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## DEVELOPING A PSYCHOMETRIC RULER: AN ALTERNATIVE PRESENTATION OF RASCH MEASUREMENT OUTPUT

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#### **Abstract:**

*Rasch measurement is one of the most popular analytical techniques available in the field of psychometrics. Despite the advantages of Rasch measurement, many researchers and consumers of information have noted that interpreting Rasch output can be an arduous task. The purpose of this paper is to respond to this problem by presenting an alternative method for reporting results that is arguably more user-friendly and easily interpretable by consumers of research.*

**Key words:** Psychometric Ruler; Rasch Measurement Output; Rasch model

Rasch measurement is one of the most popular analytical techniques available in the field of psychometrics and is quickly becoming the norm for instrument validation studies. The advantages of Rasch modeling have been well documented in the literature (see Wright and Stone, 1979; Wright and Stone, 1999; Smith, Jr. & Smith, 2004; and Bond & Fox, 2007). Despite the advantages of Rasch measurement, many researchers and consumers of information have acknowledged that there is much room for improvement with regard to output reporting. This is not to say measurement software creators have failed by any means, but being able to interpret Rasch output, such as the "item map" (or Wright Map), can be an arduous task. In the authors quest to more effectively convey the valuable information obtained from Rasch analyses, this work is intended to provide an alternative presentation of Rasch output that is more user-friendly and easily interpreted by consumers of research. Particularly, the authors will produce a psychometric ruler comparable to that of the physical sciences that can be interpreted in the same way.

This article will begin by providing an overview of objective measurement in the social and behavioral sciences, followed by a brief synopsis of Rasch measurement. A discussion of the psychometric ruler will be presented, followed by an explanation as to how readers can produce one from their own Rasch output. A demonstration will be provided on

a universally interesting topic, namely measuring skepticism. A presentation of the psychometric ruler will follow, accompanied by a discussion of how to interpret the results. Strengths, weaknesses and implications of the psychometric ruler will also be discussed.

## LITERATURE REVIEW

### ***Objective Measurement, Abstractions and the Imaginary Inch***

Psychometrics is the field of study that attempts to measure psychological factors, such as knowledge, abilities, attitudes, personality traits, and so on. In psychometrics, tests, surveys, and other instruments are used to quantify and measure abstract data. When most people think of measurement they think of concrete measures. For example, a person's height in inches appears to be a concrete measure. However, the inch used to measure height is a man-made idea. There is no such thing as a naturally occurring inch. Inches are simply abstractions that have taken on meaning for the purpose of generating a common frame of reference. Thurstone (1931) said:

The linear continuum which is implied in all measurement is an abstraction... there is a popular fallacy that a unit of measurement is a thing such as a piece of yardstick. This is not so. A unit of measurement is always a process of some kind which can be repeated without modification in the different parts of the measurement continuum (p. 257).

Once a common frame of reference exists, more meaning is available. When a hierarchy of some kind is produced additional meaning is provided. For example, measures from 1-10 imply that 10 is more than 9, 3 is less than 4, and so on. Also, when the distances between the measures are interval in nature, it implies that 4 is twice as much as 2, and 5 is half the amount of 10. It is these properties that many famous researchers have required for objective measurement (see Campbell's (1920) requirement for concatenation, L. L. Thurstone's Law of Comparative Judgement (1927), Guilford's (1936) definition of measurement, and Luce and Tukey's (1964) requirement for conjoint additivity).

Again, consider the example of height. Suppose we take a sample of 100 adults and measure their heights. Perhaps previous research tells us that most adults will fit into the range of 50" to 80". We do not need to develop a scale that ranges from 1 to 100 inches to describe our sample. We may wish to simply create a ruler that contains the ranges 48" to 84" and determine where within this range the top of each person's head fits on the scale. The range of 48-84" does not mean that we will not encounter people in our sample that are less than 48" tall or greater than 84" tall. This range is simply a useful criterion for measuring the average range of heights for adults. It is important to understand that whatever the range of the scales we used, the meaning of the inch as it relates to height does not change.

When we make measures of mental constructs we must adhere to the same criteria. When we administer a test or a survey, our common frame of reference is its items. Like a ruler, items must be placed along a continuum, a hierarchy ranging from easy to difficult (to endorse). Just as Guttman (1944) realized a test score is ambiguous without understanding the response pattern of the scores represented, we must also realize the probabilistic nature

of the interactions between the persons and items. That is, a more able person always has a greater probability of getting particular items correct than someone who is less able. Conversely, an item that is very difficult will always have a greater probability of being answered incorrectly than a less difficult item. When measuring the mental construct of "ability" an estimate can be established based on the difficulty level of a particular item along with how an individual responds to that item. The same concept can be extended to surveys and non-tests scenarios where one is concerned with measuring a person's agreeability to statements that contain their own varying degree of difficulty to endorse.

### **Rasch Measurement**

The Rasch family of models are the only psychometric models that meet the requirements for objective measurement. Rasch models are logistic, latent trait models of probability for monotonically increasing functions. Unlike statistical models that are developed based on data, Rasch measurement models are static models that are imposed upon data. Rasch models assume the probability of a respondent agreeing with a particular item is a logistic function of the relative distance between the person and item location on a linear continuum. Dichotomous and polytomous versions of the model are available, and can be extended into various scenarios. With survey research, polytomous models are often employed. When a survey utilizes a rating scale that is consistent with regard to the number of response options (i.e., a 5-point rating scale for all items), the Rating Scale Model (Andrich, 1978) would be the appropriate model to apply. The formulae for the Rating Scale Model are presented below:

$$\ln (P_{nij}/P_{ni(i-1)}) = B_n - D_i - F_i$$

where,

$P_{nij}$  is the probability that person  $n$  encountering item  $i$  is observed in category  $j$ ,

$B_n$  is the "ability" measure of person  $n$ ,

$D_i$  is the "difficulty" measure of item  $i$ , the point where the highest and lowest categories of the item are equally probable.

$F_i$  is the "calibration" measure of category  $j$  relative to category  $j-1$ , the point where categories  $j-1$  and  $j$  are equally probable relative to the measure of the item. No constraints are placed on the possible values of  $F_j$ .

Researchers who employ Rasch analysis techniques are largely concerned with the extent to which observed data match what is expected by the model. An evaluation of fit statistics provides key indicators of how well the data fit the model, helping to establish content validity. With survey data, it is critically important that the rating scale is functioning well. An evaluation of rating scale functioning should include confirmation that response options provide some form of ordering and each response option can be distinguished from all other options, thus illustrating that respondents were able to clearly identify the difference between each rating scale category. These quality control checks ensure both the structural and communicative validity of the rating scale.

Because Rasch measurement is not sample dependent, it is expected that the scale would work in the same manner regardless of the sample. For example, males and females who have the same endorsability level should have the same probability of endorsing an item. Therefore, if results revealed males responded to a particular item differently than females, the item would be exhibiting differential item functioning (DIF), therefore possibly

biasing results. Naturally, items that exhibit DIF should be considered for removal as they impede the production of objective scales. Once all necessary quality control checks have been completed and sufficient evidence for validity exists, items can be mapped to produce a hierarchy which speaks to the construct validity of the measures. It is this hierarchy that will be presented in an alternative manner in this work.

**Purpose/Objective**

The purpose of this study was to provide a demonstration of Rasch measurement and construct a user-friendly and easily interpretable alternative representation of the psychometric ruler resulting from Rasch measurement output. Although the psychometric ruler presented here is largely metaphorical in nature, it does possess the properties and characteristics of a ruler used in the physical sciences. That is, abstract ideas and mental constructs are plotted along a physical ruler to distinguish the psychometric properties of each item in relation to the other. It is the researchers' intentions that presenting results in the manner presented in this work will aid in the understanding of Rasch measurement output, particularly the output produce from Rasch-based item maps.

**METHODOLOGY**

**Sample and Data Source**

In 2010, renowned sociologist Dr. Peter Nardi published a study of magicians' beliefs about the paranormal. He was particularly interested in learning to what extent magicians believed various paranormal phenomena were possible. Nardi hypothesized that magicians would make a very interesting research sample because they are either true believers of paranormal phenomena, or because they are essentially "in on the secrets", the biggest skeptics of all. Nardi administered a web-based survey in various magician Websites, discussion boards, and Internet chat rooms and was able to obtain a sample of 227 responses. The lead researcher contacted Dr. Nardi and requested his data. Dr. Nardi kindly obliged and promptly sent the complete dataset and codebook. It is from this secondary source that the data in this study were obtained.

**The Psychometric Ruler**

Creating a psychometric ruler involves transforming raw scores to interval measures. Winsteps measurement software (Version 3.69) was used to perform the Rasch analysis in this study (Linacre, 2010). Winsteps software produces measures, called logits, for each person and item in the dataset. In order to create a continuum that is meaningful and easy for interpretation, logits often need to be rescaled. Here, the minimum item logit value was -1.67 and the maximum item logit value was 1.02. A rescaling procedure was conducted that placed the minimum logit at 1 and the maximum logit at 10 on the new scale (although this could easily be presented in the opposite manner should a researcher choose). The formula for the transformation of logits to a scaled score is as follows:

- SS = m (Di) + b, where
- SS = Scaled Score
- m = slope
- Di = item difficulty estimate
- b = intercept



To convert item difficulty estimates to the present scale (1-10), the following formula was used:

$$\text{Rescaled Logit Value} = (3.3457 * Di) + 6.5874$$

All rulers require units of measures that are equidistant throughout the scale. Here, scaled scores constitute the units that would be considered inches on a typical ruler. Scaled scores range from 1-10 in this example. Additionally, within each of these scaled score units are additional units that are increments of 10 (whereas an actual ruler would contain increments of eight). These subunits represent 1/10 of a scaled score. The purpose of using increments of 10 is for easy interpretation, as most people are comfortable with scales that range from 0-10, 1-10, 1-100, 100-1,000, and so on.

## **RESULTS AND DISCUSSION**

Whenever Rasch analyses are performed a series of quality control checks must be performed. Largely, these checks evaluate the extent to which observed data fit the model's expectations. Additional checks evaluate the structure and quality of the rating scale, quality of items, and other diagnostics. However, because the purpose of the present study is not to present content findings from a data analysis, per se, the majority of these critical steps of Rasch analysis will not be presented in this study. Instead, results will focus only on information relevant to the alternative presentation of results as guided by the purpose of this study.

