversely proportional to the mean cost to reach $j$. Then Equations (1A) and (1B) can be postulated on economic grounds. This, together with the hypothesis of statistical independence implied by the cost interpretation, gives rise to other equations of the system.

The generality of the model is indicated by the fact that many social models are but special cases of this system with the value of the two elasticities predetermined: Input-output ("pull") model is the case when $\alpha = 1$ and $\beta = 0$; Markov ("push") model when $\alpha = 0$ and $\beta = 1$; the traditional gravity model when $\alpha = 1$ and $\beta = 1$; and biproportional adjustment (namely RAS) model when $\alpha = 0$ and $\beta = 0$.

---


7/ In this case, $t_{ij}$ is related to a set of $i-j$ specific data other than $M_{ij}$. 
In our case of modeling labor flows among countries and sectors/occupations in the regions of Middle East and North Africa, the real world situation and the needed planning application call for an adoption of the general model by combining $a = 0$ and $\beta = 0$ and $a = 0$ and $\beta = 1$. This allows us an opportunity of computing the remaining parameters and endogenous variables which can then be used not only for forecast but for planning purposes.

C. Adapted Model of Labor Flows in the Middle East and North Africa

The labor movement situation in the Middle East and North Africa and the reality of modeling requirements is such that the Bank has to make the following three major assumptions:

(a) National/occupational supply of certain type of labor can be forecasted (planned) first and then is to be allocated to each receiving country and sector;

(b) National/sectoral demand for labor can be forecasted (planned) first and then is to be allocated to each sending country and occupation class;

(c) There is shortage of the labor force (in the categories to be modeled) in the region and the regional supply of the workers has the first crack at clearing the market. Then, the rest of the world stands ready to meet any regional deficits, no less and no more.

These assumptions can be translated into the general model summarized in the last subsection in terms of elasticity values. The first two assumptions amount to: $a = 0$ and $\beta = 0$ for each country and sector/occupation in the region. The third assumption means that a special
category called "the rest of the world" has to be created (indexed by F) with the following characteristics:

(a) \( \alpha_F = 1.0 \);

(b) although \( M_{F*} \) (the total inflow of labors into the region from the rest of the world) is a component in the model, \( M_{*F} \) (the total outflow from the region into the rest of the world) is not to be included in the model and, consequently, \( W_F, C_F \) and \( \beta_F \) do not exist and have no meaning.

Hence, we have to adapt the general model in the previous subsection to construct a coherent model that has mixed elasticities but lacks certain variables and parameters.

In order to make such a mixed model operational and refer more specifically to the third assumption, we state the following specifications:

(a) \( t_{Fj} = 1 \), that is, the rest of the world has a uniform, full accessibility to each country/sector in the region when \( M_{Fj} \) is not zero;

(b) \( V_F = 1 \), that is, the supply from the rest of the world is treated as a dummy slack variable.

With these values available, the following specific model is derived from the general model. First, it follows that:

\[
\begin{align*}
\Sigma_j M_{ij} &= M_{i*} = V_i D_i = V_i \\
\Sigma_i M_{ij} &= M_{*j} = W_j C_j = W_j \\
\Sigma_j M_{Fj} &= \Sigma_j M_{*j} - \Sigma_i M_{i*} = \Sigma_j W_j - \Sigma_i F V_i
\end{align*}
\]
Equation (2) says that the sum of actual workers from i (country and occupation), regardless of what country and sector they are in, indeed equals the supply by i or indeed match the forecast (planned) total. Equation (3) says that the sum of workers actually employed by j (country and sector), regardless of nationality, including those from the rest of the world, indeed equals the demand by j or indeed match the forecast (planned) total.

Equation (4) says that for a pool in labor deficit in the region (i.e., \( \sum_i V_i < \sum_j W_j \)) the rest of the world will fully make up the deficit.

The following equation is implied in the equation system (1):

\[
M_{ij} = \frac{V_i}{D_i} \frac{W_i}{C_j} t_{ij}
\]

For the workers from the rest of the world (F), this flow can be obtained by inserting the known parameters into Equation (1E):

\[
M_{Fj} = V_F W_j D_F C_j^{\beta-1} t_{Fj}
\]

\[
= W_j D_F C_j^{\beta-1} t_{Fj}
\]

\[
M_{Fj} = \frac{W_j}{C_j}
\]

(5a)

The regional demand is directly obtainable from Equation (1C):

\[
D_i = \sum_j M_{*ij} t_{ij}
\]

\[
D_i = \sum_j \frac{W_j}{C_j} t_{ij}
\]

(6)
But for the rest of the world, it is:

\[ D_F = \sum_j M_{ij} t_{Fj} \]

\[ W_i = \sum_j M_{ij} \]

\[ = \sum_j M_{Fj} \]

(6a) \[ D_F = M_{F*} \]

To obtain the regional supply \( C_j \), we combine Equations (3), (5) and (5a):

\[ W_j = \sum_i M_{ij} = \sum_{i \neq F} M_{ij} + M_{Fj} \]

\[ = \sum_{i \neq F} \frac{V_i}{D_i} \frac{W_i}{C_j} t_{ij} + \frac{W_j}{C_j} \]

\[ = \frac{W_j}{C_j} \left( \sum_{i \neq F} \frac{V_i}{D_i} t_{ij} + 1 \right) \]

which gives:

(7) \[ C_j = \sum_{i \neq F} \frac{V_i}{D_i} t_{ij} + 1 \]

As mentioned earlier, there is no meaning of \( C_F \). Thus, Equations (2) - (7) complete the adaptation of the system (1) to a mixed model for this particular regional labor flow situation.

