Labour analysis based on time input-output tables[1]

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Abstract. The paper is focused on the description of the methods and tools for the analysis of labour intensity. A model example is based on the figures for the Czech Republic covering period of 1990-2010. We applied the approach using Time Input-Output tables broken down by commodity. Besides the methods of the analysis, the paper briefly describes current compilation procedures of Time Input-Output Tables, as well. We compiled Time Input-Output Tables (TIOTs) for 1990-2010 with respect to available data sources. TIOTs combines published Supply and Use tables, data on hours worked and data on wages and salaries. The key results are expressed as indices of labour intensity and these indices are compared with volume indices of gross value added and also with the development of capital endowment of labour. Labour intensity is estimated as a ratio of index of hours worked and volume index of output. The development of capital endowment of labour describes the change of the amount of capital per one unit of labour. We used net stocks of fixed assets as capital indicator and the hours worked from the TIOTs as labour indicator. We transformed net stocks of fixed assets (obtained from Czech national accounts) from the industry classification to the commodity classification. One of the key advantages is that the results are not affected by changes in price level and it allows interesting comparisons in long period.

Key words: Time Input-Output tables, hours worked, labour intensity, capital endowment of labour

Introduction

Input-output tables are one of the possible tools to describe processes within a national economy. While monetary input-output tables are expressed in monetary units, time input-output tables show allocation of the number of hours worked in the national economy among production of products. The time input-output tables could be seen as an extension beside the mentioned monetary input-output tables. The symmetric input-output tables as part of the system of national accounts are compiled because of economic (econometric) analysis using knowledge of technical and economic relations. Such analyses are used for assessments of impacts of various changes on the economy.

Compilation of the symmetric time input-output tables consists of several steps. The time supply and use tables in comparison to the monetary supply and use tables are compiled in the simplified form and describe allocation of the number of hours worked among commodities in each industry. Simplified supply and use tables expressed in hours worked are used for compilation of symmetric time input-output tables, which are the base for derivation of input-output models connected with working time during the process of production.

The data from monetary input-output tables for more years can be used for evaluation of the development of structure of national economy in monetary units especially in view of material and other inputs into the production. Also comparison in view of hours worked using time input-output tables for more years allows the evaluation of the development with focus on amount of labour time needed for production of products. Linking both of these approaches gives the possibility to evaluate the development of labour intensity connected with each group of products according to commodity classification.

The aim of this article is to compare the development of three indicators in the Czech Republic according to sections of the commodity classification during the period 1990-2010. The first indicator is labour intensity of production of products. The second one is the labour endowment with capital

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and the last indicator is gross value added. The output of the compiled symmetric time and monetary input-output tables are used to achieve this aim.

Labour analysis based on time input-output tables

There are certainly more possibilities of various analyses based on time input-output tables (TIOT). As it was written in Introduction, this paper is focusing on the evaluation of the labour intensity development, on the evaluation of the development of labour endowment with capital and both these indicators are compared to the development of the gross value added.

The evaluation of the labour intensity development according to products which is the partial aim of this article is partly based on the results of compiled time input-output tables (TIOT). The Methodology for compilation of the TIOT and its final form for the Czech Republic are described in [16]. As it is written in [3] or in [10], it is an old dream of economic science to describe economical activities using nonmonetary units. The compilation of the mentioned TIOTs is based on the knowledge written in [3], [11] and [10].

The foundations for use of the input-output tables focusing on human labour are put probably by Stäglin for example in [9] who doesn't use time units but number of employees. It should be noted that his aims were different because he focused in his work on the analysis of situation of individual professions on the labour market. As it is pointed out in the mentioned resources it should be taken into account that also the compiled TIOT for the Czech economy could be and probably are partly distorted due to human capital.

The number of hours worked is one of possible approaches to description of labour inputs to the production process. The labour intensity is somewhat different approach to the assessment of labour productivity. More about the labour productivity in the Czech Republic is written in [7] and [13].

The next partial goal is to evaluate the development of labour endowment with capital in the Czech Republic during the period 1990–2010. This evaluation is based on the economic theory. The indicator called labour endowment with capital gives the information on amount of capital, which can be used by employees in their work.

Due to more comprehensive analysis, the development of labour intensity and the development of labour endowment with capital are compared to the development of physical volume of gross value added.

