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Using PEPA to Model the Unemployment Problem

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Case Study Egypt

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Abstract- In this paper, we use performance evaluation process algebra PEPA to model the interactivity between different variables affecting unemployment in four basic modules representing the balance between job seekers and job opportunities. This model constitutes a new application area for this process algebra formalism. We focus on the particularity of Egypt's labour market showing the dynamics between the supply and demand of job opportunities in the market.

This has the advantage over the current techniques of demonstrating to decision makers the multiple dimensions and consequences of applying different strategic policies. It also allows looking into the specifics of not only the increase or decrease of the unemployment rate, but also the stability of the unemployment rate i.e., turnover of employees/works.

Keywords: Stochastic Process Algebra, PEPA, Unemployment Problem, Decision Making

I. INTRODUCTION

Unemployment is a persistent and alarming problem to the worldwide nations. According to the International Labour Organization (ILO), 160 million people in the world today are unemployed [1]. In Egypt, which is considered a youth society, the problem is expanding. With the increasing number of educated people, the yearly cumulative outcome of the education system is more than can be absorbed by the labour market and that raises imbalances in the Egyptian labor market [2] Data published by the Central Agency for Public Mobilization and Statistics (CAPMAS) [3] indicate that unemployment rates have increased from 8.8 percent in the second quarter of 2008 to 9.2 percent in the same period of 2009, i.e., there were some 2.34 million people unemployed out of a workforce of 25 million.

According to the World Bank and Ministry of Trade and Industry, although Egypt has invested in the education sector in recent years, the high rate of illiteracy (more than 30 per cent) points to serious shortcomings in the education system. Every year another 800,000 school leavers flood onto the labour market, and only about 31% of them manage to find a job [4]. Additionally, job hunting duration for

fresh graduates could extend to 3 years [5].

This unemployment problem is complicated and it is neither due to the sluggishness of growth nor the return of growth. However, "it is the manner in which each country manages this process that results in that country having more or less growth or more of fewer unemployed persons" [6]. Governments apply different strategies and policies to solve this problem, but, due to the complexity of the problem, the consequences of implementing any strategy are not clear.

The complexity of the unemployment problem can be represented by a network of multiple factors (entities) and their interactions in an economic system. These interactions are often difficult to represent and analyse. Process algebra models, which originally have been developed for concurrent systems analysis, support representation and reasoning complex interactions between components as stochastic process algebra defines time and maps models to stochastic processes. These models representation is program like source codes whose interpretation, according to defined syntax- driven rules (operational semantics), is exact and precise. By using process algebras, it is possible to first design individual components and then construct modules as their combination, thus supporting compositionality.

Process algebras, from their use in computer science, have been equipped with steady-state and transient model analysis tools, as well as applications for simulation and (probabilistic) model checking of models. Performance Evaluation Process Algebra (PEPA) language has few but powerful operators that represent basic actions and elements of the system, thus permitting the modellers to tune the level of detail of the model represented and avoid unnecesary complex details. Also, PEPA has the ability to handle multi-way synchronizations [7].

In the paper, we are using PEPA to model labour distribution among different labour markets (i.e., government, public sector, private sector, and aboard labour markets) and accordingly, we can calculate the unemployment rate and visualize the impact of any changes. The next section portrays the unemployment problem in Egypt and demonstrates the limitations of techniques measuring unemployment rates. The third section recaps the syntax and semantics of Performance Evaluation Process Algebra PEPA. In the fourth section, the unemployment model is described focusing on Egypt's case. The fifth section is about the experiments and results. The conclusion and future work is in the final section.

II. LITERATURE REVIEW

A. Unemployment problem in Egypt

A number of factors affect the nature of unemployment problem in Egypt. The implementation of Egypt Reform and Structural Adjustment Program of 1991, ERSAP 91 has contributed to the unemployment problem and consequently the stability of the social welfare of the society. The process of privatising large State Corporations has led to a large reduction in the number of the staff [5]. Additionally, inability of the economic and investments policies to encourage labour intensive industry has failed to absorb more labour. The legislative and institutional rules have produced investment patterns that are biased against labour-intensive growth. This has weakened the ability to create jobs [8] & [9]. Besides these factors, the "education-occupations mismatch" has added to the problem [10]. "Although Egypt has made a substantial progress with respect to access to education, the education system is not providing markets with the quantity and quality of educated individuals most in demand" [11].