### ***Item Statistics***

Item statistics for the original Rasch output are presented in table 1.

Table 1

#### *Item Logit Values*

Items	Measure	SE
Channeling (spirit controlling a person in a trance)	1.02	.13
Astrology	.81	.12
Communication with the Dead	.74	.12
Bigfoot (Sasquatch)	.74	.12
Loch Ness Monster	.68	.13
Reincarnation	.44	.11
Clairvoyance (Predict the Future)	.36	.11
Ghosts	.07	.10
Haunted Houses	.07	.10
UFOs	-.01	.10
ESP (Extra Sensory Perception)	-.32	.09
Creationism or Intelligent Design	-.89	.09
Devil	-1.00	.09
Angels	-1.07	.10
Life After Death	-1.67	.11

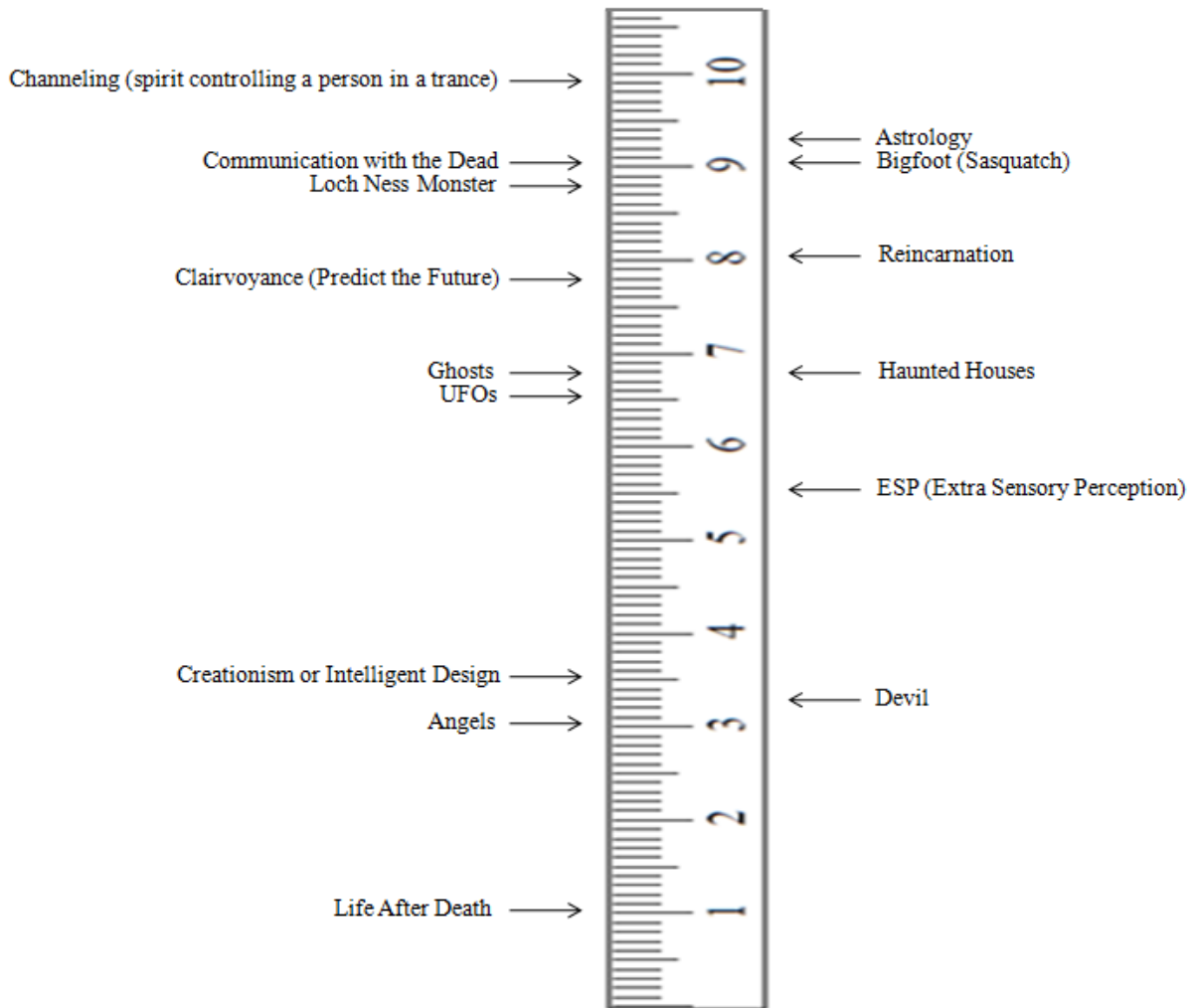
After performing the rescaling procedure mentioned previously, the rescaled logit values are presented in table 2. Note, Winsteps software has a function that can automatically rescale values without having to use the manual formula presented in the methodology section. Also, it is apparent that identical values in table 1 may appear slightly different in table 2. This is because logit values presented in these tables have been rounded to two decimal places. Full logits values were used when transforming to a score, thus why results differ slightly in table 2.

Table 2

<i>Items Rescaled</i>		
Items	Measure	SE
Channeling (spirit controlling a person in a trance)	10.00	.45
Astrology	9.30	.40
Communication with the Dead	9.08	.40
Bigfoot (Sasquatch)	9.05	.41
Loch Ness Monster	8.87	.42
Reincarnation	8.05	.37
Clairvoyance (Predict the Future)	7.81	.36
Ghosts	6.84	.34
Haunted Houses	6.83	.33
UFOs	6.56	.34
ESP (Extra Sensory Perception)	5.52	.32
Creationism or Intelligent Design	3.63	.32
Devil	3.25	.32
Angels	3.01	.32
Life After Death	1.01	.36

***Psychometric Ruler***

As mentioned previously, item logit measures were rescaled to fit a continuum ranging from 1– 10. Although this is purely for metaphorical and illustrative purposes, a physical ruler was created that contained the psychometric values for each item from Table 2. This ruler allows one to visualize the psychometric distance between each item as it relates to the extent to which magicians believed in each of the following (See Figure 1).



To interpret the ruler, first identify the items that appear at the extreme ends. At 1.0, the item *Life After Death* is present. This indicates survey respondents believe this is the easiest item to endorse relative to the others presented on this survey. Located at the other end of the ruler (value of 10.0) is the item *Channeling (spirit controlling a person in a trance)*. Survey respondents believe this item is the most difficult to endorse (or agree with) relative to the other items presented on this survey. Notice, a hierarchical pattern is present. Items appearing near the bottom of the ruler are indicated to be the easiest to endorse, or in this case believe in, whereas items at the top of the ruler are believed to be the most difficult to endorse (or believe in).

The purpose of this study was to construct a physical ruler for psychological constructs and ideas in order to demonstrate both what is possible in the arena of psychometrics and at the same time produce an alternative presentation of Rasch output results. By examining the ruler one can see that some of the items appearing in close proximity to one another share a conceptual relationship. For example, all items below the "4" mark appear to have a religious or spiritual correlation. Similarly, between (approximately) 6.5 and 7.0, *haunted houses* and *ghosts* appear in close proximity. Additionally, between (approximately) 8.5 and 9.0 *Bigfoot* and the *Loch Ness Monster* appear close together on the scale. Being able to visualize these conceptual relationships allows readers to better interpret results, and

perhaps develop a more meaningful interpretation of results that are presented solely by numbers.

## **CONCLUSION & LIMITATIONS**

Rulers are such a common symbol in the U.S. society that one would be hard-pressed to find someone who cannot relate to the concept. For this reason, the authors contend that interpreting the psychometric ruler is easy and intuitive. It is the authors' hope that even persons with an aversion to quantitative methods might have an appreciation for the psychometric ruler.

For this demonstration the topic of skepticism was measured. This topic was selected because of its universal appeal, as opposed to a specific content area which may or may not resonate as well with readers. Despite the advantages mentioned in this work, these authors would like to caution that the psychometric ruler is purely metaphorical. Although the psychometric ruler contains many of the properties of a physical ruler (i.e., starting/ending points, interval scaling, precise subsampling, etc.), some elements are not as easily transferrable. For instance, the psychometric ruler ranged from 1 to 10. In actuality, this ruler could have been scaled to any range. Therefore, one cannot say that an item that appears at 10.0 is 10 times greater (or perhaps more intense) than an item that appears at 1.0.

From a Rasch measurement perspective, however, perhaps the greatest limitation of this particular psychometric ruler is only half the information are presented from an actual Rasch measurement software-produced item map. Item maps are particularly useful in presenting the invariant interaction of both persons and items. Probabilities that an individual will correctly answer a test item or endorse a survey item can all be approximated from the item map. The use of the psychometric ruler in this research presents only the item side of the map. Depending upon where the mean of the person distribution falls on the actual item map would determine to what extent persons were able to endorse each item. Although this information is absent in the psychometric ruler, meaningful interpretation of item results can still be made. However, it is pertinent to point out that those who utilize Rasch measurement software will already have full item map output prior to constructing a psychometric ruler like that proposed in this study. Therefore, researchers always have the option to present the results as currently produced by the software, or to produce a psychometric ruler for more user-friendly displays.

An additional, yet minor, limitation of the psychometric ruler (as proposed here) pertains to the nature of difficulty estimates produced from the Rasch analysis. For example, when several items have difficulty estimates that are in close proximity to one another, their proximity on the psychometric ruler will still be very close together even after a re-scaling procedure has been performed. Because all measures have some error associated with them, items that appear at virtually identical locations on the ruler might actually appear in a slightly different order depending on the effects of error. This is inevitable for all measurement. However, in all instances it is good practice to always report both item difficulty measures and standard errors for each item so that readers may better investigate the precision of measurement and have a more informed perspective about the extent to which the psychometric ruler is valid.

In sum, Rasch measurement output has historically been criticized for what some believe to be difficult output to interpret. It is the authors' hope that the preceding demonstration can aid others in their pursuit to conduct better measurement of abstract data and produce more meaningful and user-friendly output for audiences in various arenas.