Data

There are two main datasets which can be used for fulfilling the goals of the paper. The supply and use tables are one of them. The second source of data is the number of hours worked. The European System of Accounts [3] defines the number of hours worked as the total number of hours really worked by employee or self-employed person during the accounting period.

The information on hours worked in the Czech economy, according to CZ-NACE classification, is published by the Czech Statistical Office (CZSO) on its website together with other indicators of the national accounts. The information on hours worked in connection with national account is important particularly for the calculation of the ratio value added per worker in each industry of the national economy. The length of time work of employees is necessary to be taken into account for this indicator. Hence the amount of full-time equivalent workers (FTE) is more preferable for the analysis related to the labour input. The data from statistical surveys [1] as well as the administrative data sources are used for the labour inputs estimates in the last years. Something more about the use of administrative data sources in the Czech Republic is written in [14].

As it is described below, other data sources for compilation of the TIOT are also used. Mainly it consists of data on labour inputs as data on average hourly wages broken down by industry and the data on average monthly wages and average monthly fund of working hours. Beside the data on

labour inputs the data on Net stocks of fixed assets as a data entry on capital is used. All this data in needed form is calculated based on the data from the Czech national accounts database.

Methodology

For the compilation of symmetric TIOT, the method of transformation of data from the supply and use tables into the symmetric input-output tables (SIOT) form broken down by commodity is used. This method is described for example in [3]. In the Czech Republic the method based on product transformation assumption (method A) is used for compilation of the SIOT. For the compilation of the TIOT broken down by commodity the Almon's approach is used. The Almon's method is described in [1].

For the use of the mentioned method of compilation of the TIOT, the first step is to compile simplified supply and use tables expressed in hours worked. The methodology has changed a little in comparison to the methodology written in [14]. The simplified supply and use tables consist of output matrix on resource side and of the matrix of intermediate consumption and vector of final use in time units on the use side. The output matrix expresses how many hours of total hours worked in the industry is related to the production of the particular product. The matrix of intermediate consumption presents how many hours are related to the production of particular products which are intermediate in the industry. Only domestic produced products are used for the allocation of the hours worked on the use side.

For compilation of output matrix expressed in hours worked the published data from the supply and use tables as well as data on average hourly wages broken down by industry are used. The wages of workers in the industry are probably different when one worker is working on production of the particular commodity and the second one is working on another commodity. For this reason it is supposed that hourly wage for the work on the particular product corresponds to the average hourly wage related to the industry where production of this product is typical. Each value of the output matrix expressed in the hours could be estimated using the equation (1)

$$T_{ij} = \frac{x_{ij}}{w_i}, \tag{1}$$

where T_{ij} is the number of hours worked needed for production of value of output x_{ij} product i in the industry j by the average hourly wage for production of product i.

Due to the fact that the assumption on allocation of average hourly wage in the output matrix is simplistic, the industry sums of the hours worked will be hardly the same as the published data on hours worked broken down by industry. The matrix of the T_{ij} is used for creation of the structure matrix which is used for allocation of the hours worked according to the industry among the specific commodity. The final matrix can be considered as the output matrix expressed in hours worked.

For the purpose of allocation of the hours worked in connection with process of production it should be taken into account the time spent on production of capital products on the use side. It is desirable to consider only the part of produced capital products which are connected with the current year's output. Therefore it can be used consumption of fixed capital (CFC) which has required properties. For more information about CFC in the Czech Republic see [5]. The depreciation rates are estimated using the equation (2)

$$d_{ij} = \frac{cfc_{ij}}{x_j}, \tag{2}$$

where d_{ij} is depreciation rate for product i in the industry j, cfc_{ij} means consumption of fixed capital connected with product i in the industry j, x_j is output in industry j. The depreciation rates are used

for the transformation of the CFC to the time units. Then CFC in hours worked is done by the equation (3)

$$cfc_{ij}^{(t)} = t_j d_{ij}, \tag{3}$$

where cfc_{ij} with upper index *(t)* means consumption of fixed capital in time units connected with product *i* in the industry *j*, t_j is time spent by production in industry *j*.