However, during 1998-2006, the unemployment rate has been slightly reduced. Assaad [11] refers this to three main factors: "(i) the slow-down in the growth of the working age population and the shift of the age

structure of the youth population away from the 15-19 age group, which had the highest unemployment rates in 1998; (ii) the slowdown in government hiring, which reduced the incentive of female graduates so as to remain unemployed while queuing for government jobs or withdrawing all together; (iii) the acceleration of employment growth in the private sector, leading to earlier transitions into employment, at least for young male new entrants"[12].

B. Unemployment Models

The difficulty is to represent these factors and their interactions by means of conventional analytical and/or statistical tools. Classical models such as, the classical model of the labour market, the natural rate of unemployment, Okun's law, structural unemployment, Non-Accelerating Inflation Rate of Unemployment (NAIRU), and Phillips curve[13] are simple and calculate different aspects of the problem focusing partially on certain elements and ignoring others. El Kassas and his colleagues use statistical methods to estimate separately the labor demand, the labor supply and the unemployment for different scenarios in Egypt [14]

The Social Accounting Matrix (SAM), which is the data base of the Computable General Equilibrium Model (CGE), addresses many factors simultaneously in a symmetric matrix. It represents the balance between

the supply and demand of the commodity, total income and total expenditure of the funds, or savings and investments of macroeconomic factors in a square of rows and columns [15]. This data base can show the effects of policy changes and track the distributional consequences of policy choices. However, it cannot be used for forecasting, since the calculations are calculated at a certain point of time i.e., coefficients are results of a specific year data (benchmark).

Although SAM appears simple conceptually, it requires a great deal of skills to calculate complicated matrices and high quality data. Because the supply and the demand sides are calculated separately, modifications and adjustments happen frequently to balance the matrices. The complexity usually increases while inverting very large matrices and recalculating the coefficients to maintain the balance. Clearly, it does not tolerate inconsistencies in data.

For developing countries, this is one of the major problems they suffer at two levels. Initially, because of the shortage in funds, the data collected are usually estimates. So, a lot of adjustments are made to fit the data in the matrix. For example, the changes made the Mozambique' SAM in 1995 to achieve a balance is an adjustment of 295 $ m. for a country where 38% of population live for less than 1$ in the period 1994 – 2004, this SAM adjustment added 4.40$ to each person's

income in the agricultural sector [16], [17], [18]. On the other level, developing countries, with ill-structured and malfunctioned management systems, a lot of resources are wasted, so estimates of productions outcomes are not usually exact.

Developing a different representation to the interactions and relationships between supply and demand of job opportunities would be a contribution especially if it avoids earlier problems and decomposes the effects of policy change and tracks the distributed consequences. This can help strategic decision makers because "strategic decision is likely to be complex in nature, be made in situation of uncertainty, affect operational decision, requires an integrated approach, and involves considerable changes" [19].

Performance Evaluation Process Algebra (PEPA) allows demonstrating the system by representing its components and the whole system consists of the interaction between those components. PEPA is based on the Markov chain theory and allows a large number of vector-matrix multiplications. The matrix size is the number of states in the Markov chain. Besides, in some models with strong structural conditions PEPA's underlying Markov chain is not solved as a single system of equations, but it is decomposed into sub-models. The sub-models behave as if they were independent and the decomposed solution yields the same

steady state probability distribution as the monolithic solution. Therefore, using PEPA is a step ahead of just using Markov chain theory in solving economical problems [20].

Building an abstract and a comprehensive model of the unemployment problem using PEPA can show the simultaneous impact of any change. This model also can be flexible to expand and include more details and at the same time will be able to avoid the earlier discussed matrix adjustment problems.

III. INTRODUCTION TO PEPA

Performance Evaluation Process Algebra (PEPA) describes a system as an interaction of the components and these components engage in activities [7]. It was originally defined for the performance modeling of systems with concurrent behavior. Systems are represented as the composition of components or agents which undertake actions. In PEPA, a system is consists of a set of *components* which carry out *activities*. Each activity is defined by two entities (α, r); where α is an *action type* and r is duration which is exponentially distributed. Because of the exponential distribution of the activity duration, the underlying Markov process of a PEPA model is a continuous time Markov process. The structured operational semantics of PEPA are shown in Figure 1.