D. Estimation of the Model's Parameters

The estimates \( \hat{t}_{ij}, \hat{D}_i, \hat{C}_j \) of the underlying variables are obtained directly as follows:
(a) From Eq. (5a), we obtain

\[ C_j = \frac{W_j}{M_{Fj}} \]  

(b) choosing an arbitrary value for all \( D_i \)'s, say \( K \), we obtain from Eq. (5):

\[ t_{ij} = \frac{M_{ij} \cdot D_i}{V_i \cdot W_j} = K \frac{M_{ij} \cdot C_j}{V_i \cdot W_j} \]  

(c) From Eq. (6), by joining Eq. (9), we obtain

\[ \hat{D}_i = \varepsilon_j \cdot \hat{t}_{ij} = \varepsilon_j \cdot \frac{M_{ij} \cdot C_j}{V_i \cdot W_j} \]

and after the appropriate simplifications, this reduces to

\[ \hat{D}_i = K \]

That is, any value uniformly assigned to \( \hat{D}_i \) for all \( i \) is consistent with the model.

The \( \hat{t}'s \) may now be obtained directly. Since, from Eq. (8),

\[ C_j = \frac{W_j}{M_{Fj}} \]

we can substitute it into Eq. (9) and, after simplifying, obtain:

\[ t_{ij} = \frac{(M_{ij})}{V_i} / \frac{(M_{Fj})}{K} \]  

Since \( K \) is any constant, we can define it as

\[ K = \varepsilon_j W_j - \varepsilon_i V_i = M_{F*} \]
so that Equation (9a) becomes

\[ t_{ij} = \frac{(M_{ij})}{V_i} / \frac{(M_{Fj})}{M_{F*}} \]

Equation (9b) gives a straightforward method for estimating \( \hat{t}'s \).

Setting \( K = M_{F*} = \sum_j M_{Fj} \) centers the values of the \( \hat{t}'s \) around unity.

Equation (9b) also provides a clear interpretation of the estimated \( \hat{t}'s \): \( \hat{t}_{ij} \) is the ratio of the proportion of workers from \( i \) who go to \( j \), \( (M_{ij}/V_i) \), to the share of foreign workers who go to \( j \), \( (M_{Fj}/M_{F*}) \). Foreign workers, in this Model, come where they are called: they have no preferences or differential accessibility. Therefore, the ratio of the frequency or share of workers from a given intra-regional origin at a destination to the frequency or share of foreign workers at that destination is, in effect, a comparison of "observed" and "expected" values and, as such, an estimate of the transitivity, \( \hat{t} \).

The implications of this are the following:

1. \( \hat{C}'s \) may be estimated in the calibration period;
2. \( \hat{D}'s \) may not be estimated (i.e., distinguished from each other) in the calibration period.
3. \( \hat{t}_{ij} \)'s will be proportionately correct one to another destination from a common origin; but
4. \( \hat{t}_{ij} \)'s from diverse origins may not be compared from the perspective of a single destination. Therefore, the information generated is:
   1. \( \hat{C} \) estimates;
   2. \( (\hat{t}_{ij}/\hat{D}_i) \) estimates.
E. Simple Projection, Given Future Supply and Demand Marginals

The parameters of the Model have been estimated for an initial period, and now the question is to move the matrix forward to a future period. For the future period (2) we have new projected unelastic marginals of supply \( (V_i^2) \) and demand for labor \( (W_j^2) \) at each origin and destination. It is assumed, in this exercise, that nothing else is changed: this amounts to assuming that the true \( t \)'s are unchanged, and that therefore the \( \hat{t} \)'s remain our best estimates of them.

The estimation procedure (which is rapid) is simply to iterate to the desired significant digits between:

\[
(10) \quad C_j^2 = \sum_i \frac{V_i^2}{D_i^2} \hat{t}_{ij} + 1
\]

and

\[
(11) \quad D_i^2 = \sum_j \frac{W_j^2}{C_j^2} \hat{t}_{ij}
\]

This values of \( \hat{D}_i^2 \) and \( \hat{C}_j^2 \), together with the \( \hat{t}_{ij} \)'s are inserted into a modified form of Eq. (5).

\[
(5b) \quad M_{ij}^2 = \frac{V_i^2}{\hat{D}_i^2} \frac{W_j^2}{\hat{C}_j^2} \hat{t}_{ij}
\]

to yield the projected matrix of labor exchanges.

The product of this procedure is:

\[
(1) \quad \text{a set of } M_{ij}^2 \text{'s}
\]
(2) a set of \( \hat{D}_i^2 / \hat{D}_i^1 \)'s; 
(3) a set of \( \hat{C}_j^2 / \hat{C}_j^1 \)'s; and from the estimation procedure in the previous section, we have 

(4) as set of \( \hat{t}_{ij} \)'s.

The estimates of \( \hat{M}_{ij}^2 \), \( \hat{D}_i^2 / \hat{D}_i^1 \), and \( \hat{C}_j^2 / \hat{C}_j^1 \) will be correct, as will be shown in the next section.

F. A Hypothetical Example and the Systemic Procedure of Estimation

It may be useful to use a numerically worked out example to illustrate the various relations among a "true" model and the systemic procedure; in the next section (G) we will relate these to the RAS technique for updating matrices. We start off in this hypothetical example by assuming we know the true t's operating in the region in a 4 x 6 matrix, and that the initial V's and W's are given. These are shown in Table 1.

