STATISTIKA

STATISTICS
AND ECONOMY
JOURNAL

VOL. **96** (3) 2016

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Reflection of the Economic Crisis in the Consumer and Entrepreneurs Subsectors[1]

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Abstract

National accounts provide data about the economic behaviour of the sector of households as a whole and, to a limited extent, also divided into the consumer and entrepreneur sub-sectors. Time series of the sub-sector data are short, but cover the periods of significant economic changes. It is usual that final consumption expenditure and investments grow in times of economic growth. Recessions and crises are reflected in cautious consumer activity – lower consumption and less interest in investments and consequently in loans. When the signs of a crisis occur, producers immediately reduce costs and investments, and try not to increase their indebtedness. This paper should help identify manifestations of these general observations concerning consumers' and producers' behaviour in the period from 2009 to 2014, namely, behaviour of households in the Czech Republic viewed as consumers and as entrepreneurs. The article focuses in this context also the information value of the data for subsectors.

Keywords

Households, consumer sub-sector, entrepreneur sub-sector, economic crisis

JEL code

E21, C82

INTRODUCTION

Households are generally defined in the national accounts as a consumer sector, that is, their main economic role is that of consumption and their main financial source is income from labour. However, this characterisation unconditionally applies only to a part of the household sector, namely, to households as consumers. In addition to consumers, the household sector also contains entrepreneurs, meaning small-scale trade owners, whose main economic role is that of producing non-financial goods

[1] This article was processed with contributions from long-term institutional support of research activities by the Faculty of Informatics and Statistics, University of Economics, Prague, Czech Republic.

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and services and their sources draw on sales of their own products. In other words, their economic behaviour is different from that of consumers', being analogous to the behaviour of non-financial corporations.

However, consumption must be considered within the framework of the scope and relationships of disposable income, as well as savings, because households, on a general level, form a significant contributor to national savings, and economic theory ranks the latter among the fundamental roots of economic growth and prosperity. Consumers enter the income distribution process as a subject that pays less than it gets (households must, first of all, pay taxes on production and imports, income taxes, and social contributions; on the other hand, they receive wages, social benefits and other types of income). They thus create, in the form of disposable income, sufficient resources to cover their immediate needs (in the sense of final consumption expenditure), and simultaneously they create savings. Households thus represent a sector that should generate resources sufficient for creating the national savings while simultaneously representing a subject to produce sufficient available resources in the economy to alleviate the deficit chronically created by the general government, which also means reducing the deficit with respect to foreign countries. Households as consumers play the role of a subject whose economic result (as recorded on the non-financial account) is positive (profit). It means that consumers traditionally play the role of creditors.

Households as entrepreneurs exhibit signs characteristic for the economic behaviour of non-financial corporations (even though there are differences based on the specific role of a small-scale producer).[5] For such producers, the decisive data are recorded on the production account (the value added), generation on income account (the value structure of the value added), and acquisition of non-financial assets account (investments). In this context, the dominant index is the value added they create.

In periods of economic growth, the offer of consumer and mortgage loans gets wider and both expenditure on the final consumption and investments of consumers are growing.

Consequently, their savings and financial savings rates (already low for Czech households)[6] go down. Under such conditions, serious macroeconomic consequences are brought about if consumption by households quickly grows. Those households that do not create sufficient resources have to cover part of their consumption and investments with the aid of loans. This increases households as consumers' indebtedness in the form of loans and, together with the decreasing rates of savings and financial savings can, despite a favourable economic climate, lead to insolvency and inability to meet liabilities.

In the years of recession, and even crisis, coming after years of economic growth, a turn occurs in behaviour of households as consumers, characterised by a cautious approach to consumption and little interest for investments and long-term loans. However, this turn does not come immediately. As a rule, a crisis first hits non-financial and financial corporations, possibly also general government;[7] and households are only hit after a certain time lag.[8] It should also be true that, in the years of crises, households restrict their both non-financial and financial investments, or try to put their free resources into lower-risk assets.[9] Producers (mainly represented by non-financial corporations) respond

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5 A small-scale producer is understood as an economic unit whose legal entity is not different from the individual who carries out the production activity (in the Czech Republic they run their businesses pursuant to the Trade Licence Act, but are not entered in the Commercial Register – merchants, farmers, lawyers, advisors, artists, etc.).