As it is mentioned above, this paper deals with the allocation of the number of hours worked only in output matrix on the resources side and in the matrix of intermediate consumption and vector of final use on the use side. For the purpose of maintaining the balance equity according to products, the allocation of the hours worked can be done using equations (4) and (5). The equation (4) is used for transformation of the vector of final use to the time units

$$y_i^{(t)} = t_i \frac{y_i}{c_i + y_i}, \tag{4}$$

where t_i is time spent by production of product i, y_i is final use of product *i* in monetary units and c_i means the value of intermediate consumption of product *i*. The matrix of intermediate consumption is transformed using the equation (5) to the time units

$$c_{ij}^{(t)} = t_i \frac{c_{ij}}{c_i + y_i}, \tag{5}$$

where c_{ij} is value of intermediate consumption of product *i* in the industry *j* in monetary units.

This approach ensures the validity of assumption that the resources are equal to the uses expressed in hours worked. Compiled output matrix, matrix of intermediate consumption, matrix of CFC in time units in the form product x industry are used for the compilation of the TIOT. The symmetric TIOT in the form product x product are compiled using the above mentioned transformation, described in [1].

The labour intensity can be considered as the time needed for the production of one unit of the specific product. On the level of the national economy it is not possible to clearly set the number of produced units of each commodity according to the industry. The development of the labour intensity can be assessed using the compiled TIOT and indices of physical volume of the output broken down by commodity. Indices of physical volume are also taken from the supply and use tables. The development of the labour intensity can be described by the equation (6)

$$i_{LI,i,t} = \frac{i_{T,i,t}}{i_{q,i,t}}, \tag{6}$$

where $i_{LI,i,t}$ is index of labour intensity of production of product *i* in the year *t*. Index $i_{T,i,t}$ shows in the numerator the development of the number spent on production of product *i* during the year *t* in view to a base year. The denominator indicates the index of physical volume for product *i* in the year *t* in view to a base year.

For the evaluation of labour endowment with capital which is partial aim of this paper, the methodology described in [18] is used. The indicator to be evaluated is based on the economic theory. Therefore the methodology for calculation of the labour endowment with capital is overtaken from [8]. In accordance to the [8] the evaluation of the labour endowment with capital the equation (7) is used

$$g_k = \frac{K_1 / L_1 - K_0 / L_0}{K_0 / L_0}. \tag{7}$$

In the equation (7) *K* represents net stock of capital and *L* means the amount of hired labour in time units. Based on this equation, the evaluation of labour endowment with capital means the relative change of the average labour endowment with capital between two selected years. Before the equation (7) is applied the figures on net stocks of capital broken down by industry need to be transformed to the commodity classification. For this purpose it is used the methodology described in [17].

The last methodological point is aimed to calculate the physical volume of gross value added broken down by commodities from the published SIOTs for the Czech economy. The calculated indices are confronted with the labour intensity development and also with the development of the labour endowment with capital. SIOTs are published only in current prices in the Czech Republic. Therefore price indices are derived according to commodities in the simplified way based on the published supply and use tables. The price indices which informs about the price changing in the period of five years, can be calculate using the equation (8)

$$I_{p,i,T} = I_{p,i,t-1} \cdot I_{p,i,t-2} \cdot I_{p,i,t-3} \cdot I_{p,i,t-4} \cdot I_{p,i,t-5}, \tag{8}$$

where $I_{p,i,t-1}$-$I_{p,i,t-5}$ are relevant chain-linked price indices for particular products and $I_{p,i,T}$ is the price index for the whole period. This method is applied for calculation of price indices separately for the output and intermediate consumption. Output and intermediate consumption in constant prices are estimated based on the results of (8) using the equation (9)

$$XX_{i,T}(T-5) = \frac{XX_{i,T}(c.p.)}{I_{p,i,T}} \tag{9}$$

where $XX_{i,t}(T\text{-}5)$ represents value output or intermediate consumption of product *i* in constant prices, $XX_{i,t}(c.p.)$ is value of output or intermediate consumption of product *i* in current prices. Gross value added in constant prices is done using the equation (10)

$$GVA_{i,T}(T-5) = Output_{i,T}(T-5) - IC_{i,T}(T-5), \tag{10}$$

where *GVA* means gross value added and *IC* is intermediate consumption. The final volume index of gross value added can be calculated using the equation (11)

$$I_{q,i,T} = \frac{GVA_{i,T}(T-5)}{GVA_{i,(T-5)}(c.p.)}, \tag{11}$$

where $GVA_{i,T}(T\text{-}5)$ is gross value added in constant prices and $GVA_{i,(T-5)}(c.p.)$ means gross value added in current prices in the past. The indices $I_{q,i,T}$ are then confronted with the indices of labour intensity and with the change of labour endowment with capital.