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# REVISITING THE RELATIONSHIP BETWEEN SHADOW ECONOMY AND THE LEVEL OF UNEMPLOYMENT RATE. A SVAR EMPIRICAL INVESTIGATION FOR THE CASE OF UNITED STATES

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### Abstract:

*The paper analyses the relationship between shadow economy and unemployment rate using a Structural VAR approach for quarterly data during the period 1982-2011. The size of the shadow economy as % of official GDP is estimated using a Structural Equation Approach with quarterly data for the period 1982-2011. Thus, the shadow economy is modeled like a latent variable using a special case of the structural equation models-the MIMIC model. His dimension is decreasing over the last two decades.*

*The relationship between the two variables is further tested by imposing a long-run restriction in the Structural VAR model to analyze the impact of the shadow economy to a temporary shock in unemployment. The impulse response function generated by the Structural VAR confirms that in the short-run, a rise in the unemployment rate in formal sector will lead to an increase in the number of people who work in the shadow economy.*

**Key words:** shadow economy, unemployment rate, MIMIC model, Structural VAR, United States.

## 1. INTRODUCTION

The relationship between the shadow economy and the level of unemployment is one of major interest. People work in the shadow economy because of the increased cost that firms in the formal sector have to pay to hire a worker. The increased cost comes from the tax burden and government regulations on economic activities. In discussing the growth of the shadow economy, the empirical evidence suggests two important factors: (a) reduction in official working hours, (b) the influence of the unemployment rate.

Enste (2003) points out that the reduction of the number of working hours below worker's preferences raises the quantity of hours worked in the shadow economy. Early retirement also increases the quantity of hours worked in the shadow economy.

Also, Boeri and Garibaldi(2003) show a strong positive correlation between average unemployment rate and average shadow employment across 20 Italian regions during the period 1995-1999.

Giles and Tedds (2002) state that the effect of unemployment on the shadow economy is ambiguous (i.e. both positive and negative). An increase in the number of unemployed increases the number of people who work in the black economy because they have more time. On the other hand, an increase in unemployment implies a decrease in the shadow economy. This is because the unemployment is negatively related to the growth of the official economy (Okun's law) and the shadow economy tends to rise with the growth of the official economy.

Dell'Anno and Solomon(2006) found a positive relationship between unemployment rate and shadow economy, showing that a positive aggregate supply shock will cause an increase in the shadow economy by about 8% above the baseline.

The paper analyzes the relationship between SE and UR using a structural VAR approach (SVAR).The paper is divided into two sections presenting the data, and the methodology and also the main econometrical results.

## **2. DATA AND METHODOLOGY**

### **2.1. Data**

In the econometrical demarche of the investigation of the relationship between U.S. shadow economy (SE) and unemployment rate (UR), we used quarterly data seasonally adjusted covering the period 1982:Q1 to 2011:Q2.

The size of the shadow economy (SE) as % of official GDP was obtained applying the MIMIC model, that allows to consider the SE as a "latent" variable linked, on the one hand, to a number of observable indicators (reflecting changes in the size of the SE) and on the other, to a set of observed causal variables, which are regarded as some of the most important determinants of the unreported economic activity (Dell'Anno, 2003). A detailed description of the estimation methodology is presented in Alexandru and Dobre (2010).The 4-1-2 MIMIC model with four causal variables (taxes on corporate income, contributions for government social insurance, unemployment rate and self-employment) and two indicators (index of real GDP and civilian labour force participation rate) is chosen to be the best model for the U.S. shadow economy.

The empirical results point out that the shadow economy measured as percentage of official GDP records the value of 13.41% in the first trimester of 1982 and follows an ascendant trend reaching the value of 16.77% in the last trimester of 1984.

At the beginning of 1985, the dimension of USA shadow economy begins to decrease in intensity, recording the average value of 6% of GDP at the end of 2009. For the last two years 2010 and 2011, the size of the unreported economy increases slowly, achieving the value of 7.3% in the second quarter of 2011. The results of this estimation are not far from the last empirical studies for USA (Schneider 1998, 2000, 2004, 2007, Schneider and Enste 2001).Schneider estimates in his last study, the size of USA shadow economy as average 2005/06, at the level of 7.9 percentage of official GDP.



The series of unemployment rate expressed in % was seasonally adjusted taken from Bureau of Labour Statistics.

Analyzing the graphical evolution of the both variables, it can be point out that we have a strong direct relationship between SE measured as % of official GDP and the UR.

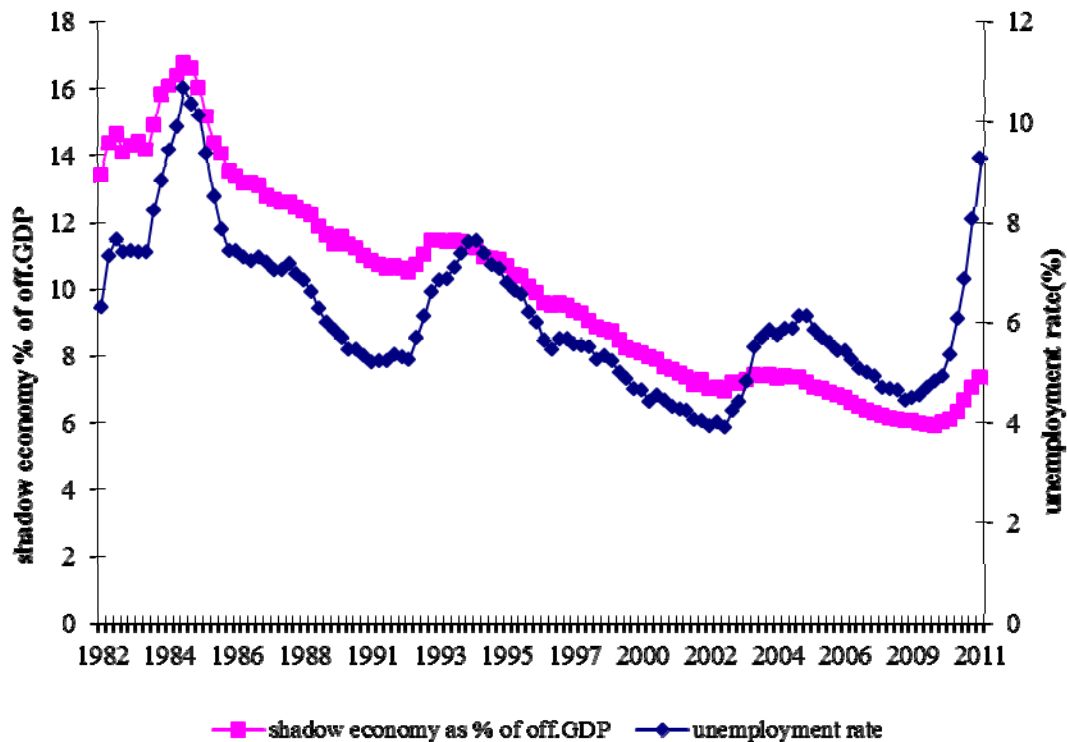


Fig.1. Shadow economy vs. unemployment rate

## 2.2. Methodology

After we estimate the size of the shadow economy, we investigate the existence of a structural relationship between shadow economy and unemployment in order to extract information on aggregate supply and aggregate demand disturbances. We use the Structural Vector Autoregression Approach (SVAR) to isolate disturbances as developed by Blanchard and Quah(1989).

The structural VAR methodology with long-run restrictions proposed by Blanchard and Quah(1989) does not impose restrictions on the short-run dynamics of the permanent component of output, but incorporates a process for permanent shocks that is more general than a random walk. Also, the methodology provides an alternative way to obtain a structural identification. Instead of associating each disturbance ( $\epsilon_t$ ) directly with an individual variable, they consider the shocks as having either temporary or permanent effects. They then treat these shocks like exogenous variables. The objective is to decompose real GNP into its temporary and permanent components. Economic theory is used to associate aggregate demand shocks as being the temporary shocks and aggregate supply shocks as having permanent effects. Using a bivariate VAR, Blanchard and Quah(1989) show how to decompose real GNP and recover the two pure shocks that cannot otherwise be quantified.

In the same manner, we consider a Vector Autoregression representation of a system composed by two variables that are the first differences of the shadow economy (SE) and

unemployment rate (UR). The Blanchard - Quah technique requires that both variables must be stationary.

Thus, the two variables that compose VAR are:

$$X_t = \begin{bmatrix} \Delta SE_t \\ \Delta UR_t \end{bmatrix} \quad (1)$$

The classical VAR can be writing as:

$$\Delta SE_t = b_{10} - b_{12} \Delta UR_t + \gamma_{11}^1 \Delta SE_{t-1} + \gamma_{12}^1 \Delta UR_{t-1} + \dots + \gamma_{11}^p \Delta SE_{t-p} + \gamma_{12}^p \Delta UR_{t-p} + \varepsilon_{dt} \quad (2)$$

$$\Delta UR_t = b_{20} - b_{21} \Delta SE_t + \gamma_{21}^1 \Delta SE_{t-1} + \gamma_{22}^1 \Delta UR_{t-1} + \dots + \gamma_{21}^p \Delta SE_{t-p} + \gamma_{22}^p \Delta UR_{t-p} + \varepsilon_{st} \quad (3)$$

We can re-write the above equations in a matrix form:

$$\begin{bmatrix} 1 & b_{12} \\ b_{21} & 1 \end{bmatrix} \begin{bmatrix} \Delta SE_t \\ \Delta UR_t \end{bmatrix} = \begin{bmatrix} b_{10} \\ b_{20} \end{bmatrix} + \begin{bmatrix} \gamma_{11}^1 & \gamma_{12}^1 \\ \gamma_{21}^1 & \gamma_{22}^1 \end{bmatrix} \begin{bmatrix} \Delta SE_{t-1} \\ \Delta UR_{t-1} \end{bmatrix} + \dots + \begin{bmatrix} \gamma_{11}^p & \gamma_{12}^p \\ \gamma_{21}^p & \gamma_{22}^p \end{bmatrix} \begin{bmatrix} \Delta SE_{t-p} \\ \Delta UR_{t-p} \end{bmatrix} + \begin{bmatrix} \varepsilon_{dt} \\ \varepsilon_{st} \end{bmatrix} \quad (4)$$

Furthermore, in general form it becomes:

$$BX_t = \Gamma_0 + \Gamma_1 X_{t-1} + \dots + \Gamma_p X_{t-p} + \varepsilon_t \quad (5)$$

where:

$X_t$  is a vector of the two considered variables,  $\Gamma_t$  are the matrices of coefficients,  $p$  lags are considered and  $\varepsilon_t$  is the vector of error terms.