6 See Hronová and Hindls (2008), Janáček (1999).

7 Whether or not the non-financial corporation and/or general government will be hit most seriously depends on many circumstances, among which the causes of the particular crisis are most important. A more detailed treatment of these issues can be found, e.g., in Czesany (2002), Hájek (2008).

8 The fact that this tendency is generally present in the final consumption expenditure values of households and the general government has been verified by a test of significance in a group of 33 developed countries. More details can be found in Hindls and Hronová (2012).

9 See also Hronová and Hindls (2013).

to a crisis in a different way. When the signs of a crisis occur, they immediately reduce costs (especially both non-financial and financial investments), and try not to increase their indebtedness.

This paper should help identify manifestations of the above-mentioned general observations concerning consumers' and producers' behaviour in the period from 2009 to 2014, namely, behaviour of households in the Czech Republic viewed as consumers and as entrepreneurs. To this end, we will use the data for the household sub-sectors in the Czech Republic according to ESA 2010, complementing our analysis with a look at the evolution of the economic behaviour of the household sector as whole.

1 NATIONAL ECONOMY CONTEXT

In the late 1990s, the Czech economy underwent a short crisis, brought about by internal causes, and from 1999 to 2008 there was a period of a high GDP growth rate (with 4.0% as average annual growth). This growth was supported by a constantly growing demand by households (with the average annual growth at 2.9%), investments into fixed capital (with the average annual growth at 5.5%), as well as a high growth rate of turnover with abroad, when the growth rate of exports (12.2% annual average growth) was higher than that of imports (11.6% annual average growth).

This boom period in the Czech Republic was terminated when signs of the worldwide financial crisis came in 2008, followed by the economic and fiscal recession periods 2008–2010 and 2010–2012. Since the industrial and construction sectors declined in 2009, investments into fixed capital were substantially reduced, and both imports and exports went down as well (by 10% year-to-year). Nonetheless, the Czech economy managed to maintain active balance values for trade and services, when the CZK (Czech Crown) was moderately strengthening. Negative consequences in the production were reflected in the slow-down, stagnation and finally decrease of households' final consumption expenditure (see Table 1). The rate of indebtedness slowed down as well. The economic recession and the accompanying increase of the unemployment rate led to an increase of the government debt and deficit, and to focusing the economic policy exclusively on "budget responsibility".[10] Hence the recovery was unstable and the economic crisis came back in 2012 and 2013.

In 2014, economic growth returned with all its positive aspects: growing industrial production (especially, in the secondary industry focused on demand from abroad), growing construction activities (for the first time after five years of decrease), growing retail, investments by both businesses and the state without a significant increase in indebtedness, reduced unemployment rate, growing real wages (after a two-year decrease), and a surplus on the balance of payments on the current account (first since 1993). All of that at a low average annual inflation rate, reduced influx of investments from abroad, and a weakening CZK (due to the intervention by the Czech National Bank).

Table 1 Year-to-year growth rates for selected indices in the national economy of the Czech Republic (percentages)

Index	2008/07	2009/08	2010/09	2011/10	2012/11	2013/12	2014/13
GDP	2.7	–4.8	2.3	2.0	–0.9	–0.5	2.0
GFCF	2.5	–10.1	1.3	1.1	–3.2	–2.7	2.0
FHCE	2.9	–0.7	1.0	0.3	–1.5	0.7	1.5
Industrial production	–1.8	–13.6	8.6	5.9	–0.8	–0.1	5.0
Construction production	0.0	–0.9	–7.4	–3.6	–7.6	–6.7	4.3
Inflation rate	6.3	1.0	1.5	1.9	3.3	1.4	0.4

Note: GDP – Gross Domestic Product, GFCF – Gross Fixed Capital Formation, FHCE – Final Consumption Expenditure by Households.
Source: <www.czso.cz>

[10] Meaning to keep the general government's deficit below 3% of GDP.

The periods of prosperity and crisis, expressed by means of the GDP growth, have different effects on the economic behaviour of individual sectors. A succinct measure of their economic activities is given by their net lending/borrowing. Czech non-financial corporations as a whole went through the crisis with positive balances or low deficits, the households as a whole had high surplus values of resources. Hence the consequences of the financial and economic crisis mainly hit the general government (see Table 2).