Results

Table 1 describes the development of economic indicators of the interest. Labour intensity decreased while the real output as well as real gross value added increased during the whole period. At this level the development of labour endowment with capital was also decreasing but this indicator stayed in positive numbers during the whole period. It seems that between 2005 and 2010 there existed a capital expansion. Table 2 provides list of commodities connected with figures in Table 1.

Table 1 Development of labour intensity, output, gross value added and capital endowment of labour in the period 1990–2010

	Labour intensity development				Volume indices of output				Volume indices of gross value added				Development of labour endowment with capital			
CZ-CPA	**1995**	**2000**	**2005**	**2010**	**1995**	**2000**	**2005**	**2010**	**1995**	**2000**	**2005**	**2010**	**1995**	**2000**	**2005**	**2010**
Total	**93.6**	**75.9**	**56.9**	**49.5**	**103.2**	**123.7**	**160.2**	**188.1**	**97.5**	**105.6**	**129.0**	**148.8**	**0.11**	**0.06**	**0.02**	**0.00**
A	85.3	85.2	63.0	55.7	65.3	62.5	65.4	66.5	120.7	120.0	143.3	105.3	0.11	0.02	0.03	0.00
B	63.4	61.6	48.2	41.8	78.8	59.2	57.1	54.4	107.6	69.6	66.4	51.4	0.26	0.16	0.04	0.05
C	93.3	63.8	43.1	33.1	88.1	125.8	181.2	216.6	83.1	126.1	186.0	249.3	0.14	0.09	0.04	-0.06
D	49.4	30.1	24.1	20.0	166.8	187.3	213.5	219.7	49.1	38.6	42.6	40.3	0.34	0.16	-0.05	0.14
E	65.9	59.7	59.6	52.7	124.1	156.0	180.4	203.0	60.0	55.4	69.7	53.9	0.32	0.19	0.02	-0.09
F	95.8	86.3	71.8	66.5	130.3	120.3	145.4	167.7	76.3	47.8	52.4	60.4	0.59	0.17	0.01	0.09
G	131.6	117.9	88.0	73.7	87.4	104.5	139.4	175.2	46.1	66.3	100.8	113.0	-0.40	0.27	0.24	-0.14
H	90.9	70.3	58.1	47.3	114.3	129.3	160.0	187.2	97.2	98.2	111.7	125.4	0.10	0.21	0.06	0.03
I	52.9	59.7	56.3	73.8	248.9	244.0	230.8	216.8	124.6	104.3	70.8	56.5	-0.18	-0.13	0.05	0.19
J	31.2	20.5	15.4	16.0	279.6	489.9	680.1	851.8	231.4	312.1	434.2	556.7	-0.56	0.14	-0.09	0.03
K	113.5	111.1	73.0	64.3	260.9	326.4	404.7	517.6	325.1	444.6	365.9	608.4	0.37	0.06	0.01	0.04
L	194.9	144.6	81.4	76.3	108.7	135.2	170.1	234.8	134.1	132.4	135.1	167.4	-0.23	-0.05	0.00	0.05
M	52.6	48.9	42.4	41.9	191.5	213.0	280.7	324.4	174.3	151.1	217.8	227.0	0.48	0.03	0.01	-0.01
N	63.6	86.6	63.0	57.1	168.3	142.8	180.5	204.4	147.0	162.9	161.9	185.1	0.32	0.59	0.10	0.18
O	64.6	58.5	56.0	50.3	121.1	131.6	151.9	158.0	103.2	104.3	111.7	119.9	0.29	0.04	0.04	-0.03
P	82.5	77.5	75.6	61.7	112.8	113.9	127.5	140.8	125.4	114.1	123.2	130.9	0.20	0.09	0.00	0.02
Q	117.4	133.2	110.1	113.9	90.1	73.0	86.7	90.6	101.5	76.8	86.7	73.7	0.07	0.08	-0.05	-0.02
R	91.5	71.7	62.9	64.4	102.2	130.6	148.5	159.9	113.2	95.8	100.7	95.8	0.37	-0.07	0.09	0.09
S-U	129.8	131.6	128.5	152.8	93.3	91.9	88.2	90.7	121.9	84.6	72.7	76.0	-0.15	0.05	0.14	-0.13