By multiplying with the inversion of B matrix ( $1 - b_{12}b_{21} \neq 0$ ) we obtain:

$$X_t = B^{-1}\Gamma_0 + B^{-1}\Gamma_1 X_{t-1} + \dots + B^{-1}\Gamma_p X_{t-p} + B^{-1}\varepsilon_t \quad (6)$$

$$\text{Further, } X_t = A_0 + A_1 X_{t-1} + \dots + A_p X_{t-p} + e_t \quad (7)$$

$$X_t = A(L)X_t + e_t \quad (8)$$

Since the demand-side and supply-side shocks are not observed, the problem is to recover them from a VAR estimation. The critical insight is that VAR residuals are composites of pure innovations  $\varepsilon_{dt}$  and  $\varepsilon_{st}$ .

In the particular bivariate moving average form, the VAR can be written:

$$\begin{bmatrix} \Delta SE_t \\ \Delta UR_t \end{bmatrix} = \sum_{i=0}^{\infty} L^i \begin{bmatrix} b_{11i} & b_{12i} \\ b_{21i} & b_{22i} \end{bmatrix} \begin{bmatrix} \varepsilon_{dt} \\ \varepsilon_{st} \end{bmatrix} \quad (9)$$

The vector  $\varepsilon_t = \begin{bmatrix} \varepsilon_{dt} \\ \varepsilon_{st} \end{bmatrix}$  contains the two structural shocks, the demand one and the

supply one. The elements  $b_{11i}$  and  $b_{21i}$  are the impulse responses of an aggregate demand shock on the time path of the shadow economy and unemployment rate. The coefficients  $b_{12i}$  and  $b_{22i}$  are the impulse responses of an aggregate supply shock on the time path of shadow economy and unemployment rate respectively.

According to Blanchard and Quah, the key is to assume that one of the structural shocks has a temporary effect on  $\Delta SE$ . We assume that an aggregate supply (unemployment rate) shock has no long-run effect on shadow economy. In other words, we impose a long-run restriction on the relationship between the observed data (SE) and the unobserved structural shock ( $\varepsilon_{st}$ ) such that:

$$\sum_{i=0}^{\infty} b_{12i} = 0 \tag{10}$$

Equation (10) is an Aggregate Supply Shock stating that the second structural shock (aggregate supply) has no long-run effect on shadow economy.

### 3. EMPIRICAL RESULTS

In order to analyze the nature of the relationship between the two variables, we use the Structural VAR approach, for Blanchard and Quah(1989) methodology. In order to identify supply and demand shocks, we start by running a bivariate VAR model.

Both variables included in the VAR analysis, are suspected to have a unit root. To verify this, ADF and PP unit root tests were applied; the results are presented in table 1. The size of the shadow economy seems to be stationary in ADF test at level, but this is not justified by PP test. Furthermore, both tests reveal that the variables are non-stationary at their levels but stationary at their first differences, being integrated of order one, I(1).

**Table 1. ADF and PP tests for Unit Root analysis**

		Shadow Economy(SE)			Unemployment rate(UR)		
		T&C	C	None	T&C	C	None
Level	ADF	-3.09	-1.39	-1.68***	-1.03	-2.14	-0.22
	lag	(3)	(3)	(6)	(1)	(1)	(1)
	PP	-2.26	-0.92	-1.61	-1.41	-1.69	0.03
	lag	(6)	(6)	(6)	(6)	(6)	(7)
First diff.	ADF	-3.43*	-3.39**	-3.33*	-4.40*	-4.17*	-4.17*
	lag	(2)	(2)	(2)	(0)	(0)	(0)
	PP	-6.99*	-6.97*	-6.73*	-4.69*	-4.52*	-4.53*
	lag	(5)	(5)	(6)	(3)	(3)	(3)

Note:

<sup>a</sup> T&C represents the most general model with a drift and trend; C is the model with a drift and without trend; None is the most restricted model without a drift and trend. Numbers in brackets are lag lengths used in ADF test (as determined by SCH set to maximum 12) to remove serial correlation in the residuals. When using PP test, numbers in brackets represent Newey-West Bandwidth (as determined by Bartlett-Kernel).

<sup>b</sup> Both in ADF and PP tests, unit root tests were performed from the most general to the least specific model by eliminating trend and intercept across the models (See Enders, 1995: 254-255).

<sup>c</sup> \*, \*\* and \*\*\* denote rejection of the null hypothesis at the 1%, 5% and 10% levels respectively.

<sup>d</sup> Tests for unit roots have been carried out in E-VIEWS 6.0.

Because the both series are integrated of the same order,  $I(1)$  we will difference the variables and we introduce the first difference in the VAR analysis. Including a sufficient number of lags to eliminate serial correlation from the residuals is crucial as using a lag structure that is too parsimonious can significantly bias the estimation of the structural components.

While according to SC and HQ criterions the optimal number of lags is found to be 1, AIC, LR and FPE criterions state that the optimal lag length is 4. Since the usual advice is that when quarterly data are available a minimum length of four is necessary and in order to be sure that through the number of chosen lags the residuals do not remain with autocorrelation, we have selected the optimal number of lags to be 4.

We have estimated a VAR model with four lags who verifies the stability condition<sup>1</sup>. Furthermore, we impose on this VAR a long-run restriction which specifies that the long run effect of the supply shocks on the shadow economy is null. Starting from this model, we analyze the impulse response function for the structural version of the model.

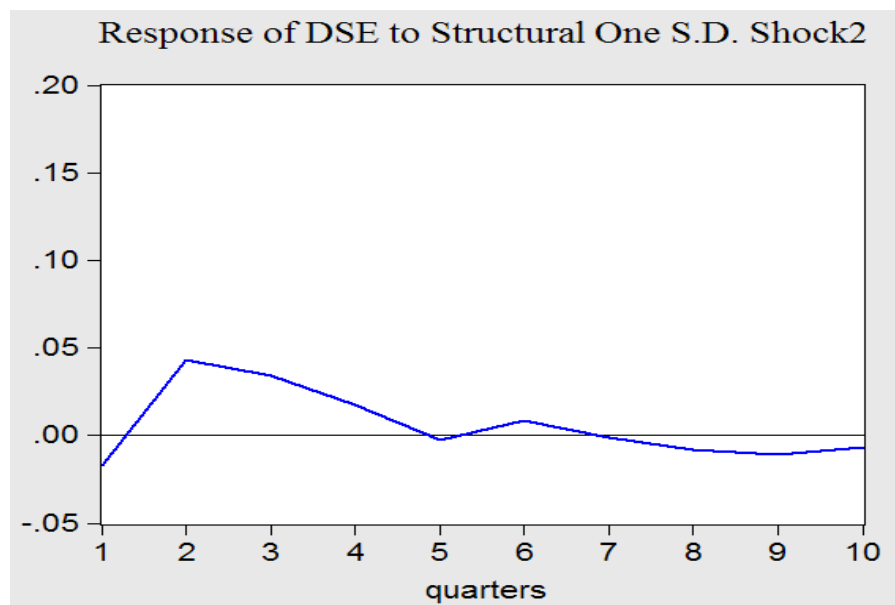


Fig 2. Effect of an aggregate Supply Shock on the size of the Shadow Economy

In the short-run, the positive aggregate supply shock causes a rise in the shadow economy by about 5% above the baseline. This occurs in the second quarter following the initial shock. Subsequently there is a steady decline towards the baseline until the first quarter of the second year. It can be observed that in second quarter of the year, the size of the shadow economy as % of official GDP fits on a slightly upward slope, but lower than the initial rise. Further, we have a gradually downward tendency until the end of the period.

The interpretation that we might derive from here could be the following; Assuming that the hypothesis according to which there is a strong and positive correlation between the size of the shadow economy measured as % of a country's GDP and the unemployment rate is valid then, we might conclude from here that employment in the shadow economy

<sup>1</sup> Since each VAR represents a system of linear first-order difference equations, it is stable only if the absolute values of all eigenvalues of the system matrix lie inside the unit circle.

constitutes a form of labor market transition between or rather from unemployment back into formal employment.

In other words one might also conclude that an unemployed worker dislocated by the shock from the formal economy, while being unemployed finds, via employment in the shadow economy a way of updating its skills and competencies and thus facilitates his or her own return into formal employment. This also can serve as to validate a rather less punitive approach towards undeclared work, more into the line of the "emersione" (surfacing) techniques adopted in Italy.

Severe recessions typically produce strong labor market recoveries. If growth continues, it may soon lead to more hiring. The second quarter of 2010 brought an end to a run of five consecutive quarters of extraordinary productivity growth as firms generated more output with fewer workers. That strategy may now be running out of road. Between April and June businesses sharply increased the number of hours worked by employees, which is often a prelude to hiring new workers<sup>2</sup>.

#### 4. CONCLUSIONS

In this paper, a structural VAR methodology with long-run restrictions was applied to analyze to relationship between shadow economy and unemployment rate for the case of United States.

The size of the shadow economy estimated using the MIMIC model is decreasing over the last two decades, from thirteen to seventeen percent between 1982 and 1985 up to 7 % of official GDP at the end of 2011.

The impulse response function generated by the Structural VAR confirms that in the short-run, a rise in the unemployment rate in formal sector will lead to an increase in the number of people who work in the shadow economy.

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## SIMULATION MODEL OF A SERIAL PRODUCTION SYSTEM

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### Abstract:

*A simulation model describing serial production is outlined. Production process is carried out under random disturbances. The control algorithm of the model is based on the analysis of essential states. Decision-making is based on preference rules. The model can be applied to all types of working shops or sections.*

**Key words:** serial production; simulation model; preference rules; method of essential states; randomised rules.



## 1. INTRODUCTION

Let us consider a simulation model describing serial production at a working shop or section [1,2]. Assume that the shop consists of  $L$  groups of equipment, each of which  $\ell_h$ ,  $h=1,2,\dots,L$ , having  $m_h$  machines or units of the same type. During the planning horizon  $[T_0, T_{pl}]$ ,  $N$  batches of parts are processed within the shop, each consisting of  $n_i$ ,  $i=1,2,\dots,N$ , parts of the same type. Directive time limits  $T_i$  are set for operating each batch.