We also know the underlying suppositions under which the allocation model is to run: (a) that all of the labor indigenous to the region will be allocated; (b) that the foreign labor will take up any necessary slack; and (c) that the region's V's and W's are inelastic. These considerations provide the structure of the equations in Section 2 above. Using the equations of this section, by a simple iterative procedure (basically cycling between \( \hat{D} \)'s and \( \hat{C} \)'s, and then to \( \hat{M} \)'s) we estimate the "true" migration flows which would result, and the D's and C's. These are shown in Table 2.

Similarly, given the second period's V's and W's, and utilizing the "true" t's (which are here assumed to remain unchanged) we calculate the matrix of M's and the D's and C's of the second period. These are shown in Table 3.
Table 1: "True" Values of t's, V's, and W's for Period 1 and Period 2

<table>
<thead>
<tr>
<th></th>
<th>t</th>
<th>V1</th>
<th>V2</th>
<th>W1</th>
<th>W2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.80000</td>
<td>.75000</td>
<td>.45000</td>
<td>.30000</td>
<td>.20000</td>
</tr>
<tr>
<td></td>
<td>.30000</td>
<td>.20000</td>
<td>.70000</td>
<td>.65000</td>
<td>.30000</td>
</tr>
<tr>
<td></td>
<td>.10000</td>
<td>.20000</td>
<td>.30000</td>
<td>.30000</td>
<td>.65000</td>
</tr>
<tr>
<td></td>
<td>1.0000</td>
<td>1.0000</td>
<td>1.0000</td>
<td>1.0000</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>VI</th>
<th>V1</th>
<th>V2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.10000</td>
<td>.20000</td>
<td>.30000</td>
</tr>
<tr>
<td></td>
<td>.30000</td>
<td>.20000</td>
<td>.70000</td>
</tr>
<tr>
<td></td>
<td>.10000</td>
<td>.20000</td>
<td>.30000</td>
</tr>
<tr>
<td></td>
<td>1.0000</td>
<td>1.0000</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

Table 2: Computed "True" M's, C's, and D's for Period 1
(using Eq. (10) and (11) for period 1)

<table>
<thead>
<tr>
<th>M1</th>
<th>D1</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5737</td>
<td>7.2044</td>
</tr>
<tr>
<td>2.3040</td>
<td>4.5863</td>
</tr>
<tr>
<td>.97610</td>
<td>5.8291</td>
</tr>
<tr>
<td>4.1462</td>
<td>12.380</td>
</tr>
<tr>
<td>C1</td>
<td>2.4118</td>
</tr>
<tr>
<td>D1</td>
<td>2.3447</td>
</tr>
<tr>
<td>2.9783</td>
<td>48.589</td>
</tr>
<tr>
<td>63.716</td>
<td>46.242</td>
</tr>
<tr>
<td>130.00</td>
<td>30.219</td>
</tr>
</tbody>
</table>


Table 3: Computed "True" M's, C's, and D's for Period 2;
Ratios of C's and D's of the two Periods
(using Eq. (10) and (11) for period 2)

<table>
<thead>
<tr>
<th>M</th>
<th>C</th>
<th>D</th>
<th>p^2</th>
<th>D^2/D^1</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.042</td>
<td>2.4233</td>
<td>2.6900</td>
<td>2.5218</td>
<td>1.5131</td>
</tr>
<tr>
<td>14.782</td>
<td>2.3742</td>
<td>2.5218</td>
<td>1.8730</td>
<td>1.7392</td>
</tr>
<tr>
<td>4.5428</td>
<td>3.6059</td>
<td>1.0000</td>
<td>1.0000</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

Table 4: Estimates \( \hat{\tau} \)'s, \( \hat{C} \)'s, and \( \hat{D} \)'s from the
First Period "Data" of \( M_1 \) in Table 2
(Eq. (8) and (9b))

\[
\begin{array}{ccccccc}
\hat{\tau}^1 & \hat{C} & \hat{D}^1 \\
2.6900 & 2.5218 & 1.5131 & 1.0087 & .67249 & .33625 & 130.00 \\
.80269 & .53513 & 1.8730 & 1.7392 & .80269 & .53513 & 130.00 \\
.20404 & .40808 & .61212 & .61212 & 1.3263 & 1.3263 & 130.00 \\
1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 1.0000 & 130.00 \\
C^1 & 2.4118 & 2.4232 & 3.3520 & 3.1430 & 3.2411 & 2.9783 \\
\end{array}
\]

Tables 1, 2, and 3 provide a hypothetical "real" world; the task is to simulate this "real" world for projection (and later on for analysis) under conditions of information which are only partial. Most particularly, we assume that our only information is: (a) the migration of period one; (b) the V's and W's of period one (which are simply the marginals of the migration matrix); (c) the V's and W's of period two; and (d) the ground rules within which the
allocation model is to work: these are the inelasticity of labor supply (V's) and demand (W's) within the region; the priority of regional labor supply; the elastic availability of foreign labor to fill in the voids.

The information available is therefore of two types: (1) numerical information (M's in the first period, and V's and W's in both periods), and (2) contextual (priorities and elasticities). It is this information which is used in Section D about to derive an estimation procedure for the t's, C's, and D's in the first period. Table 4 shows the results of using this procedure. Note that the ratio's of the t's are correct along each row, that the D's are undifferentiated, as mentioned earlier, and that the C's are correct estimates.