Table 2 Net lending/borrowing of the national economy of the Czech Republic and its sectors (bn CZK, current prices)

Institutional sector	2007	2008	2009	2010	2011	2012	2013	2014
Non-financial corporations	–211.0	–135.4	9.7	–57.1	–99.3	–49.5	–17.5	–78.2
Households	57.6	47.4	105.5	75.2	70.9	90.9	75.3	104.2
– as entrepreneurs	–	–	6.8	–7.3	36.9	–12.1	19.2	–72.3
– as consumers	–	–	98.7	82.5	34.0	103.0	56.1	176.5
General government	–26.6	–84.6	–216.2	–174.5	–108.9	–157.9	–47.2	–84.6
Total economy	–155.2	–161.2	–71.5	–127.2	–112.4	–46.0	43.5	–10.5

Source: <www.czso.cz>

The economic behaviour of small-scale entrepreneurs in the household sector measured by the records on the national accounts is different not only from that of households as consumers but also from that of non-financial corporations. Hence we will base our analysis here on the data from the groups of consumers and entrepreneurs in the household sector. Data provided by the Czech Statistical Office are available for the household sector as a whole from the period of 1990–2014. The values of the indices for the consumer and small-scale entrepreneur groups, or the entrepreneur and consumer sub-sectors[11] are only available for the period of 2009–2014. Even that short time series will, however, help us explain the differences in behaviour of small-scale entrepreneurs and consumers in a complex period full of turbulent fluctuations and trace the consequences of the recession and crisis conditions for these two important sub-sectors of the household sector. Last but not least, this very existence of these differences in the economic behaviour in the years of crises is a confirmation for the necessity to monitor and assess, on a long-term basis, the data for the entrepreneur and consumer sub-sectors of the household sector. The analysis of the economic behaviour of these sub-sectors will be complemented with a view on the household sector as a whole.

2 GENERATION OF INCOME

The basic economic role of small-scale entrepreneurs is the production of goods and services, and the dominant index is that of value added and its structure; on the other hand, the main economic role of households as consumers is the consumption covered from their disposable income. However, households as consumers significantly contribute to the generation of the gross domestic product, not only by market activities (providing the dwelling services) but also by production for their own use (dwelling services produced by owner-occupiers, agricultural products retained by farmers and household services produced by employing paid staff).

[11] The Czech Statistical Office publishes data for the households according to the basic economic roles (production vs. consumption), speaking about these groups as sub-sectors. It distinguishes between two sub-sectors: households as entrepreneurs (S.141), and households as consumers (S.142). For the sake of understanding, we are going to employ this notation (both verbal and in codes) in the present paper despite the fact that it is not compliant with the official classification (in which S.141 and S.142 denote employer sub-sectors, i.e., entrepreneurs including self-employed).

Table 3 Proportion of consumer and entrepreneur sub-sectors in the creation of GDP in the Czech Republic (percentages)

Sub-sector	2009	2010	2011	2012	2013	2014
Entrepreneurs (S.141)	13.6	13.2	12.7	12.2	11.8	11.7
Consumers (S.142)	5.8	6.0	5.9	5.8	5.8	5.7
Households – total	19.4	19.2	18.6	18.0	17.6	17.3

Source: <www.czso.cz>, authors' calculations

The data shown in Table 3 indicate a decreasing proportion of the household sector in the creation of the GDP; this fact is a consequence of the decreasing proportion of small-scale entrepreneurs. Their Gross Value Added (GVA) went constantly down every year from 2009 to 2013 (in current prices); the year 2014 brought growth of the GVA; even then it amounted to merely 93.4% of the 2009 GVA (in current prices). The GVA was moderately growing in the consumer sub-sector (except for 2012); the total growth amounted to 6.1% for the entire period under assessment (in current prices).

The value structure of the GVA is for the household sector (and its sub-sectors) fundamentally different from that of other sectors. While the most significant GVA component is given by the compensation to employees in other sectors, for households it mainly consists of mixed income and operating surplus. Generally, households as consumers have only limited numbers of employees (in the provision of household services); and entrepreneurs are predominantly self-employed (so their labour compensations are included in the mixed income).[12] The net taxes on production and imports have a low value (and, consequently, a low proportion); hence the operating surplus and the mixed income are the main components of the net value added, and consequently of the GVA in both sub-sectors. Consumption of fixed capital is the second most important component of the GVA created by the consumers. The consumer sub-sector's proportion of this component in the GVA is substantially larger than that of the entrepreneur one's – the reason is that the apartments and houses owned by consumers have high values.