An arbitrary part  $D_i$  in the  $n_i$ -th batch goes through a certain number of operations  $O_{ij}$ ,  $j=1,2,\dots,Q_i$ , on different groups of equipment, different operations possibly being performed on one and the same group of equipment,  $\ell_{j_1} = \ell_{j_2}$ .

Each technological operation is characterized by a number for the group of equipment and the duration of the operation (values  $\ell_j$  and  $t_{ij}$ ). All operations on part  $D_i$  are carried out in a definite technological sequence  $\{O_{ij}\}$ ,  $j=1,2,\dots,Q_i$ , which must not be disrupted.

Each group of machines in the  $\ell_h$ -th group of equipment handles a queue of parts waiting to be processed on that group of machines. The queue discipline at moment  $t$  is formed by randomized preference rules, i.e., parts are assigned for processing at a frequency in proportion to the value of preference function  $F(p_i)$ .

It is convenient to assume the preference function equal to a value inversely proportional to the position rank of part  $p_i$ , denoting the deadline time required to accomplish processing the part by symbol  $T_i$ . The position rank may be then calculated by

$$p_i = \delta \left( T_i - \sum_{j \in A_i} t_{ij} - t \right), \quad (1)$$

$$\text{where } \delta = \begin{cases} 1 & \text{when } T_i - \sum_{j \in A_i} t_{ij} - t \geq 0, \\ 0 & \text{otherwise.} \end{cases}$$

Here  $t$  denotes the current moment of time,  $A_i$  stands for the set of operations on the  $i$ -th part still being uncompleted. The preference function is determined by

$$F(p_i) = \frac{n_i}{p_i \cdot \sum_{i \in B} \frac{n_i}{p_i}}, \quad (2)$$

where  $B$  denotes the set of parts on queue at moment  $t$  when rank position  $p_i$  ( $i \in B$ ) is calculated, and  $n_i$  stands for the number of parts of the  $i$ -th batch unprocessed.

## 2. THE SIMULATION ALGORITHM

The simulation model's algorithm is based on the following information about each batch of parts stored in a separate Array I:

- $i$  is the number of the batch of parts;
- $T_i$  is the directive deadline for processing the batch;
- $n_i$  is the quantity of parts in the batch;
- $\ell_j, t_{ij}$  are the numbers of groups of equipment and the time for performing the operation on the machines of the group (placed in order for the technological processing of the parts), respectively.

A separate Array II provides information on the groups of equipment, which includes the number of the group of equipment  $\ell_j$  and the number of units of equipment  $m_j$ .

The algorithm simulates advancement of parts from operation to operation, as well as processing of parts; in particular, it simulates the corresponding changes of information about the part. This includes  $i$ , the number of the batch;  $f_i$ , the number of the part in the batch;  $O_{ij}$ , the number of the routine operation on the part; and  $t_{i,j-1}$ , the termination moment of the preceding operation.

By storing and processing this information, we can simulate the individual processing of each part in the batch and obtain the total characteristics necessary for simulating the system as a whole.

We will employ the following symbols for recording the flow chart of the simulation model's algorithm:  $A$  denotes calculating blocks,  $F$  - blocks for simulating random variables,  $T$  - blocks for transforming and processing information;  $L$  - blocks for checking logical conditions,  $K$  is a counter, and  $Z$  is the block for terminating computation and providing final results of the simulation. Symbol  $A^m$  means that upon the block's completing the procedure, we must unconditionally proceed to block  $m$ . Also,  $L^{m,n}$  testifies that a check of logical conditions is required, and depending on its results, go to either block  $m$  or  $n$ . In all other cases, when the corresponding index in the upper right part of the block is absent, proceed to the next block of the algorithm. The index in the lower right part of each block designates its ordinal number in the logical structure of the algorithm.

This is the flow chart of the simulation model's algorithm:

$T_1$   $T_2$   $L_3^{1,4}$   $T_4$   $T_5$   $T_6$   $A_7$   $L_8^{6,9}$   $T_9$   $F_{10}$   $L_{11}^{9,12}$   $L_{12}^{5,13}$   $T_{13}$   $T_{14}$   $T_{15}$   $L_{16}^{17,18}$   $T_{17}$   $L_{18}^{15,19}$   
 $T_{19}$   $F_{20}$   $L_{21}^{19,22}$   $T_{22}$   $A_{23}$   $L_{24}^{22,25}$   $T_{25}^{26,27}$   $A_{26}^{23}$   $T_{27}$   $L_{28}^{22,27}$   $L_{29}^{13,30}$   $L_{30}^{31,32}$   $A_{31}^{30}$   $A_{32}$   $L_{33}^{44,34}$   
 $A_{34}$   $L_{35}^{38,36}$   $L_{36}^{37,33}$   $A_{37}^{44}$   $A_{38}$   $L_{39}^{40,42}$   $T_{40}$   $L_{41}^{45,43}$   $T_{42}$   $T_{43}$   $L_{44}^{46,32}$   $K_{45}$   $L_{46}^{47,4}$   $A_{47}$   $K_{48}$   
 $L_{49}^{50,1}$   $A_{50}$   $Z_{51}$ .

The main idea of the simulation model's algorithm boils down to a combination of the method of essential states [1,2] with the simulating-at-a-constant-speed technique [1,2]. Let us briefly outline the algorithm blocks' functioning in greater detail:

Blocks 1-3 (in cycle) form array  $M_i$  of "accompanying cells" for the initial information on each batch. From the array obtained, Block 4 forms a queue to the  $L$  groups

of equipment. The address of the destination of the accompanying cell in the queue is determined on the basis of relation  $r = k + 2i \cdot \ell_j$ , where  $k$  is the address of an arbitrary memory cell of the computer.

When the array of accompanying cells is completely formed, Block 7 determines the value of the corresponding priority coefficient for each batch. The calculation takes into account all the parts of the batch, except those already processed.

Blocks 9-11 normalize values  $F(p_i)$  in a way to comply with the conditions for normalizing and determining the probability within the given bounds:  $0 \leq F(p_i) \leq 1$ ,  $\sum_{i \in B} F(p_i) = 1$ .

Blocks 5, 6, 8 and 12 form array  $M_{II}$  in cycle, occupying memory cells similarly to array  $M_I$ .

Before beginning to simulate the loading of the equipment by means of a random numbers generator, Block 14 singles out the number of machines assigned to the  $L$  groups of equipment. In order to reflect the work of the machines, a special array of memory cells  $M_{III}$  is assigned for this purpose.

Block 16 reveals unoccupied machines, while Block 17 memorizes their amount. Block 20 engages the random numbers generator as many times as the number of unoccupied machines. A machine is regarded unoccupied if condition

$$\sum_i F(p_i) < \xi_{jM} \leq \sum_{i+1} F(p_i) \tag{3}$$

holds, where  $\xi_{jM}$  are random independent values uniformly distributed in interval  $[0,1]$ , their quantity being equal to the number of unoccupied machines.

Block 23 evaluates  $\sum_{i \in B} F(p_i)$ , and Block 25 checks compliance with (3) for each random variable. If (3) holds, Block 27 memorizes the address of the batch sent to the machine and calculates the time value of the unproductive idleness of the parts in that batch.

Blocks 30 and 31 dispatch the values of the duration of processing each operation fed in, to unoccupied cells of the memory array  $M_{III}$ . After "loading" the machines, Block 32 changes the time counter by value  $\Delta t$ , and Block 34 subtracts the contents of the time counter from the operation processing duration. Block 34 is guided by Block 33 comprising the counter of the number of loaded machines. If the processing is accomplished, the contents of one or more cells  $\langle \alpha \rangle$  of array  $M_{III}$  is equaled zero.

The analysis of array  $M_{III}$  is controlled by Block 35. When  $\langle \alpha \rangle = 0$ , we proceed to Block 38, which memorizes the time when the operation has finished processing. When  $\langle \alpha \rangle > 0$ , Block 36 applies to Block 33 in order to continue checking the contents of other array cells. When  $\langle \alpha \rangle < 0$ , Block 37 registers the machine's idle time.

Block 39 checks whether all the parts in the batch have been processed, Block 40 removes the batch from the queue and changes the operation number in the corresponding “accompanying cell” if all the parts in the given group of equipment are processed.

Block 41 checks whether any batch has finished processing. If a batch has not been completely processed, Block 42 changes the number of the part, and Block 43 reports that there is a released machine. Block 44 checks whether there are unoccupied machines. When  $H$ , return to Block 32 to continue simulating of processing the parts at the regarded operation. If the batch has been fully processed, Block 45 increases the number of processed batches by one.

Block 46 checks whether all the batches have been fully processed. If not, return to Block 4 to simulate processing of the remaining batches. When all the batches have been fully processed, Block 47 memorizes the total time for processing all the batches, summing up the values of non-productive idleness of the parts in all batches, and determines the values of idleness for all the machines.

Block 48 keeps the number of the iterative simulation cycle implemented, and Blocks 50-51 calculate the histogram, and print out the results of the simulation.

### **3. THE MODEL**

It can be well-recognized that regarding simulation of large-scale serial (mass) production, it is characterized by the fact that assembly sections consume parts uniformly, while processing of parts is carried out in batches.

This is how the formalized flow chart of materials can be presented for such production. Assembly is ensured by sets of items and parts in special stores or bunkers, which are kept supplied by intermediate machine shops. No batch of parts is fed into production before the level of parts ready for assembly reaches a certain fixed value, called the order point. In turn, the machine shop, where the processing is to begin, places orders in the factory stores for the appropriate raw and semi-manufactured materials. The purpose of production we describe here is to ensure the assembly of parts needed with a given reliability at the minimum production expenditures, whose basic components are cost of equipment and of raw and semi-manufactured material reserves.

The simulation model on Fig. 1 is based on an analysis of essential states, such as the moment of the routine order for any batch of parts, the moment when processing begins, when transferring from one operation to another, when completing the processing, moment when equipment goes out of commission and is restarted, as well as beginning of the shift, month, or year.

The random parameters of the simulation model are:

- 1) the duration of non-stop work by machines and the time for repairing them;
- 2) the number of workers;
- 3) the number of discarded parts; and
- 4) time when there is lack of semi-manufactured or raw materials necessary for feeding a batch of parts into production.