Source: own calculations

When we look at the development connected with Products of agriculture, forestry and fishing (A), one can see quite stable output (about 65%) in comparison with the output of these products in 1990. Real gross value added was also quite stable till the year 2000 that is about 20 % more in comparison with the gross value added in 1990. There was a significant increase of the value added connected with this group of products in 2005. This was followed by decrease in this indicator on the level of about 105 % in comparison to 1990. Labour intensity development shows the decreasing tendency from 2000 onwards. It is probably caused by the movement of the employees from the industry of agriculture to other industries. Moreover, the development of labour endowment with capital shows a capital deepening during the whole time.

Table 2 The list of commodities connected with Table 1

CZ-CPA	
A	Products of agriculture, forestry and fishing
B	Mining and quarrying
C	Manufactured products
D	Electricity, gas, steam and air conditioning
E	Water supply; sewerage, waste management and remediation services
F	Constructions and construction works
G	Wholesale and retail trade services; repair services of motor vehicles and motorcycles
H	Transportation and storage services
I	Accommodation and food services
J	Information and communication services
K	Financial and insurance services
L	Real estate services
M	Professional, scientific and technical services
N	Administrative and support services
O	Public administration and defence services; compulsory social security services
P	Education services
Q	Human health and social work services
R	Arts, entertainment and recreation services
S-U	Other services

Source: CZSO

Special attention should be paid to Manufactured products (C) due to its importance for the Czech economy. Only in 2010 there were negative values of the development of labour endowment with capital. It is caused by economic recession which began in 2009. We can see capital deepening of these products in the period before 2009. Also the output corresponds to this development of capital endowment of labour. There are obvious efforts to continuously increase the value added in connection with these products. Moreover, it could be said that human labour is partly replaced by capital. This underlines the development of labour intensity which decreased during the whole period.

In the last years, the situation in Construction (F) was quite discussed. Table 1 shows the decrease in labour intensity during the whole period. Despite the recession in 2010, the capital endowment of labour was not negative though investments are decreasing.

It seems that the situation connected with products of Wholesale and retail trade services (G) shows similar properties as in the case of manufactured products. The results show the decrease in labour intensity, the increase in output, the increase in gross value added and only the specific development of labour endowment with capital. There was almost no investment in the period

1990–1995 according to this indicator. During the next ten years there was a state of capital deepening which was followed again by the decrease of the labour endowment with capital. It was probably due to economic recession.

The information about development in connection with financial and insurance services is also realistic. We can see the increase in labour intensity for the period 1990–2000. It means the output was produced by higher hiring of human labour. The period 2000–2010 was in the sign of the decrease in labour intensity. It was probably caused by the development in the information and communication technologies. There is an obvious increase of importance of financial sector from the point of view of output. Gross value added showed multiple increases in comparison with the value added in 1990 during the whole period. The figures on labour endowment with capital show higher investment in the period 1990–1995. Since the 1995 we can see only moderate capital deepening.

In the same way the development of the rest of commodities could be evaluated. The description of the development of selected indicators concentrates on the crucial commodities for the Czech Republic in this paper.

Conclusion

The paper focused on the methodology of compilation of the Time Input-Output tables and following methodology of usage of data from these tables. It focuses on the commodity structure of the working time and its development. From this point of view results of the analysis described in this paper show quite realistic view of the economic development. The commodity structure of the allocation of the working time could be improved with an appropriate including quality of human capital. At the moment it is not possible due to unavailability of suitable data sources.

Comprehensive view on the four estimated indicators represents a basis for evaluation of the development connected with a particular group of products. Based on this information, we can evaluate whether investments into the capital assets can be substituted by human work or human work can be replaced by machines. There could be also a situation when the development based on Time Input-Output tables will be in contrast with the development of monetary data from other sources. This situation could indicate errors in any of the data sources.

Nevertheless it should be noted that the results of application of the method provide only a kind of additional information to ordinary published information in supply and use tables. Some weaknesses of the methods could be identified while analysing specific products in detail.

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