Prefix

$$\frac{}{(\alpha, r).E \xrightarrow{(\alpha,r)} E}$$

Choice

$$\frac{E \xrightarrow{(\alpha,r)} E'}{E + F \xrightarrow{(\alpha,r)} E'} \qquad \frac{F \xrightarrow{(\alpha,r)} F'}{E + F \xrightarrow{(\alpha,r)} F'}$$

Constant

$$\frac{E \xrightarrow{(\alpha,r)} E'}{A \xrightarrow{(\alpha,r)} E'} \; (A \stackrel{def}{=} E)$$

Hiding

$$\frac{E \xrightarrow{(\alpha,r)} E'}{E/L \xrightarrow{(\alpha,r)} E'/L} \; (\alpha \notin L) \qquad \frac{E \xrightarrow{(\alpha,r)} E'}{E/L \xrightarrow{(\tau,r)} E'/L} \; (\alpha \in L)$$

Cooperation

$$\frac{E \xrightarrow{(\alpha,r)} E'}{E \underset{L}{\bowtie} F \xrightarrow{(\alpha,r)} E' \underset{L}{\bowtie} F} \; (\alpha \notin L) \qquad \frac{F \xrightarrow{(\alpha,r)} F'}{E \underset{L}{\bowtie} F \xrightarrow{(\alpha,r)} E \underset{L}{\bowtie} F'} \; (\alpha \notin L)$$

$$\frac{E \xrightarrow{(\alpha,r_1)} E' \quad F \xrightarrow{(\alpha,r_2)} F'}{E \underset{L}{\bowtie} F \xrightarrow{(\alpha,R)} E' \underset{L}{\bowtie} F'} \; (\alpha \in L), \qquad R = \frac{r_1}{r_\alpha(E)} \frac{r_2}{r_\alpha(F)} \min(r_\alpha(E), r_\alpha(F))$$

Figure 1: Operational Semantics of PEPA

Prefix: $(\alpha, r).\ E$

Such a component will subsequently behave as E after it carries out the activity $(\alpha,\ r)$ which has action type α and a duration which satisfies exponential distribution with parameter r.

Choice: $E + F$

The component $E + F$ represents a system which may behave either as E or as F. The activities of both E and F are enabled. If one of them is chosen, which depends on whether its activity is completed first, the other will be discarded and the system will then behave as the derivative resulting from the evolution of the chosen one.

Constants: $X \stackrel{def}{=} E$

They are components whose meaning are given by a defining equation such as $X \stackrel{def}{=} E$ which associates with the constant X the behavior of the component E. Constants are also used to describe infinite behaviours; for example; $X = (a,r).X$ denotes the component that performs the activity (a,r) ad infinitum.

Hiding: E/L

The possibility to abstract away some aspects of a component's behavior is provided by the hiding operator denoted E/L. Here, the set L identifies those activities which are to be considered internal or private to the component and which will appear as the unknown type τ.

Cooperation: $E \bowtie_L F$

We write $E \bowtie_L F$ to denote cooperation between E and F over L. The set which is used as the subscript to the cooperation symbol, the cooperation set L, determines those activities on which the cooperands are forced to synchronise. For action types not in L, the components proceed independently and concurrently with their enabled activities. We write $E \,||\, F$ as an abbreviation. If a component enables an activity whose action type is in the cooperation set it will not be able to proceed with that activity until the other component also enables an activity of that type. The two components then proceed together to complete the shared activity. The rate of the shared activity may be altered to reflect the work carried out by both components to complete the activity.

The PEPA syntax is introduced by means of the following grammar:

$S ::= (a, r).S \mid S + S \mid C_S$

$P ::= P \bowtie_L P \mid P/L \mid C$

where S denotes a sequential component and P denotes a model component which executes in parallel. C stands for a constant which denotes either a sequential component or a model component. C_S stands for constants which denote sequential components. The effect of this syntactic separation between these types of constants is to constrain legal

PEPA components to be cooperations of sequential processes, a necessary condition for an ergodic underlying Markov process. The following diagram shows how the PEPA language is used to generate a continues time Markov chain for performance modeling, where SOS is the structured operational semantics, CTMC is continues time Markov chain and Q is the matrix that represents it.