Using the estimates of Table 4, and given the V's and W's of the second period, we estimate the matrix of M's in the second period and its C's and D's by the procedures outlined in Section E. These are shown in Table 5. Note that the second period M's exactly replicate the "true" M's. Equally, the C's are correct estimates of the C's. In the case of the D's, we do not obtain an estimate of their absolute value; we do, however, obtain a correct estimate of the relative change in D between periods for each labor pool: compare the values in the column headed "D2: D1" in Tables 3 and 5.

In short, what is obtained by this method is:

1. A "correct" projection of the M's;
2. A "correct" estimate of C's in the first and second periods;
3. A "correct" estimate of the relative change in D's from the first to second periods; and
4. An estimate of t's correct to a ratio along rows.
Table 5: Estimated M's, C's, and D's for the Second Period:

<table>
<thead>
<tr>
<th>M^2</th>
<th>D^2</th>
<th>D: D'</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.042</td>
<td>7.6872</td>
<td>6.0738</td>
</tr>
<tr>
<td>14.782</td>
<td>8.0465</td>
<td>37.086</td>
</tr>
<tr>
<td>4.5428</td>
<td>7.4186</td>
<td>14.654</td>
</tr>
<tr>
<td>20.633</td>
<td>16.848</td>
<td>22.186</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C^2</th>
<th>S^2</th>
<th>R^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.4233</td>
<td>2.3742</td>
<td>3.6059</td>
</tr>
<tr>
<td>3.3952</td>
<td>3.2691</td>
<td>2.9695</td>
</tr>
</tbody>
</table>

Table 6: Estimated M's for the Second Period by RAS Method; R's and S's

<table>
<thead>
<tr>
<th>M</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.043</td>
<td>7.6877</td>
</tr>
<tr>
<td>4.5431</td>
<td>7.4192</td>
</tr>
<tr>
<td>20.631</td>
<td>16.846</td>
</tr>
<tr>
<td>S</td>
<td>3.9021</td>
</tr>
</tbody>
</table>

The "correct" projection of the M's is replicated for this simple projection by the RAS method, as we shall see in the next section. The systemic approach provides, in addition, other estimates (C's, D's and t's) which can be useful for evaluation and for the development of alternative policy scenarios.
G. RAS and the Systemic Method

Table 6 exhibits the projection of the migration flows of period one (Table 2) to the second period by the RAS technique. It also shows the relative values of $R_i$ and $S_j$ (which $R_i$ being the numeraire). Note, of course, that the projected $M$'s are "correct."

The RAS technique for updating matrices, such as those of input-output table is, methodologically, simplicity itself. Given any matrix $M^1$, it may be transformed to any other matrix $M^2$ by premultiplying it by a diagonal matrix $R$ and post multiplying it by a diagonal matrix $S$; the only problem is to find the proper $R$ and $S$, and simple algorithms are available.

This technique is simple and powerful. A common use is to update a matrix of flows to a second period where only the marginals are specified, and this is essentially the case here. The shortcoming of this technique is that it functions as a "black box": under a general assumption of ceteris paribus, it generates $R$'s and $S$'s which are very difficult to interpret, and in effect merely transform the first matrix into the second, yielding no information on their own. Any anomalous results which may be obtained remain, therefore, as objects of suspicion.

Since in simple projection, the RAS technique yields in this case the same projected results as the systemic model, it is interesting to see their exact relation.

It is not necessary to take the space for the full proof of the following relations, but the reader can easily derive them or check them out numerically in the hypothetical example laid out in Tables 1 to 6. We will use $x^2$ to indicate the value of a variable $x$ in the second period, and $x^1$ in the first.
In the RAS method (using algebraic rather than matrix notation):

\[(12) \quad \hat{M}^2_{ij} = R_i \cdot S_j \cdot M^1_{ij}\]

While for the systemic approach, it can be readily derived from (5b) and (9) that:

\[(13) \quad \hat{M}^2_{ij} = \left( \frac{v_i^2}{v_i} \cdot \frac{D_i^1}{D_i^2} \right) \left( \frac{w_i^2}{w_i} \cdot \frac{C_j^1}{C_j^2} \right) M^1_{ij}\]

so that, for the terms expressed in \(i\):

\[(14) \quad R_i = \frac{v_i^2}{v_i} \cdot \frac{D_i^1}{D_i^2} \]  

\(i \neq F\)  

\(\frac{v_i^2}{v_i} \cdot \frac{D_i^1}{D_i^2}\)

(recall that the ratio \(D_i^1/D_i^2\) is estimated "correctly," although \(D_i^1\) cannot be estimated absolutely); and for the terms expressed in \(j\):

\[(15) \quad S_j = \frac{w_i^2}{w_i} \cdot \frac{C_j^1}{C_j^2}\]

Equations (14) and (15) address interregional labor exchanges. But, whereas RAS handles the foreign sector in exactly the same way as intraregional labor flows, the systemic approach makes a distinction. In terms of the more general theory, \(\alpha = \beta = 0\) for intra-regional labor exchanges, but in the case of foreign labor \(\alpha = 1\). The \(R_i\) term, when written out fully in general theoretical terms is:

\[(16) \quad R_i = \frac{v_i^2}{v_i} \left( D_i^2 \right)^{a-1} / \left( D_i^1 \right)^{a-1}\]
which reduces to Eq. (14) when \( \alpha = 0 \). But in the case of the foreign sector, where \( \alpha = 1 \) and \( V_F = 1 \), it reduces to:

\[
(17) \quad \frac{R_F}{V_F^2 (D_F^2)^{1-1}/V_F^1 (D_F^1)^{1-1}} = 1
\]

Table 6 shows \( R_F = 1.2752 \), but this is immaterial. R's and S's are constant only to a product. All that is needed is to divide the R's by 1.2752 and to multiply the S's by the same amount.