A high proportion of consumers' operating surplus, mixed income, and consumption of fixed capital also means that the proportion of consumers' gross operating surplus and mixed income in the GVA amounts to about 99%, while in the entrepreneur sub-sector the average proportion was 86.2% in the period under assessment. The average values for the components of the GVA for the consumer and entrepreneur sub-sectors from 2009 to 2014 are shown in Table 4.

Table 4 Structure of Gross Value Added for the consumer and entrepreneur sub-sectors (as percentages of GVA)

Component	Entrepreneurs (S.141)	Consumers (S.142)
Net operating surplus	–	53.7
Net mixed income	77.3	14.0
Consumption of fixed capital	8.9	31.3
Compensation of employees	15.4	0.2
Net taxes on production and imports	–1.6	0.8
Gross value added	**100.0**	**100.0**

Source: <www.czso.cz>, authors' calculations

[12] Let us recall that the mixed income includes income from business activities as well as the labour income of the small-scale producers.

We must note about the above-stated data that the consumers' operating surplus is generated not only by providing dwelling services to other subjects, but also to themselves. This, of course, deforms the view of the actual "profit" from such activities and, in relation to the specific character of the property income (see below), the analysis of the disposable income creation in individual sub-sectors it is hard to interpret.

3 DISPOSABLE INCOME AND THE USE THEREOF

The creation of the disposable income and the use thereof for consumption is a focus of our analysis of the households as consumers. Small-scale entrepreneurs have no final consumption; their disposable income hence equals the savings,[13] meant for investments. For households as consumers, the value of savings is calculated as a difference between the disposable income and final consumption expenditure values. When evaluating the economic behaviour of the consumers and small-scale entrepreneurs in the household sector, we will first have a look at the household sector as a whole.

The structure of disposable income in the household sector evolves insignificantly in time; the main component is that of wages, and the most dynamic (regarding the time evolution) component is usually that of the property income. The reduced economic activities in the crisis time and the growing unemployment should cause, on the one hand, a decrease in the proportion of wages, income from business and current taxes (especially the income tax on the income of individuals and legal entities); and, on the other hand, an increase in social benefits and a growing balance of the social income. Table 5 shows the time evolution of the structure of the net disposable income.

To a limited extent, the data shown in Table 5 confirm the general points stated above. After the beginning of the economic crisis in 2009, the proportion of income from labour (wages and salaries) went down because employers very quickly responded to the signs of the coming crisis;[14] on the other hand, the proportion of income from the businesses of small-scale producers(i.e., the mixed income) further grew in that year. The subsequent decrease of the proportion of the mixed income (and of its value expressed in current prices) was caused by decreasing net value added created by entrepreneurs between the years 2009 and 2013; the latter decrease is a clear sign of reduced economic activity. A turning point came as late as in 2014, when the entrepreneurs' net value added went up by 4% (in current prices) compared with the year before; this increase was mainly caused by an increase in the mixed income by 7.4%.

Table 5 Structure of net disposable income (percentages of NDI)

Index	2007	2008	2009	2010	2011	2012	2013	2014
Wages and salaries	61.2	60.7	58.0	58.3	59.7	60.7	61.5	61.6
Net operating surplus	6.0	6.1	6.1	6.3	6.2	5.9	6.0	5.9
Mixed income	22.4	21.1	21.7	21.2	20.6	19.6	19.0	19.9
Balance of property income	7.2	7.4	6.7	6.3	6.3	6.2	6.4	5.8
Balance of social income values[15]	12.1	12.1	14.3	14.5	14.8	15.0	14.4	14.2
Balance of other income values	–0.2	–0.1	–0.1	–0.1	–0.4	–0.2	0.3	0.4
Current taxes	–8.7	–7.3	–6.7	–6.5	–7.2	–7.2	–7.6	–7.8
Net disposable income (NDI)	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Source: <www.czso.cz>, authors' calculations

[13] The same as for the non-financial corporations.

[14] In 2009, the wages paid in the Czech economy (in current prices) went down by 2% in comparison with the year before.

[15] Social benefits – social contributions.

Both in 2009 and in 2014, the balance of the property income went down substantially,[16] due to the year-to-year decrease (in current prices) in the received interest amount by 33.8% and paid interest amount by 41.6% in 2009 (the same values were, respectively, 28.3% and 35.9% in 2014). It is also interesting to compare the absolute values of the received and paid interest. The interest amount received by households in 2014 (21.5 bn CZK, current prices) is the smallest in the entire time series since 1993, while the interest amount paid by households in 2014 (11.1 bn CZK, current prices) is the second smallest; the smallest one occurred in 1993. This fact is a consequence of very low interest rates on both deposits and loans, and unwillingness of households to increase their indebtedness (an increase of households' indebtedness in the form of loans in 2014 amounted to mere 36.0% of the same increase in the last year before crisis, 2008).