The time for processing parts per operation is considered a deterministic value.

The simulation model is adaptive in that the order points can be corrected if the frequency at which the planned production program being not carried out for period  $[0, T_{pl}]$

goes beyond the bounds of the planning horizon. After this, the entire simulation cycle is repeated upon setting the realization anew. There can also be corrections of preference rules  $Q$  when there are queues of batches of parts for the machines.

#### 4. APPLYING PREFERENCE RULES

Unlike the preference rules considered in [1,2], which are used mainly in small-scale serial and serial production systems, preference rules in large-scale serial production are represented in the form

$$Q = \varphi\{t, t_s, k, k_f, \vec{\eta}, \vec{\eta}_\ell, t_i, t_w, t'_w, c, p, n\}, \quad (4)$$

where:

- $t$  is the current time;
- $t_s$  is the order moment;
- $k$  is the number of operations to be performed;
- $k_f$  is the number of operations completed by moment  $t$ ;
- $\vec{\eta}$  is a vector, each  $i$ -th coordinate of which designates the coefficient of loading groups of equipment on which the  $i$ -th operation on the batch considered is carried out;
- $\vec{\eta}_\ell$  is the vector of coefficients of loading equipment for operations uncompleted by moment  $t$ ;
- $t_i, t_w, t'_w$  are the duration for processing a batch of parts at the  $i$ -th operation, the total processing time for all operations, and the total processing time for operations uncompleted by moment  $t$ ;
- $c$  is the cost of raw and semi-manufactured materials;
- $p$  is the given reliability of supplying the assembly with ready parts of a given type; and
- $n$  is the number of parts in the batch being processed.

$Q_1 = t - t_s$  is one of the simplest preference rules. It indicates the degree to which a batch of parts is behind the order point.

If we exclude the duration of processing parts in operations already completed from rule  $Q_1$ , we obtain rule  $Q_2 = t'_w - t_w + t - t_s$ , which characterizes the total idleness of the batch of parts in the course of operations done by moment  $t$ .

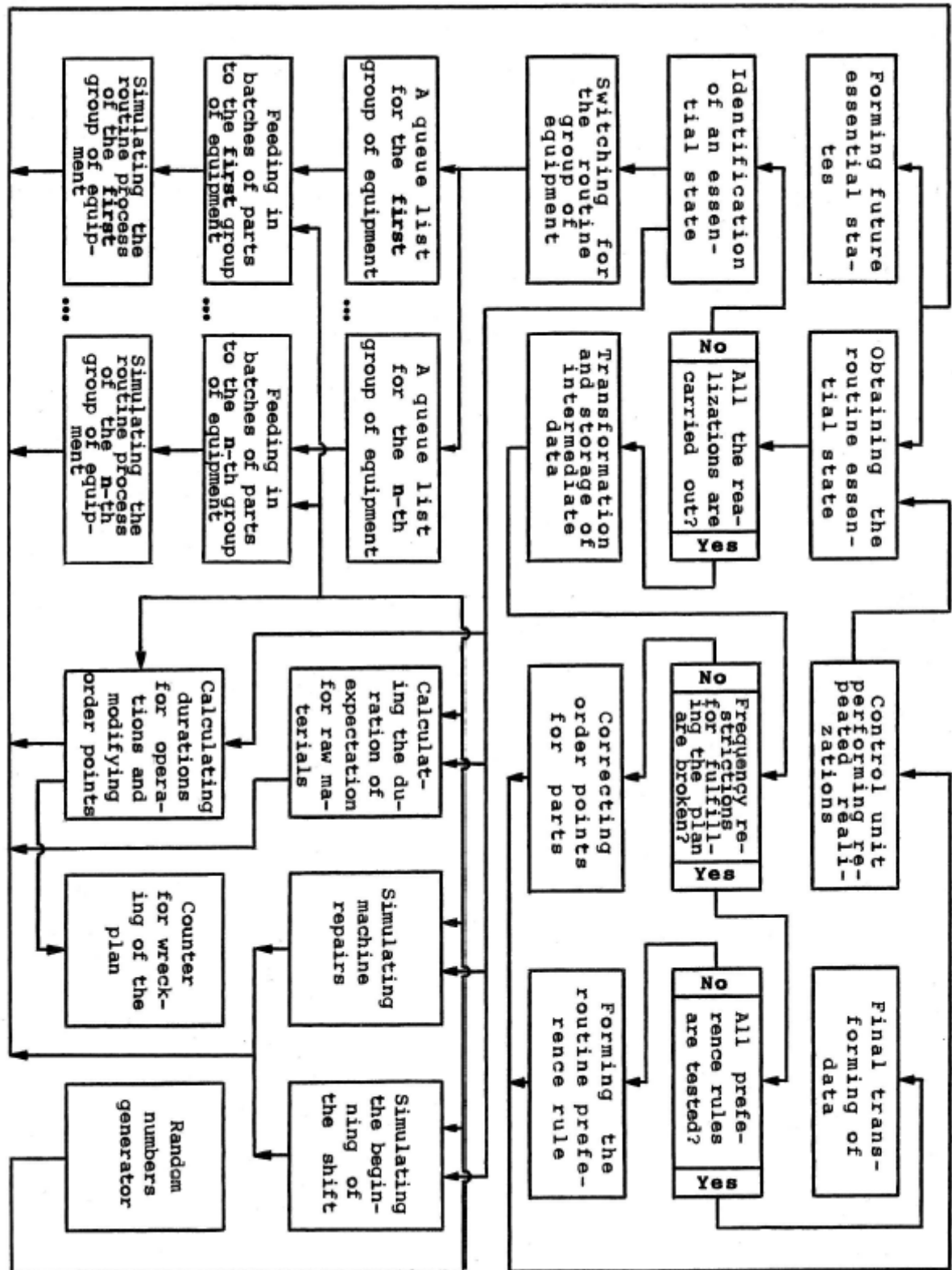


Figure 1. Flow-chart of the simulation model for large-scale production type

If we take into account the possibility of parts being idle in subsequent operations, preference should be granted to batches of parts designated to go through a large number of operations before processing is finished. In other words, the preference rule must forecast

any idleness of the parts in future. In the simplest of cases, these considerations lead us to rules  $Q_3 = Q_1 \cdot k / (k_f + 1)$  and  $Q_4 = Q_2 \cdot k / (k_f + 1)$ . A more accurate idleness forecast should account not only for the number of uncompleted operations, but also for coefficients of loading the respective groups of technological equipment. Examples of such rules are  $Q_5 = Q_1 \cdot f_1(\bar{\eta})$ ;  $Q_6 = Q_2 \cdot f_1(\bar{\eta})$ ;  $Q_7 = Q_1 \cdot f_2(\bar{\eta})$ ;  $Q_8 = Q_2 \cdot f_2(\bar{\eta})$ , where

$$f_1(\bar{\eta}) = \frac{\sum_{i=1}^k \eta_i^2}{k_f + 1}, \quad f_2(\bar{\eta}) = \frac{\sum_{i=1}^k \frac{1}{1-\eta_i}}{\sum_{i=1}^k \frac{1}{1-\eta_i}}, \quad (5)$$

It is natural to assume that other conditions being equal, we should prefer more expensive parts, as well as parts for which the given reliability of supply for assembly is higher. These considerations bring us to the following rules:

$$\begin{aligned} Q_9 &= Q_1(c + 3t_w); & Q_{12} &= Q_1(1-p)^{-1}; \\ Q_{10} &= Q_5(c + 3t_w); & Q_{13} &= Q_9(1-p)^{-1}; \\ Q_{11} &= Q_8(c + 3t_w); & Q_{14} &= Q_{10}(1-p)^{-1}. \end{aligned} \quad (6)$$

It is natural to assume that other conditions being equal, we should prefer more expensive parts, as well as parts for which the given reliability of supply for assembly is higher. These considerations bring us to the following rules:

$$p_j = \frac{t - t_s^j}{\sum_{j \in S} (t - t_s^j)}. \quad (7)$$

The simulation model makes it possible to test all the listed rules and find the most efficient of them.

To conclude this paper it should be noted that optimization units do not enter into the simulation models for derail and large-scale serial types of production described above. These optimization units should be considered apart.

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## METHODS FOR ASSESSING THE INFORMATION TECHNOLOGIES AND COMMUNICATION IMPACT ON COMPANIES

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#### Abstract:

*The determination, identification and evaluation of the impact of Information Technologies and Communication use in companies are complex issues that require quantitative and qualitative approaches that take into account one or at most two parameters. Most of the empirical studies focused on the impact of Information Technologies and Communication on the economy are statistical approaches that take in consideration only one performance criteria of the company, such as Information Technologies impact on productivity or the impact of Information Technologies on investments. The impact study approach can have an a priori and a posteriori perspective. Before the introduction of Information Technologies it is necessary to make some predictions or estimates. After the introduction of Information Technologies, the actual assessment takes into account the effects. The research proposes a methodology for assessing the impact of Information Technologies taking in consideration a priori and a posteriori aspects. Also, it is developed a metrics for the evaluation the quantitative impact assessment such as Information Technologies endowment of labor, and efficiency of funds invested in Information Technologies. The methodology consists by an algorithm that can be implemented in companies. The calculating the proposed indicators help quantify the effect of applying Information Technologies and establishing their effectiveness.*

**Key words:** Information Technologies, companies, impact assessment, metrics

#### INTRODUCTION

Although more than 25 years have passed since Solow (1987) introduced the concept of computer productivity paradox in economics, his observation of concerning the slow productivity growth remained valid despite the revolution in the field of Information and



Communication Technology (ICT). Nevertheless, over the last years, productivity in the United States has significantly improved, and the perception on the Information Technology (IT) has reversed, being seen by many as the renewal driving force of the productivity increase in the United States following 1995. The global growth studies show significant contributions on the productivity both from the IT production industries and the industries using IT, while the comparisons at industry level show that IT intensive industries enjoyed the largest productivity after 1995 (Baily, 2002). Similarly, the function of production estimated using data from companies or industries show a significant relation between IT and productivity, case studies documenting the major benefit of IT in various industries such as transport and health. Marquez and Ovalle (2001) assess the possible impact of the new communication technologies on the performance of a generic supply chain. A simulation study has been accomplished in order to conceptualize the integration process that could take place in the v, and to measure the supply chain flexibility improvements as a consequence of a faster and shared information flow. These results show orders of magnitude of the improvements in terms of operational and financial metrics.