Whereas, for straightforward projection, the RAS and the systemic methods result in the same outcome, the systemic projection unpacks the RAS black box to a considerable degree by making use of what is known of the structure of the interactions. The mysterious R's and S's can be seen as products of ratios of the values of interpretable variables in the first and second periods (and hence dimensionless). If we rewrite Eq. (14) as

\[
R_i = \frac{V_i^2 / D_i^2}{V_i^1 / D_i^1}
\]

we see immediately that \( R_i \) represents the relative change from one period to the next of the ratio of the inelastic supply of labor \( i \) (\( V_i \)) to the opportunities or quantitative demand for workers from \( i \) (\( D_i \)). Similarly, if we rewrite Eq. (15) as

\[
S_j = \frac{W_j^2 / C_j^2}{W_j^1 / C_j^1}
\]

we can readily interpret \( S_j \) as the relative change from one period to the next of the ratio of inelastic demand for labor at \( j \) (\( W_j \)) to the quantitative supply of workers per opening at \( j \) (\( C_j \)).
The systemic procedure disentangles to a considerable degree row (D), column (C), and interaction (t) effects, and thus enables the model user to interpret and intervene to avoid getting caught up with the RAS's sometimes anomalous results. The relation of the various parts of the exercise documented in Tables 1 through 6 can be seen in diagram in Figure 1.

**Figure 1: The Structure of the Estimation Process**

H. Policy Uses: Limiting $\hat{M}'s$

It is possible, as in the RAS method, to set one or more elements of $\hat{M}'s$ to preselected values, and to run the rest of the model around those fixed elements. For instance, if $\hat{M}_{ij}^2$ is to be predefined to be some value $x$, the relevant $t_{ij}$ would be set to zero to prevent additional arrivals, the relevant $V_i^2$ and $W_j^2$ would be reduced by $x$ and the model would be run as usual.

If the condition is set as $\hat{M}_{ij}^2 \leq x$ or $\hat{M}_{ij}^2 \geq y$, the procedure is similar but proceeds by iteration. The model is first run unconstrained; if the condition is satisfied, no more is needed. If the condition is not met,
the constraint is most probably binding and the procedure is the same as above.

A likely use of exploring such constraints would be to examine their consequences for other flows in the system. Some of these other flows, after adjustment, might be considered too high or too low. In extreme cases, strong shifts in other flows or actual inconsistencies might be revealed; such findings would obviously raise serious questions as to the feasibility of the constraints.

I. Policy Uses: Modifying the t's

It is possible to introduce policy considerations by modification of the t's. Imagine that a certain $M_{ij}$ is regarded as too low by the host country j which would like to fill more of its labor needs with nationals from i. Country j tries to increase labor from i by a variety of devices: propaganda, direct recruitment, facilitation of visas and work permits, special facilities such as housing, wage supplements, family permits and family allowances, etc. In so doing, it would be trying to raise the value of $t_{ij}$. There is no clear procedure by which one could assign a given increase (or decrease) to $t_{ij}$ associated with a particular package of inducements (or restraints) to labor migrants from i to j. Therefore, the increase (or decrease) attributed to $t_{ij}$ must be a matter of judgement: one might say that the policies have made it 60% easier (or 50% harder) to go from i to j, and therefore multiply the original $t_{ij}$ by 1.6 (or by .5).

Conversely, a labor supplying country i may alter its preferences for whatever reasons, as to the destination of its nationals, and attempt to the $t_{ij}$'s by one or another means: visas, propaganda, placement programs, etc. Again, it would be a matter of judgement as to the proportion by which
the $t_{ij}$'s would be changed.

For this purpose, we may consider $t_{ij}$ to be the product of $l_{ij}$ and $k_{ij}$, where $l_{ij}$ is the preference or affinity of origin $i$ for destination $j$, and $k_{ij}$ is the preference or affinity of destination $j$ for origin $i$. Judgemental proportional changes may be assigned to $l_{ij}$ or $k_{ij}$ by client countries or Bank staff, and changes in $t_{ij}$ would be their product.

Clearly, we cannot measure directly $l_{ij}$ or $k_{ij}$. But, conceptually, a policy-induced increase of 50% in $k_{ij}$ would increase $t_{ij}$'s value by a factor of 1.5. Similarly a 30% increase (decrease) in $l_{ij}$ would result in an increase by a factor of 1.3 (a decrease by a factor of .3) in $t_{ij}$. Simultaneous changes in $l_{ij}$ and $k_{ij}$ would result in changes in $t_{ij}$ proportional to the factor changes in $l_{ij}$ and $k_{ij}$.

In the extreme case, where $j$ bans nationals from $i$, or where $i$ forbids its national to go to $j$, we have that $l_{ij} = 0$ or $k_{ij} = 0$, and in either case, $t_{ij} = 0$. This case, although extreme, is not unknown in the Middle East.

We can consider introducing some behavioral economic variables thanks to the structure of the transitivity coefficient ($t$) as a product of two coefficients ($l$) and ($k$) each representing the desirability of moving from $i$ to $j$ from the perspective of the migrant and the receiving country respectively.