The balance of social income only concerns the consumer sub-sector, but it is a result of the evolution of social contributions, whose amount depends on the levels of wages and employment, and social benefits, whose amount always increases when the economic activity is in recession. This fact is also indicated by the high values of the said balance in the years 2009 and 2012, when the crisis prevailed. However, the balance values for the property income and current taxes must be analysed with respect to the differences in the economic behaviour in the two sub-sectors.

Table 6a Selected indices for the entrepreneur and consumer sub-sectors (bn CZK, current prices)

Index	2009		2010		2011	
	S.141	S.142	S.141	S.142	S.141	S.142
Net operating surplus	–	126.2	–	130.7	–	128.2
Mixed income	418.2	28.2	407.0	32.0	393.1	32.9
Wages and salaries, receivable	–	1 190.9	–	1 206.1	–	1 236.7
Property income – balance	–387.2	525.7	–399.9	529.4	–340.0	470.0
– receivable	5.8	539.7	5.7	545.9	1.8	486.3
– out of it: withdrawals from income of quasi-corporations	–	387.7	–	399.3	–	337.2
– payable	393.0	14.0	405.6	16.5	341.8	16.3
– out of it: withdrawals from income of quasi-corporations	387.7	–	399.3	–	337.2	–
Primary income[17]	31.0	1 871.0	7.1	1 898.3	53.1	1 867.8
Current taxes	12.2	128.3	5.3	131.6	7.8	140.7
Social contributions	14.7	242.5	15.0	241.7	15.8	247.3
Social benefits[18]	0.1	535.4	0.1	541.5	0.1	553.0
Net disposable income (for S.141, also savings)	19.3	2 035.0	2.0	2 065.3	43.0	2 025.1

Note: S.141 – Households as entrepreneurs, S.142 – Households as consumers.
Source: <www.czso.cz>, authors' calculations

[16] The proportion of property income balance in the net disposable income thus got in 2014 to the lowest level seen since 1993.

[17] The shown values correspond to the balance on the account of primary income, after subtracting employers' social contributions, which do not belong to households but are, in line with the concept of the compensations paid to employees, recorded on the resource side of this account for households. More on this topic – see Hronová et al. (2009).

[18] In the case of entrepreneur sub-sector, the social benefits are on the payable side, paid to their employees (the so-called "other social insurance benefits" different from pensions); for the consumer sub-sector, the social benefits are on the receivable side (obtained from the state, financial corporations, and employers, including small-scale entrepreneurs).

Table 6b Selected indices for the entrepreneur a consumer sub-sectors (bn CZK, current prices)

Index	2012		2013		2014	
	S.141	S.142	S.141	S.142	S.141	S.142
Net operating surplus	–	123.8	–	125.1	–	126.1
Mixed income	375.1	35.1	362.2	35.2	389.8	35.6
Wages and salaries, receivable	–	1 271.5	–	1 285.4	–	1 317.8
Property income – balance	–379.5	509.6	–339.2	473.2	–456.0	580.0
– receivable	1.6	520.1	2.9	490.1	2.7	590.4
– out of it: withdrawals from income of quasi-corporations	–	376.4	–	337.7	–	454.1
– payable	381.1	10.5	342.1	16.9	458.7	10.4
– out of it: withdrawals from income of quasi-corporations	376.4	–	337.7	–	454.1	–
Primary income[13]	–4.4	1 940.0	23.1	1 918.8	–66.7	2 059.5
Current taxes	7.1	144.0	8.2	150.6	7.9	156.3
Social contributions	15.4	253.1	15.1	262.7	14.1	273.9
Social benefits[14]	0.1	566.3	0.0	563.2	0.0	576.6
Net disposable income (for S.141, also savings)	–13.9	2 104.0	12.7	2 075.1	–78.6	2 214.2