IV. THE UNEMPLOYMENT MODEL

The PEPA model is corresponding to the dynamics of the supply and demand of job opportunities in Egypt. The model is composed of four main sub-modules. The demand side has one module that represents the workforce and the supply side has three modules which are public sector, private sector and abroad.

A. Demand Side

Workforce module: This module consists of ten basic components namely pop, workforce, unemployment, workpublic, workprivate, workabroad, workpripub, workab-pub, returnpriv-workpublic and return-workpublic components. Population (pop) component deals with the inflow of people to the workforce and out of the system (retired) at any age; workforce (workforce) component shows the movement of employees/ workers from the population to become unemployed (unemployment) or employed in public sector (workpublic), private sector (workprivate), or abroad (workabroad). If employees/workers are seeking jobs, finished their contracts or fired, they go to the unemployed (unemployment) state and remain unemployed (unemployment) until they find a job opportunity in public sector (workpublic), private sector (workprivate), or abroad

(workabroad).workpripub, workab-pub, returnpri-workpublic and returnworkpublic components deal in particular with Egypt's case. Employees/ workers in the public sector are allowed to get secondment and work either abroad (workab-pub) or in the private sector (workpri_pub). After the secondment period, they return from private sector (returnpri-workpublic) or abroad (returnworkpublic) to their previous occupations (See Figure (2)).

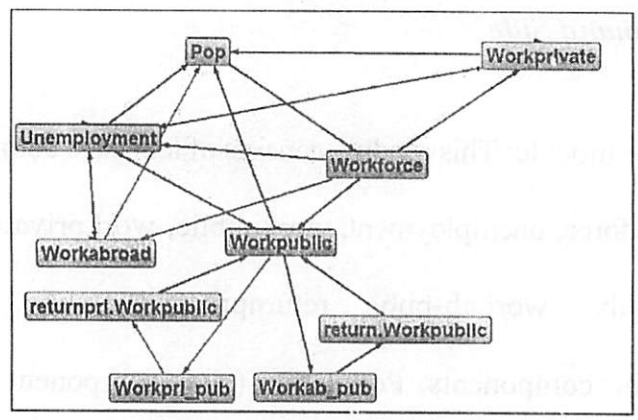

Figure (2). Demand Side: workforce module

B. Supply side

Public sector module: It has three components; Gov component that represents the state where government offers job posts; Gov_active component that represents the state when these posts are occupied; and Govloss component that represents the state, where employees occupying these posts transfer to other jobs and get secondment,

keeping their original positions to return to them after ending secondment. Public sector (Gov) can make two actions: employs workers where they go to (Gov_active) component or loses them through retirement. (see Figure (3))

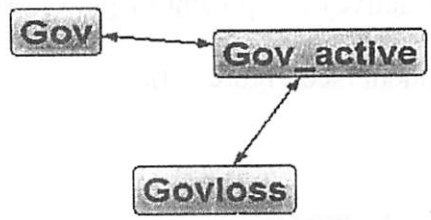

Figure (3) Supply Side: public sector module

Private module: It has two components. (Pri) component that represents the state where private sector offers jobs posts and (Pri_active) component representing the state when these posts are occupied. Employees work in the private sector and enter (Pri_active) component or get out going to (Pri) component (see Figure (4)).

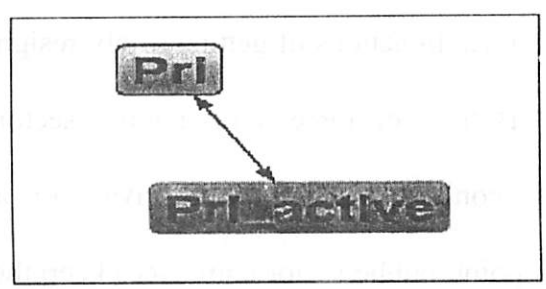

Figure (4). Supply side: private sector module

Abroad module: It is the same as private module with two components (Abro and Ab_active components). Abro component represents the state where other countries offer job posts; Ab_active component represents the state when these posts are occupied. Employees work abroad and enter (Ab_active) component or get out of this component to go to (Abro) component (see Figure (5)).