Thus $l$ would be allowed to vary between 0 and +1.0 and would represent the relative preference a given migrant from country $i$ to go to county $j$ rather than another of the available choices. This ranking of the alternatives would be the result of relative wage rates. The relationship would have the following form:
where \( a \) and \( b \) are parameters of the function.

This is the equation of an S-shaped curve (a Gompertz curve or a logistic curve) whose upper limit tends to unity.

It is possible to construct a similar curve to reflect the relationship between \( \ell \) and relative savings instead of wage rates, or even to try to combine the two. Nevertheless, we would prefer to start on the basis of relative wages only for several reasons:

(i) the data are more readily available both on a cross-section and time-series basis;

(ii) it is probable that savings rates have more of an impact on the duration of stay of the migrant (and hence the turnover of migrant stock) rather than the initial decision to migrate; and

(iii) savings patterns probably vary considerably by nationality and
occupation and hence may be more difficult to use even if the data were readily available.

The desirability of certain migrants from the perspective of the host country (represented by $k$) would be a function of:

(i) political and cultural consideration;

(ii) the size of that nationality group among the existing migrants in host country; and

(iii) the likely replaceability of this particular migrant by a national of the host country.

But $k$ could be expected to behave in accordance with the following form:

$$k = 1 - \left[ 1 + e^{\tilde{a} - \tilde{b} \left( \frac{M_{ij}}{\sum M_{nj}} \right)} \right]^{-1}$$

suitably defined values for $\tilde{a}$ and $\tilde{b}$ will make $k$ close to 1.0 and 0.0 on the boundary of [0,1] for $\left( \frac{M_{ij}}{\sum_{n} M_{nj}} \right)$.
The complete formulation of \( t_{ij} \) would be given by combining the two

functions \( W \) and \( k \) so that \( t_{ij} = F \left( \frac{W_i}{W_j}, \frac{M_{ij}}{\sum_{n} M_{nj}} \right) \) as follows:

\[
t_{ij} = \left[ 1 + e^{a-b(M_{ij}/\sum_{n} M_{nj})} \right]^{-1} \cdot \left[ 1 + e^{-\tilde{a} + \tilde{b}(M_{ij}/\sum_{n} M_{nj})} \right]^{-1}
\]

where \( a, b, \tilde{a}, \tilde{b} > 0 \), and the relative magnitude of \( a, b \) and \( \tilde{a}, \tilde{b} \) will determine the possibilities for sign alterations of the second partial derivatives of \( t_{ij} \) with respect to \( (W_j/W_i) \) and \( (M_{ij}/\sum_{n} M_{nj}) \).

It is pertinent to note that under this formulation the bounds of the variables \( (t_{ij}) \) would be more constrained than the full range 0 to 1.0, such that:

\[
0 < (1 + e^a)^{-1} < [1 + e^{a-b(M_{ij}/W_j)}]^{-1} < 1.0
\]

and

\[
0 < (1 + e^{-\tilde{a} + \tilde{b}})^{-1} < [1 + e^{-\tilde{a} + \tilde{b}(M_{ij}/\sum_{n} M_{nj})}]^{-1} < (1 + e^{-\tilde{a}})^{-1} < 1.0
\]

J. Evaluation: Using the ratios \( (\hat{D}_i^2/\hat{D}_i^2) \) and \( (\hat{C}_j^2/\hat{C}_j^2) \)

As noted in earlier sections, the estimated interperiod changes in the \( \hat{D}'s \) and \( \hat{C}'s \) are "correct," and this may be used to evaluate the outcome of a particular projection or scenario from the point of view of sending or receiving countries.

Recall that \( D_i \) is the regional demand for his labor as seen by a worker from \( i \), after taking account of his accessibility \( (t_{ij}) \) to the various destinations \( j \) and the competition \( (C_j) \) for jobs at \( j \) from all other origins. Although demand and supply are treated as inelastic, it is
clear that, from the point of view of $i$, a larger $D_i$ is preferable to a smaller one: it implies that workers from $i$ have more opportunities or choices available to them, presumably giving them greater discretion in their choice of staying at home or going to preferred destinations.

Because, as discussed above, $\hat{D}_i$ cannot be estimated, comparisons of this richness of choices is not possible among countries. But since the change $(\hat{D}_2^i/\hat{D}_1^i)$ can be evaluated, the systemic method does provide information for particular projections or scenarios as to whether the range of choices for workers from one country increases or decreases from one period to the next, and permits comparison of this change among countries.

Similarly, the $C_j$'s are statements of the regional (plus foreign) availability of workers for a job at $j$, after taking account of the accessibility of these workers ($t_{ij}$) and their alternative choices ($D_i$). Although the local demand for workers, $W_j$, is inelastic by assumption, it is better from the point of view of the receiving country to have as large a pool ($C_j$) as possible of workers from which to draw. This would enable the employer to use greater selectivity, to specify contract terms, to be more certain that there will not be unexpected shortages, etc.

For the $C$'s, by contrast to the $D$'s, we do obtain estimates for the period, as well as interperiod change estimates. Therefore, it is possible to make intercountry comparisons of the supply of labor within a period, as well as estimates of the change in supply, and this may be used to evaluate alternative projections or scenarios.