Gordon (2000), Jorgenson and Stiroh (2000), Oliner and Sichel (2000), Schreyer (2001), Spiezia (2011) and Strauss etc. (2011) have exemplified through empirical studies the ICT impact on various branches of the economy and society. Stiroh (2002) has published a study, a meta-analysis regarding the evaluation of the information technology role in fulfilling the function of production. The shown estimates do not reject the optimistic approach, but the meta-analysis outcomes and new econometric methods suggest circumspection when attempting to accurately quantify the IT impact. Differences among the econometric methods have led to the development of a wide range of estimates of the output elasticity for IT, which have very different implications for the IT importance to the economy, in the case analyzed by Stiroh (2002), the USA economy.

Estimating the production functions by levels is the most common technique presented in the specialized literature and virtually all level evaluations from the USA data highlight a high elasticity for IT. This involves either returns in excess for IT or leave out the consideration of certain outstanding variables. Construing the omitted variables seems the most sensitive issue, insomuch as increasing the volumes of scientific works within the area of microeconomics emphasises the importance of complementary innovations, such as the practice improvement at the workplace and redesign ( re-engineering ) of the company for the successful implementation of IT. A pessimistic approach is that the IT introduction does not really matter, and have been simply assigned productivity growths that are owed to other factors. This approach seems too radical, as all capital coefficients tend to be lower in these specifications, and it is unlikely that the entire capital be really unproductive.

The reported outcomes suggest that researchers have a high discretion in judging the types of evaluations that they report. In case the researchers are more inclined to report only those evaluations according to the expectations, then the published literature will over use the Ordinary Least Squares (OLS) on the levels providing these outcomes. Research on productivity focuses on regression appraisals by levels, without paying a particular attention to the heterogeneity and simultaneity problems. The conclusion of this research is that the IT introduction influences the productivity evolution, but there have to be reservations towards the results of evaluating the influence size. Stiroh (2001) asserts that the use of IT has played a critical role in the U.S. productivity revival. Europe has the experience of the influences of a less spectacular but non-unitary entering of IT in economy. There are discrepancies between

investments and ICT use between the Netherlands and Ireland relating to France, Germany and Italy and, therefore, different from the USA. IT accompanied by complementary innovations, provides solutions for sustainable growth. The IT considered input behaves as the General Purpose Technology (GPT), obviously maintained by a high elastic demand for semi-conductors/microprocessors, and generate spillovers effects or what can be called carrying away effects in the economic sectors that have invested in IT and developed complementary innovations for benefitting from all the advantages offered by IT (Basu, 2003). Thus, the IT enters into a logic of endogenous-exogenous productivity.

As regards USA, it is considered that the Solow paradox has been exceeded. Great Britain has experienced a boom in the ICT investments in the second half of the 90's, but the growth rate of Total Factor Productivity (TFP) has decreased. If investments in ICT in the UK are associated with a low TFP, it is because more resources are allocated to the reorganization and learning than than the output production. In USA and UK situation has been found to be a strong correlation between the use of IT in economic activities and TFP increase. The TFP increase is positively correlated with the ICT use, and negatively related to the boom in ICT investment. The common opinion on the USA economic boom in the second half of the 90s, is that ICT has fundamentally contributed to economic growth. It is considered that the huge investments, stimulated especially by the decline of prices, enabled the substitution by the IT capital of capital and labor. Thus, the IT entering in the economic activity explains the labor productivity increase.

The specialized literature approaches the mainly statistical impact of information technology. The research presented in this paper focuses on the non-statistical approach of studying the ICT impact by establishing an evaluating methodology of the impact, both *a priori* and *a posteriori* and proposes the introduction of new metrics and key indicators of performance for evaluation.

## **THE NEGATIVE IMPACT OF THE INFORMATION TEHNOLOGIES IN COMPANIES**

The introduction of technologies may sometimes have a negative impact on companies and business. The question is whether the IT decisions build or ruin a business. According to Thurnher (2007), the use of mobile technologies for IT management and improvement of business processes is far behind expectations, still little research has been done in analyzing critical success factors for mobile technology acceptance and usage when replacing a former paper-based process within the IT-Service area. Performingng an analysis from this perspective, we can say that within the business operation and functions, the ICT group holds a disproportionate control over what is happening or could happen in a company. The most visible is the control on the software instruments which are operated in the company. Starting with the browsers for Internet and ending with the information applications systems, the employees of most companies are not allowed to choose their own IT tools according to their wishes. Some companies allow downloading the minor software but in no way the major business solutions. When the IT group has chosen the basic computer tools, it automatically decides what employees are allowed to do.

Nevertheless, despite all significant benefits brought by the information technology in a company, there is the risk of IT governance which may become the opponent of what is really wanted. This is actually the power had by IT within a company. The company executive

knows this and most of the time it constitutes a considerable factor of frustration. Moreover, is the IT group evolving as fast as the business? Ideally yes, but in reality the IT demand is often larger than the capacity had by IT in the company, which may lead to a comstriction. If there is a perception that a request made to the IT will never be achieved or will be achieved in due time, then we can say that the IT limits the favorable possibility of a quality culture.

It is already known that IT decisions have long-term implications. In addition to positive implications, there are also negative implications. For example, choosing an ERP architecture that involves decisions concerning data storage and sharing. This may have deep implications on the stakeholders' ability to make decisions in due time. In many cases, especially in the current context, these IT decisions can build or take down your business.

Smart organizations favour the culture they want. They deliberately make decisions that encourage or discourage certain behaviors. In today's world, the brand and business culture are often interconnected and these are the ones guaranteeing the actual gain of the company on the market. Therefore, the relations between organizational culture and IT decisions to be taken, have to be very well understood. On the other hand, the lack of IT expertise can block small businesses. Recent studies prove that strategic use of IT in small businesses is the biggest challenge for their growth. CDW Corporation in the U.S.A. has monitored 152 businesses in progress or managers who have been successful in turning the business from a small one into a medium business, with 100 employees or more. In the study, 38% of respondents said that the IT management in their favor was a significant advantage ( McGillicuddy, 2007). 74% of small businesses' proprietors said they were totally involved in IT decisions throughout the entire period of their companies' development. Only 14 % responded that they considered there is enough IT for their employees to solve their work duties, and 5% answered they were conservative and only spend their money on a proven and profitable technology. In agreement with these proprietors, an aggressive IT strategy is translated into a strong development. Actually, 61% of the respondents who saw the IT as a strategic or competitive advantage had a 2-digit growth in the last 5 years. Only 43% of these companies have invested in IT so as to ensure that their employees have the same productivity increase. Small companies have rarely specialized staff for IT implementation. Only 24% of the individuals interviewed replied that they had staff members dedicated to IT. The others use IT following their own knowledge, outsource the IT , or use it with non-IT staff.

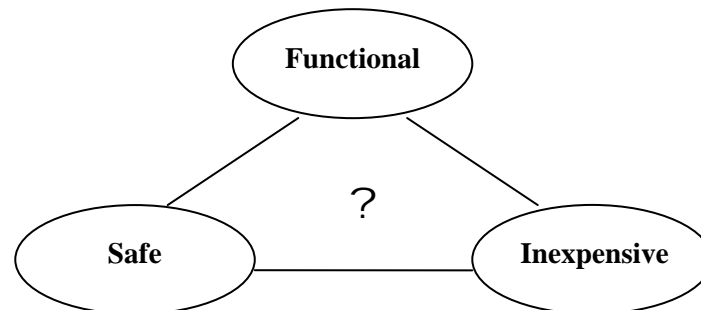
Beside the organizational aspect of the negative impact of information technology there is another impact, still negative, as regards data security. This is shown by loosening data confidentiality, through the phenomenon of "fishing" and virus infection. There are obviously certain ways of protection, but phenomena once occurred may cause significant losses to the companies.

## **THE QUANTITATIVE ASPECT IN IMPACT EVALUATION**

The impact is analyzed as an answer, an effect, a reaction of the environment, system, society, to certain stimuli, events, actions. The impact may be presented in qualitative, quantitative (numeric, percentage of increase or decrease, etc..) or mixed (qualitative and quantitative). The impact appraisal involves two levels of approach, ie conceptual level and overall level. At the conceptual level, which is the level of management knowing the impact is necessary for decision makers who, knowing the effects can identify

and treat the causes. At the general level, which can be identified with a factual level, the impact analysis is useful for the members of society, who actually bear the consequences, meaning the impact. Through the very nature of this notion, the impact approaches imply an *a posteriori* analysis, from the observed effect to causes, which in terms of the reasoning from the artificial intelligence is called, *backward chaining*. This manner is applicable to both macroeconomic and microeconomic levels and assumes the existence and statistical analysis of data for a certain period of time. There may be also an *a priori* approach, which is forecasting and useful particularly for company managers in order to know the trends and anticipate the effects, consequences.

The effects of IT entering in a business are evaluated through efficiency, productivity, business development and low costs. Since IT is one of the most dynamic areas, the technologies with more than five years being already obsolete, for withstanding the competition, a company has to keep up with the renewal pace of technologies, which is reflected in business efficiency. Increasing the labor productivity is one of the tasks of the managers, who must ensure that the employee produces more than the employer's total costs generated by its remuneration. Concerning the role of introducing IT in companies, many companies make investments because it is vogueish. Business development requires *inter alia*, online presence, new IT equipment and unique offers. The cost, along with functionality and safety, has a major effect on the beneficiary's purchase decision. An expensive product is not always a good product and a cheap product does not always bring cost savings. The main requirements of the beneficiaries for information technologies are plotted in Figure 1.



**Fig. 1.** Requirements for information technologies

Experience shows that the three conditions are contradictory and can be simultaneously met only by two of them. At this moment, it is not purchased a computer system that is safe and cheap, but not functional. Very rarely is purchased a safe and functional system, if expensive. Most choices are for a functional and inexpensive system, safety being left on the second place when making the purchase decision.