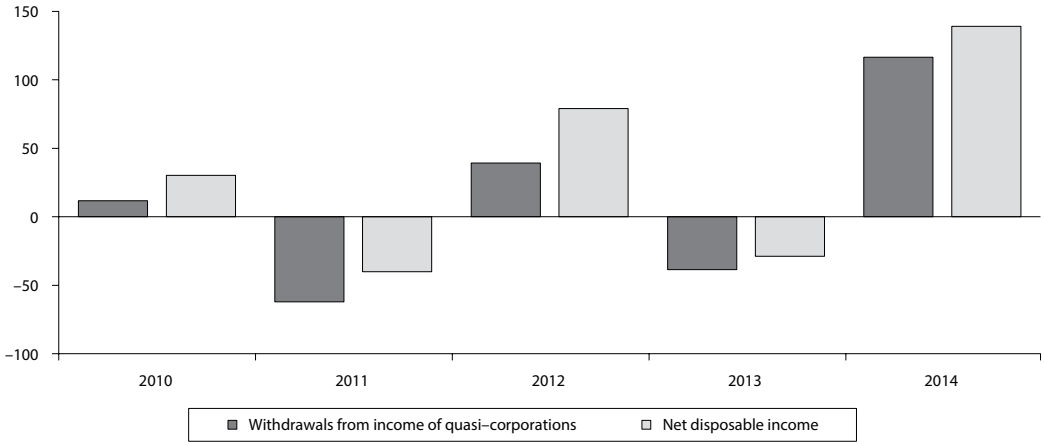
Note: S.141 – Households as entrepreneurs, S.142 – Households as consumers.
Source: <www.czso.cz>, authors' calculations

The data in Tables 6a and 6b indicate that there are high values of the property income "paid" by entrepreneurs and received by consumers. Withdrawals from income of quasi-corporations cause these high amounts compensated within the household sector. This index characterises the income drawn by entrepreneurs for their own use from the profit (mixed income) created by the quasi-corporations they own.[19] It means that a difference between the value of the mixed income and that of the withdrawals from income of quasi-corporations is the amount which entrepreneurs are willing to put aside from their profit to invest into their businesses. This amount, together with the balance of other property income types (interest and rents) makes up the entrepreneurs' primary income. The reduction of the amount which the entrepreneurs draw for their own use is a reason for the significant increase of the primary income, and subsequently of their net disposable income, and savings in 2011 and 2013; and finally their net lending (see Table 2). In this context we can say that entrepreneurs limit their consumption in favour of investments (both non-financial and financial). An opposite phenomenon (an increased withdrawals from income of quasi-corporations) in the years 2010, 2012 and, mainly, 2014, brought entrepreneurs' very low or even negative value of the primary income, disposable income, and savings. At the same time the savings is their own resource for financing their investments.

Households' final consumption expenditure was growing in the period under assessment faster than their net disposable income (the former grew in 2014 by 8.2% as compared with 2008, while the latter grew by 7.2%). In the 2010 constant prices[20] the final consumption expenditure grew only by 1.3% in the same period. In the years of the crisis, households were more cautious regarding their consumption – the volume of their demand went down (namely, the final consumption expenditure in constant prices was lower by 0.7% in 2009, and by 1.5% in 2012 – see Table 1). It was a natural response to the economically unstable environment, and the overall negative feelings in society due to the strongly restrictive economic policy. Such a substantial and long-lasting stagnation of the final consumption

[19] Entrepreneurs draw such amounts form their mixed income in their own favour as consumers.
[20] Let us recall that these are not the classical constant prices, but last year's prices chain-linked with the base of 2010.

Figure 1 Withdrawals from income of quasi-corporations – consumers and net disposable income – consumers (year-to-year growth, bn CZK, current prices)



Source: <www.czso.cz>, authors' calculations

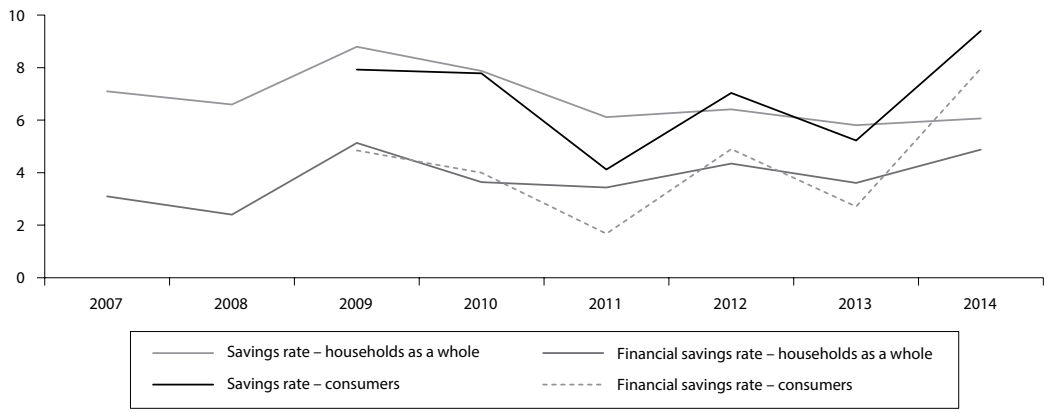
expenditure by the households in the Czech Republic has not occurred since 1993. Together with a very low inflation rate, this phenomenon attenuated the economic growth. A change of the economic policy and overall thawing of the economic environment increased the confidence felt by households in 2014.