In short, the $\hat{D}$'s and $\hat{C}$'s provide information about the range of choices for workers and employers, and thus of their ability to discriminate among choices. The $D$'s and $C$'s are, in effect, functional equivalents of shadow prices or rents.
K. Using Other Information: Econometrics for the t's

The procedure thus far has only used the information on observed labor flows, plus the assumed structure of the market in which these flows operate (clearance of the region's labor market, and the foreign sector as a slack variable). Such variables as wages, ability to save or remit, cultural or religious affinity, etc., have not been used, except by implication in the transitivity variables, t.

This is largely because such information is not systematically available within the region, so that a model predicated upon it would flounder for lack of data. But clearly, where such data are available and tractable, they should be incorporated.

For instance, where information (such as wages, savings rates, etc.) is known for alternative destinations for workers for a given country of origin, one could construct a regression model with the t's as the dependent variable, and wages, etc., at the country of destination as independent variables. Where econometric estimates are successful, projection or policy manipulation of the independent variables would allow manipulation of the relevant t's, and from these to the consequent M's.

Note particularly that various such econometric exercises could be used on various subsets of the t's, and combined with judgemental adjustments (such as suggested in Section 1 above).

In other words, the model can be run with a mix of ceteris paribus, econometric, and judgemental adjustments.
IV. RESEARCH OPPORTUNITIES

The way of adapting the general theory as outlined in III-B to this model is dictated by information availability and the special circumstance in the region considered. During the course of implementing the model for forecasting and planning in the coming years, it is expected that information sources will improve and the use of the model may change. More research will be required to ensure better utilization of the model.

Many research topics can be formulated. The following three may be among the most obvious:

(1) **Absolute value of t's.** In the current version of the model, only the relative values of t's across each row can be estimated. Although this does not prevent us from correctly forecasting the absolute value of M's and C's, the policy and planning uses of the model, which are suggested in III-H - III-K, are limited. The absolute values of t's are obtainable if we have one extra column vector of information or assumptions, such as, for instance, the relative values of t's between rows, or relative values between D's, or a vector of exogenous V's, as defined in the general model in III-B, other than $M_{i*}$. How to make the most appropriate addition of this column vector of information must be based on information availability and real world situations, and needs to be investigated. Once this information is incorporated, not only are the absolute values of t obtainable, but also, consequentially, the absolute D's can be computed. More importantly, work on decomposing the t's into their $\Lambda$ and $k$ components and plotting the relationships between these and key variables such as $(W_j/W_i)$ and $(M_{ij}/M_{nj})$ should considerably improve the usefulness of this modeling effort.
(2) Programming and planning. Once the absolute \( t^{'} \)'s become available, the model opens a door to a mathematical programming approach to the formal planning use of the model. In Section II, we discussed the difficulties of applying the programming approach to forecasting. The main difficulty remains that no sensible interaction cost between origin \( i \) and destination \( j \) can be either collected or forecasted. But once absolute \( t^{'} \)'s are obtained, it is logical to view the inverse of \( t \) as a generalized cost and, consequently, one can program to minimizing \( \sum_{i,j} \frac{M_{ij}}{t_{ij}} \) (for a future date) subject to appropriate constraints. In this way, a full fledged programming model can follow the systemic model for formal analysis of policy implications.

(3) Utilization of D's and C's. Beside the \( t^{'} \)'s, the significant information produced by the model is contained in the D's and C's. They are not only interpretable, but, in the original general model outlined in III-B, contribute to the explanation/forecast of the marginal totals \( M_{i}^{*} \) and \( M_{*j}^{*} \). But in the current adapted model, they have not been used in this fashion. That is, the marginal totals for period-2 are provided disregarding the estimated D's and C's. This is, of course, consistent with the assumption \( \alpha = 0 \) and \( \beta = 0 \). But the available D's and C's really should be utilized for a better forecast of the marginal totals. This may be approached in two ways. One is to use D's and C's in an informal way for checking on or modifying the forecast marginal totals. The other is, when exogenous \( V \)'s and \( W \)'s (as defined in the general model) are available, to return to the general model and use Equations \( -(1A) \) and \( -(1B) \), and reinstate the two elasticities \( \alpha \) and \( \beta \). Both approaches need exploration.

For those who are mathematically inclined, a fourth avenue of research is possible. Namely, the development of a proof for the uniqueness
of the system's solution presented in the Appendix to this paper. Such work could yield a more comprehensive and elegant solution to the problem or it could conversely lead to the development of an alternative and better algorithm for the solution of the systemic model.

V. CONCLUDING REMARKS

The preceding discussion has established that a systemic approach to the simulation of labor flows in the Middle East and North Africa is feasible. It will also be more efficient than the cell-by-cell programming approach, and more useful than the RAS technique because it is both manipulatable and interpretable. It is hoped that it will allow future simulation of labor migration in the Middle East and North Africa region to be even more challenging and rewarding than previous Bank efforts9/ to deal with this complex and interesting subject.

9/ See Serageldin et al., Manpower and International Labor Migration in the Middle East and North Africa, op. cit.
APPENDIX

THE SYSTEMIC SOLUTION \(^{10/}\)

One of the unresolved questions of the preceding presentation of the systemic Model was whether the iterative approach to solving for C's and D's would necessarily produce an existing and unique solution.