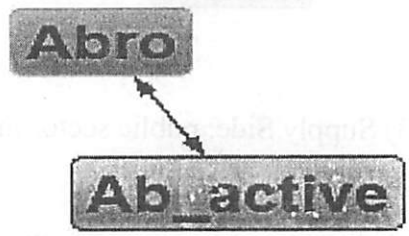

Figure (5) Supply side: abroad module

C. The complete system

The supply modules (public sector, private sector, abroad) work in parallel, while the demand sector (workforce) synchronizes with each of the supply modules in actions of getting a job, resigning or retiring from the job. Both workforce and public sector components synchronize in secondment action with private or abroad sectors modules. At that point, public sector employees keep their positions in the public sector. The PEPA representation for our system is the following:

Workforce<inpublic,inprivate,outoffer,resign_in,retir_in,prioff1,secondment,return,returnpri,resign_pri,retir_pri,resi gn_out,retir_out>

(Gov <> Pri <> Abro)

Where:

Inpublic is the action of synchronising workforce and public i.e., accepting a job offer from the public sector

Inprivate is the action of synchronising workforce and private sector i.e., accepting an offer from the private sector

Outoffer is the action of synchronising workforce and abroad i.e., accepting an offer from abroad

Resign_in is the action of synchronising workforce and public sector i.e., leaving the public sector post *Retir_in* is the action of synchronising workforce and public i.e., retiring from the public sector

Prioff1 is the action of synchronising workforce and public i.e., getting a secondment to work abroad

Return is the action of synchronising workforce and public i.e., finishing the contract of the abroad job and returning back to work in the public sector

Secondment is the action of synchronising workforce and public i.e.,

getting a secondment to work in the private sector

Returnpri is the action of synchronising workforce and public i.e., finishing the private job contract and returning back to work in the public sector

Resign_pri is the action of synchronising workforce and private i.e., resigned from the private sector and back to the unemployment state

Reti_pri is the action of synchronising workforce and private i.e., retiring from the private job

Resign_out is the action of synchronising workforce and abroad modules i.e., resigning from aboard post and back to the unemployment state

Ret_out is the action of synchronising workforce and abroad modules i.e., retiring from the abroad post.

V. EXPERIMENTS AND RESULTS

Through the analysis and solution of Markov process underlying a PEPA model, we conduct three experiments to investigate the system. To calculate variables such as entrance rate to labour force, data from the Ministry of Manpower and Migration [20] are used. The objective of these experiments besides examining the system is to test the following main questions

Main Question

Which labour market i.e., abroad, public, and private sectors does absorb more workers/employees and is stable i.e., has less turnover?

To answer this question, we test the probability that unemployment component is occupied[1] with changing few activities listed below because it reflects the steady state of the unemployment state and measures the stability of employees/workers in a post.

[1] From now on we will use the utilization terminology, that is popular in computer science, which is the probability that the system/ resource is occupied.

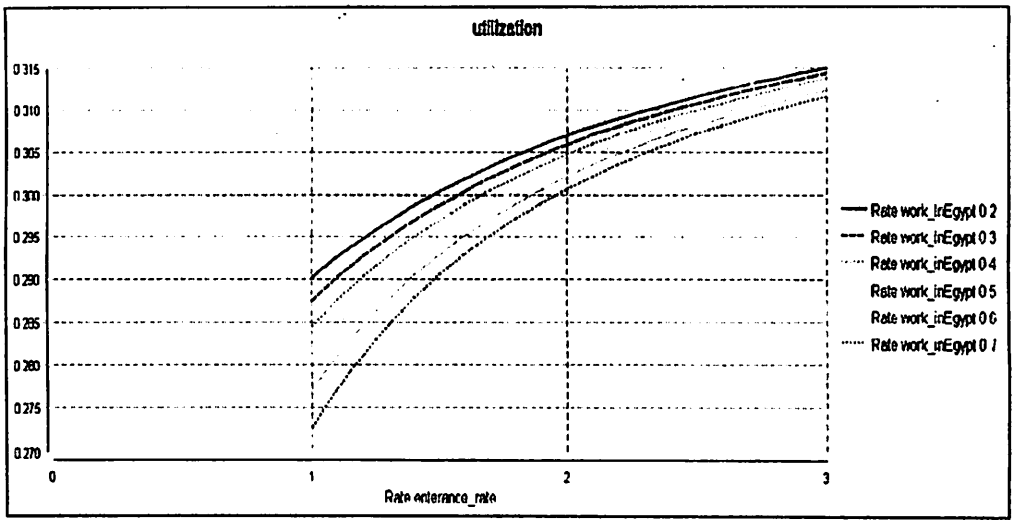

Figure (6). Utilization of the unemployment state with the change in the rate of job opportunities in Egypt and entrance rate to the workforce.