A high proportion of the final consumption expenditure by households in their net disposable income and a faster growth of the former than of the latter are reflected in a low level of savings – this level is traditionally among the lowest within the EU;[21] and it has a tendency to go down even further (see Figure 2). The savings rate by households as consumers significantly fluctuates from year to year; this phenomenon is implied by the drop in net disposable income (by 2.0% in 2011, and 1.4% in 2013, in current prices) while the final consumption expenditure was growing (by 2.0% in 2011, and 1.6% in 2013, again in current prices). Year-to-year decreases in net disposable income of consumers in the years in question were caused by changes in the structure of its generation, that is, significant year-to-year decreases of withdrawals from income of quasi-corporations (see Tables 6a and 6b, and Figure 1). The same reason there is for the substantial growth of the savings level in 2014; the increased withdrawals from income of quasi-corporations in favour of consumers amounted to 83.6% of the year-to-year increase in the net of disposable income. Withdrawals from income of quasi-corporations is internal transfer between entrepreneurs and consumers within the household sector; hence the evolution of the households' saving rate does not respond to such fluctuations.

The financial savings rate of households as consumers and households as a whole evolved in a similar way. It is therefore clear that the value of a sole index (withdrawals from income of quasi-corporations) influences the results recorded on the sub-sectors' accounts, from the primary income to the net lending/borrowing (see Table 2); and the year-to-tear fluctuations (ups and downs) of the primary and disposable income, as well as net borrowing in the consumer and entrepreneur sub-sectors are nearly exclusively caused by the changes in the withdrawals from income of quasi-corporations. This phenomenon affects not only the values of the mentioned absolute indices, but also those of relative indices

[21] Within the framework of international comparisons, a gross savings rate of households is published; its long-term value in the Euro-zone countries is between 12% and 15%, while in the Czech Republic it is between 9% and 13%.

Figure 2 Savings rate and financial savings rate (as percentages of net disposable income)



Source: <www.czso.cz>, authors' calculations

related to them. Analysing the latter therefore will not bring any significant informational value regarding the description of the economic behaviour of the sub-sectors in question; or rather, we are unable to objectively assess to what extent the recession and recovery are reflected in the data from the consumer and entrepreneur sub-sectors.

These considerations imply that, when analysing the economic behaviour of the consumer and entrepreneur sub-sectors, it is better to focus our attention on non-financial and financial investments and on changes in the assets and liabilities.

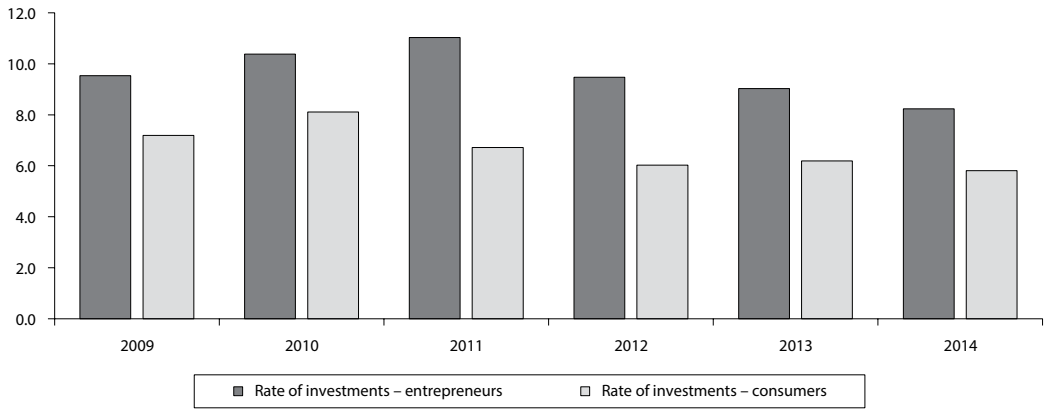
4 NON-FINANCIAL INVESTMENTS

Savings plus the capital transfer balance make up a resource for financing investments. The level of investment activities, similar to consumption, is an index reflecting the evolution of the economic cycle. In other words, a decrease in economic activities in the national economy as a whole is reflected in a decrease in investments in all sectors, including households (for households as consumers, the only investments concerned are those into apartments and houses, or possibly valuables).[22]