To examine the existence, uniqueness and stability of the solution for the C's and D's, the problem is cast at first in terms of the following equations system:

\[
\begin{align*}
C_1 &= \left( \frac{V_1}{D_1} t_{11} + \frac{V_2}{D_2} t_{21} + \ldots + \frac{V_m}{D_m} t_{m1} \right) + 1 \\
C_2 &= \left( \frac{V_1}{D_1} t_{12} + \frac{V_2}{D_2} t_{22} + \ldots + \frac{V_m}{D_m} t_{m2} \right) + 1 \\
&\vdots \\
C_n &= \left( \frac{V_1}{D_1} t_{1n} + \frac{V_2}{D_2} t_{2n} + \ldots + \frac{V_m}{D_m} t_{mn} \right) + 1 \\
D_1 &= \frac{W_1}{C_1} t_{11} + \frac{W_2}{C_2} t_{12} + \ldots + \frac{W_n}{C_n} t_{1n} \\
D_2 &= \frac{W_1}{C_1} t_{21} + \frac{W_2}{C_2} t_{22} + \ldots + \frac{W_n}{C_n} t_{2n} \\
&\vdots \\
D_m &= \frac{W_1}{C_1} t_{m1} + \frac{W_2}{C_2} t_{m2} + \ldots + \frac{W_n}{C_n} t_{mn}
\end{align*}
\]  

\(^{10/}\) This solution was developed by T. Takayama, then of The World Bank.
But to gain some insight, it is more convenient to look at the system (A.1) and (A.2) as a simultaneous equations system, substituting (A.2) into (A.1):

\[
(A.3)
\]

\[
\begin{align*}
C_1 &= \frac{V_1}{C_1} \frac{W_1}{C_1} t_{11} + \ldots + \frac{W_n}{C_n} t_{1n} \\
C_2 &= \frac{V_1}{C_1} \frac{W_1}{C_1} t_{12} + \ldots + \frac{W_n}{C_n} t_{2n} \\
\vdots &= \vdots \\
C_n &= \frac{V_1}{C_1} \frac{W_1}{C_1} t_{1n} + \ldots + \frac{W_n}{C_n} t_{nn} \end{align*}
\]

Since (A.3) above is an \( n \) simultaneous equation in \( n \) unknowns in \( C_1, C_2, \ldots, C_n \), ideally, the system may have a solution. However, analytical solutions are impossible to obtain. Therefore, let us write the right-hand-side of (A.3) as \( F_1(C), F_2(C), \ldots, F_n(C) \), and set the problem as a fixed point existence question easier to analyze:

Has the equation system

\[
(A.4) \quad \begin{bmatrix} C_1 \\ C_2 \\ \vdots \\ C_n \end{bmatrix} = \begin{bmatrix} F_1(C) \\ F_2(C) \\ \vdots \\ F_n(C) \end{bmatrix} \quad \text{or} \quad C = F(C)
\]
a unique stable solution $C^*$?

Since all the parameters of $F(C)$ are positive or zero (but not all of them zero), we can conclude that:

(A.5) \[ F(C) > 1 \quad \text{for all } C > 1 \]

If one drives $C_i$ to $+\infty$, keeping $C_j$ for all $j \neq i$ at their finite levels, one can conclude that:

(A.6) \[ F_i(C) \longrightarrow k_i \quad \text{finite positive constant}. \]

How does $F_i(C)$ approach $k_i$? This can be found from the first and second derivatives of $F_i$ with respect to $C_i$'s.

The first derivative vector of $F_i$, say for $i = 1$, has its $j$-th element as follows:

(A.7) \[ \frac{\partial F_1}{\partial C_j} = \sum_{k=1}^{m} \sum_{l=1}^{n} \left( \frac{W_{kl} C_j}{C_k} \right)^{-2} \]

and each component in this vector $\frac{\partial F_1}{\partial C}$ is positive, which can be easily generalized for any $i$.

The second derivatives of $F_i$ possess the following property:

(A.8) \[ \frac{\partial^2 F_i}{\partial C_j \partial C_k} = \begin{bmatrix} + & + & \cdots & + \\ + & + & \cdots & + \\ \vdots & \vdots & \ddots & \vdots \\ + & + & \cdots & + \end{bmatrix} \]

$F_i$ with the properties (A.7) and (A.8) take the following form:
If, further, the following conditions are met:

\[
\begin{align*}
1 & > \frac{V_{1t11}}{W_{1t11}+\ldots+W_{n11}} + \frac{V_{2t21}}{W_{1t21}+\ldots+W_{n21}} + \ldots + \frac{V_{mtm1}}{W_{1tm1}+\ldots+W_{ntm}} \\
1 & > \frac{V_{1t12}}{W_{1t11}+\ldots+W_{n11}} + \frac{V_{2t22}}{W_{1t21}+\ldots+W_{n21}} + \ldots + \frac{V_{mtm2}}{W_{1tm1}+\ldots+W_{ntm}} \\
\vdots
\end{align*}
\]

then the functions \( F_i \)'s are all concave.

One can now state that:

For sufficiently large \( C \) in a hypercube

\[
\{ H = \{ C | 1 < C_i < h_i < V_i < \infty : V_i \} \}
\]

which is compact, \( F \) maps \( C \subset H \) into itself. Therefore, \( F \) satisfies the
conditions for Brouwer's fixed point theorem.

One can therefore conclude that there exists \( \bar{C} \) that satisfies:

\[ \bar{C} = F(\bar{C}) \]

Therefore, system (A.4) has a solution

Nevertheless, it is not clear at present whether it necessarily has a unique solution and further proof may be required in this area although it should not decrease the model's applicability since many well-known simulation models do not necessarily have unique solutions.
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