First experiment tests the utilization of the unemployment state in the system and shows the impact of increasing both the entrance rate to workforce and job opportunities in Egypt (public and private sector) on the utilization of unemployment.

Clearly from Figure (6), the utilization of the unemployment increases with the increase of the entrance rate to the workforce. If, for example, the entrance rate is doubled (corresponding to 2 in the X-axis), the probability to stay in unemployment state increases from 29% to 31%, i.e., by 2%. Furthermore, increasing the chances of working in Egypt will reduce the utilization of unemployment state. However, looking at the highest curve in Figure (6) (in red colour or

darker colour), with the increase in the job opportunities in Egypt (in public and private sectors), the utilization of unemployment state will be reduced (see Figure (6)).

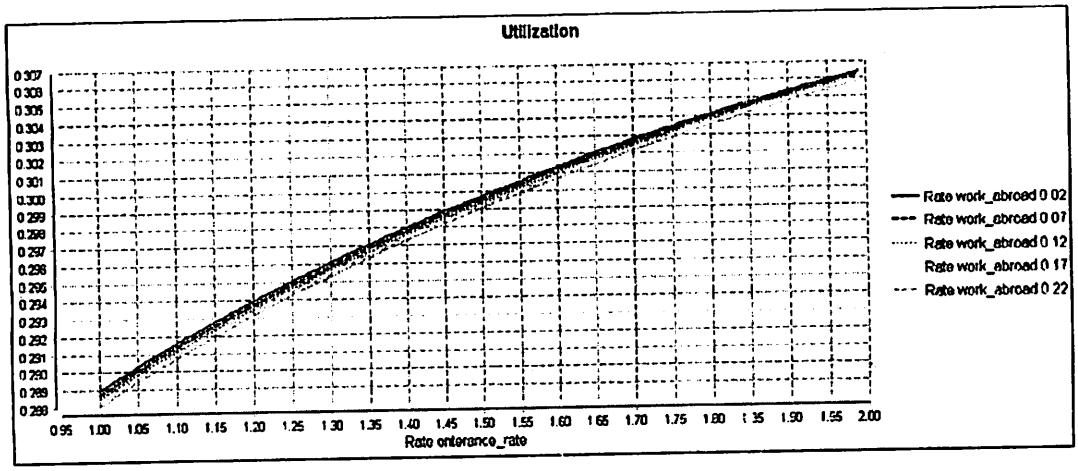

Figure (7) utilization of the unemployment resource with the change in the rate of job opportunities abroad and entrance rate to the workforce

The second experiment examines the impact of increasing both the entrance rate to workforce and job opportunities abroad on the utilization of unemployment state.

Doubling the entrance rate to the workforce will increase the probability of waiting in the unemployment state. Additionally, increasing job opportunities abroad will not have a great effect on the utilization of unemployment state (see figure (7)).

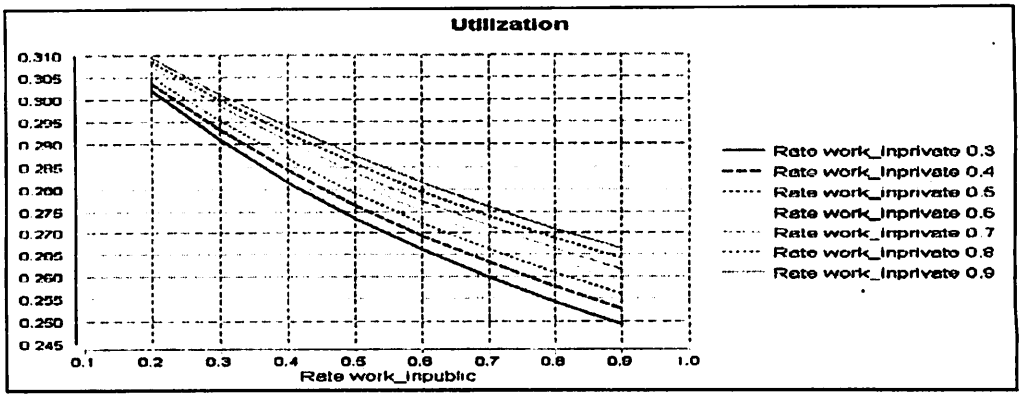

Figure (8) utilization of the unemployment resource with the change in the rate of job opportunities in public and private sectors