The study of quantitative aspects of measuring the impact of investments for information technology raise a number of problems, which are based on the following causes:

- there are no reference systems towards which to be assessed new improvements;
- the planning process of the IT installations or upgrades, may itself constitute an increase in efficiency, even without implementing a new IT system;

- the new technologies introduced in companies may put in difficulty the staff, who may have problems of adaptation, so that the new organizing in the company generated by their introduction to have initially have a negative impact on the activity efficiency in the company in the first months after implementation, so that an appraisal performed too quickly may have a false negative result and actually reflects the negative effects that may diminish or disappear over time;

- sometimes is not used the whole potential of the new technologies, situation met when it is not made an adequate training of the staff or when cultural or organizational barriers, which generate the conservation of an anti-technology mood, this causing long-term reductions in the effectiveness and impact.

Establishing the proper connection between the improvements occurred in the companies' business and causes that generated them is a challenge. At the same time, we identified the point where technology has no impact and the external factors, that have an important influence.

An innovative methodology that can capture all aspects of the impact of introducing IT in companies has to begin by applying the theory of change. An essential component of evaluating the IT impact is to understand the staff expectations to changes that the new technology will cause in labour and production. Expectations towards the information technologies, why and for whom will be produced the changes are questions that have been asked and answered by a group of key persons, including staff, end users, management board and financing persons. Also, there must be a clear understanding of the internal capacity limits: the staff may be able to receive many requests from customers, or customers relate more efficient to other resources, but this does not automatically mean that they will be better served. An important role is played by the basic training in information technology of key persons who should have at least working knowledge on the prerequisites and limitations of the information technology. Perhaps the most important key to the success of efforts to introduce new technologies is that organizations need to have an adequate training for using the new tools they possess. The efforts made to introduce IT in a company should be planned and carefully evaluated over time, while taking into account the effects on the organization, staff and services. IT is part of a broader context, namely of organizational capacity and culture.

## **TECHNIQUES FOR MEASURING THE IMPACT OF INFORMATION TECHNOLOGY ON BUSINESS**

For measuring the IT impact in business one needs to establish the most important performance indicators, called key indicators that will constitute the metrics for evaluating the IT impact. The key indicators will evaluate IT performance in the business performance. Thurnher (2007) has a major contribution in the identification of business metrics which are influenced by the mobile tool integration into mobile business processes.

The difference among the key indicators of performance is presented as follows:

- Performance indicators reflect the organizational goals;
- Performance indicators are established by companies managers;
- Performance indicators take account of the context in which the evaluation is performed;

- Performance indicators are based on legitimate data;
- Performance indicators are easy to understand;
- Performance indicators lead to action.

Key performance indicators influence, by their very nature, the actions. If a metric is not able to influence the behavior of the management team in a way that can be understood clearly in all departments, when it is a key performance indicator. Establishing the metrics and, consequently, the performance indicators, is the first step in passing through a program that implements the key indicators. The programs implementation starts by concentrating the effect on consensus, in order to be then iteratively developed. Because businesses are dynamic, refining the capacities of evaluating of performance indicators is more important than the actual measurement. Specialized literature reveals that, although there are different methodologies, most are based on a sequence of steps.

The algorithm resulted from research, which complements the existing methodologies, involves the following steps:

**Step 1.** Setting up a board for approving the key performance indicators

Performance indicators like all metrics, have low values in isolation. The best way to make sure that the system of indicators will be successful in measuring and influencing performance in companies is to reflect as early as possible the impact variations in acceptance of all stakeholders. In this regard, it is set up an Approval Board made up of key players of each department in the company. The Board of Approval is responsible for: validating/updating the performance indicators, monitoring data collection, analysis of results and transmission of results. It shall also contribute to maintaining the implementation process within correct limits, avoiding the intentional or unintentional hazard. The Board shall meet regularly and in sessions separate from those who have as agenda the budget or the company's structure and stay focused on the issues of the process and organizational performance. Having regard to the human dynamics involved in the assembly of an approval board, many technicians are tempted to skip this step, which is a huge mistake.

**Step 2.** Prioritize what is important in business

This stage begins with determining the manner in which performance within the company is measured. Each manager should be able to identify the performance of the company he leads, in each specific case and to know the strategic goals. Moreover, if the approval board was correctly constituted, this information may be provided to the members of other departments of the company. It should also be noted the priorities and weights of each objective (these will vary depending on the position of the interviewed person). Next, there will be drawn up a list of the operations that may impact, or being a support for each of the business goals. The list will be specific and will also depend on each purpose of the business.

The specialized literature identifies four general directions of the ICT operations objectives which will be mapped to the business objectives:

- Improving the efficiency of resources use;
- Decrease of failure rate;
- Improvement of the transitive operations;
- Enabling the business agility.

It has to be stressed that what matters to the individual members of the IT team is identical to what matters to the business.

**Step 3.** Giving more importance to key indicators compared to the prioritization of IT operations

At this stage, activities focus on the development of objectives list of the operation performed by IT and the list of all possible candidates for key performance indicators for each objective. Together with the approval board is passed through the list to highlight the importance of each candidate of key indicator in indicating the success or failure of each objective of prioritized IT operation. It should also be known the difficulty of measuring for each performance indicator taken into account for preparing the indicator system (candidate indicator). While there is concern for the ability of indicators to show the progress for reaching the objectives, the measurement difficulty may have practical implications when deciding on what should be firstly focused evaluation work.

**Step 4.** Gaining the consensus on a set of performance indicators

It works on the beginning in the board of approval and then in a wider board made up of people within the company, in order to obtain consensus on a set of indicators being analyzed. It is recommended to start with a set of 5-10 performance indicators. For the selection are used importance and priority criteria determined in the third stage.

**Step 5.** References and following up

It is created a reference for each performance indicator in the initial set. In this stage are validated the assumptions made in the previous steps. If seemed reasonable, is started the regular monitoring of the set of indicators. It is advisable to start with manual or semi-manual data collection and reporting indicators. If it is started directly with an automation tool there is a risk of being caught in what can or can not be automated, while the correct path is towards what is this automation. Transparency is an important problem of this process, so we need to make sure that anyone with a reasonable understanding capacity is able to understand how and why these metrics indicate the success or failure.

**Step 6.** Reevaluation and enlargement

The board of approval must regularly validate and analyze the results and propose new indicators, if this is required. Originally, the board meetings must be weekly, then monthly with weekly and daily reports of indicators. At this stage of the process may begin automating the data collection and reporting of indicators. After going through several cycles will be better understood what and how should be measured. Eventually, the automation allows to follow a number of indicators with a high degree of accuracy, and provides the possibility to supply to the organization a faster response loop.

## **METRICS PROPOSED FOR EVALUATING THE IMPACT**

Most metrics used to evaluate the information technology functions are classified according to the use functions. Such metrics for IT are divided into the following categories:

- Operational metrics: underlie an effective management and constitute effective indicators of what is executed;

- Metrics of verification or secondary: are used to verify if the completed work meets the standards and operated completed in accordance with the project;
- Performance or tertiary metrics: are indicators that refer to the performance criteria of the IT and provide information on efficiency and effectiveness.

The purpose of this research is to identify metrics intended for evaluating the impact of IT implementation in companies. The metrics that are relevant to the intended purpose must fall, according to the previous classification, in the category performance metrics.

The literature introduce several systems of metrics, which can be explained by the fact that they must be adequate to the specific nature of the organization, company etc. where the evaluation is carried out. Thus, in a study of Computer Aid Inc. company., a world leader in IT Metrics and Productivity, conducted by Spanos (2013) are identified 100 of IT metrics, divided into the following areas:

- I. Ensure the availability of the existing Processing Capabilities;
- II. Utilize Efficiently the Available Staff Resources;
- III. Timely Response to the Business Requests for New Features or Services;
- IV. Ensure the successful implementation of the system changes;
- V. Manage the cost of delivering the IT services and optimize value.

The metrics resulted following the research presented in this paper fall into the category of performance or tertiary metrics, after the function of use and belong to the the V. area, according to the above classification, and consists of the indicators presented as follows. Depending on the company objectives and strategy, all these metrics may become key performance indicators.

### 1. Endowing the labour with IT

The calculation formula used in economy to calculate the technical endowment of labor is:

$$f = \frac{K}{L}, \text{ where}$$

- K is the capital invested;
- L, workforce expenses.

We define  $f_{IT} = \frac{K_{IT}}{L_{IT}}$ , representing the IT endowment of the workforce.

- $K_{IT}$  is the capital invested in IT;
- $L_{IT}$ , workforce expences in IT.

### 2. Efficiency of the funds invested in IT

This metric is defined by the formula:

$$e = \frac{Q_{IT}}{f_{IT} \cdot L_{IT}}, \text{ where}$$

- $Q_{IT}$  is the volume of global production achieved due to IT (% of Q);
- $f_{IT}$  is the IT endowment of the workforce;
- $L_{IT}$  is the workforce expense in IT.



### 3. The amount of information entered into the organization by IT

Taking into account that the proposed indicator system evaluates the impact of IT use, the amount of information, data stored on the computing system will be measured in bytes, kilobytes, megabytes, etc.

### 4. Speed of response of the organization after the IT introduction

This metric can be defined either as the ratio of the amount of information and time of information dissemination or of system response or is simply the speed of information transmission through the transmission media.

## CONCLUSIONS

The paper highlights two ways of addressing the impact, namely: a priori, prediction, forecasting analysis and a posteriori, de facto, finding analysis. If is wanted an a priori evaluation, so a forecasting of the IT impact, before making an investment in this direction, the statistical methods are most appropriate. Rapid, even empirical methods are preferred in order to obtain an overview of what will happen, to capture particularly the trends. The impact evaluation of IT introduction in business, in order to be effective and reliable, must be carried out according to a well thought out plan which should be a part of the management strategy of the company.

The research proposes a methodology containing an algorithm that can be run through by identifying the specific elements of the organization and establishing the critical resources and risks. Metrics or performance indicators are not unique, being adequate for the purpose and objective of the business. Moreover, each of them expresses and defines a particular aspect of the company's performance and hence the impact of information technology.

Taking into account that the impact can be both positive and negative, the proposed indicators system evaluates the overall impact of IT in an organization, the total impact as an algebraic sum of impacts on components. It should be emphasized that no matter how beneficial is the effect of information technology, they are still a necessary but not sufficient condition for performance.

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