The results of the previous tests show that increasing job opportunities in Egypt has a positive impact on reducing the utilization of unemployment state. This result raises the question. "Which sector (public or private) has the major impact?"

Experiment three investigates the impact of increasing both job opportunities in public and private sectors on the utilization of unemployment state. Figure (8) shows that increasing job opportunities in the public sector will reduce drastically waiting in the state of unemployment from 30.2% to 24.9%. However, increasing job opportunities in the private sector from 30% to 80% will increase the case of being in the unemployment state from 30.2% to 31%, due to the job instability in the private sector.

VI. DISCUSSIONS

The experiments gave evidence that the unemployment model/system is operating properly. The utilization of unemployment state is reduced with the increase in job opportunities in Egypt, especially, in the public sector. This is an important issue for strategic decision markers to watch closely. Their target, besides reducing unemployment, is minimizing job turnovers, which is the rate of hiring and firing from a job. This problem can cause disturbance in the social status of the country as unemployed people will struggle to get their essential needs e.g., food, accommodations, and education and easily can be pushed to perform illegal acts to survive.

Consequently, to reduce the consequences of the Economic Reform and Structural Adjustment Program in 1991 (ERSAP 91), that promotes and shifts to the private sector, there is a need to encourage the growth of private sector however to focus on encouraging large numbers of labour intensive industries.

Meanwhile, the government has to play a role in applying and empowering appropriate labours' laws to reduce turnovers; furthermore, it can set programs to train employees/workers to acquire required skills to work in the private sector and abroad.

VII. CONCLUSION

To capture the fundamentals of Egyptian labour market, PEPA unemployment system/model presents the dynamic of the supply and demand of job opportunities in Egypt. The model shows the interactivity between different variables affecting unemployment problem. This model constitutes a new application area for this process algebra formalism. Although this system is simple, it allows strategic decision makers to see the impact of applying different policies.

The results of analysing the current situation showed the importance of confirming applying the appropriate labours' laws to reduce turnovers and supporting specialized training to increase employment in the abroad labour market and in the private sector.

Future work would be in extending this model and add other components related to labour and technology intensive to measure the utilization of unemployment with changing these components; additionally, it will be interesting to test the effect of setting different policies to encourage investments as well as educational and training programs on unemployment.

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استخدام نموذج تقييم أداء العمليات الجبرية PEPA لنمذجة مشكلة البطالة دراسة حالة مصر

د أماني الريس ود. آن نصير

ملخص باللغة العربية

نستخدم في هذه الورقة البحثية نموذج تقييم أداء العمليات الجبرية PEPA للتعبير عن الدينامية بين العرض والطلب على فرص العمل. و بالتركيز دراسة التوازن بين طالبي الوظائف وفرص العمل في سوق العمل في مصر. و هذا النموذج يشكل مجال تطبيق جديد لـــ PEPA.

والنموذج يبين التفاعل بين المتغيرات المختلفة التي تؤثر على مشكلة البطالة . وعلى الرغم من أن النموذج المقترح بسيط ، إلا أنه يتيح لصانعي القرار معرفة أثر تطبيق السياسات المختلفة ، مثل تأثير زيادة فرص العمل في الخارج أو الداخل (حكومي أو خاص) علي البطالة ومما أظهرته نتائج تحليل النموذج أنه بالرغم من زيادة فرص العمل في القطاع الخاص إلا أن عدم الإستقرار فيه أدي إلي عدم حدوث الانخفاض المطلوب في البطاله وهذا يؤكد على أهمية تطبيق قوانين لحماية العاملين في القطاع الخاص ، ودعم التدريب المتخصص لزيادة فرص العمل في سوق العمل.