In the case of households, the level of investment activities is measured by the rate of investments, viewed as the proportion of fixed capital formation and of disposable income; for both of these indices, we can consider either gross or net value. Even though we speak about net disposable income above, we will now use the gross rate of investments, i.e., the proportion of the gross fixed capital formation and of gross disposable income. We will do so not only because consumption of fixed capital, falling into the gross disposable income, is a resource for financing investments, but also to achieve a better comparability with the index measuring the entrepreneurs' investments. For the entrepreneur sub-sector we have to measure the investments with respect to the fact that the character of the economic behaviour of households as entrepreneurs is similar to that of non-financial corporations, for which the investments are measured via the gross fixed capital formation and the gross value added. Data on the investment rates for both sub-sectors are given in Figure 3.

[22] Households as consumers expend all articles of both short- and long-term use at the time of the purchase, have no stock, and the only investments into fixed capital are those into apartments and houses. The latter fact follows from the definition of the final consumption expenditure by households.

Figure 3 Rates of investments (percentages of gross disposable income – for consumers, and of gross value added – for entrepreneurs)



Source: <www.czso.cz>, authors' calculations

Figure 3 indicates a decreasing rate of investments by both consumers and entrepreneurs, implied by a decreasing volume of the investment activities. The value of the gross fixed capital formation went up (in current prices) until 2011; this growth was followed by decrease, observed in each year of the period under assessment until its end (the value of the gross creation of fixed capital in 2014 amounted to a mere four-fifths of this value in 2009). Consumer investments evolved in a similar way,[23] but the decrease in the value of investments was observed as early as 2011 for them (with a year-to-year decrease of 18.6%). After that, investments into fixed capital stagnated – their value in 2014 was at a mere 88.0% of that of 2009. Neither very low interest rates on mortgage loans nor the stagnating prices of real estate brought increased interest of households as consumers in investing into their dwellings. The data on the evolution of investments testify (better than the indices studied above) to the differences in the economic behaviour of consumers and entrepreneurs – consumers´ response to the coming crisis is very slow in consumption, but quick in limiting non-financial (and also financial – see below) investments.

5 FINANCIAL INVESTMENTS AND INDEBTEDNESS OF HOUSEHOLDS

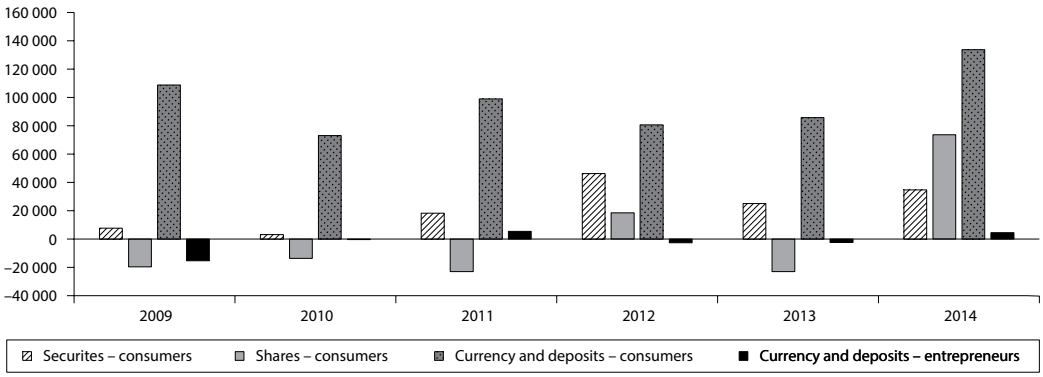
The conclusions based on the analysis of the data recorded on the non-financial account of households as consumers should be adequately reflected in the values of financial transactions and changes in the assets held by households. A quick response of households as consumers to the coming crisis, manifested as limiting their investments into dwellings, was also seen for financial investments.

Figure 4 unambiguously confirms that, in an uncertain economic climate, consumers significantly restrict their financial investments, or focus on depositing their free resources in lower-risk assets (mainly short-term loans and treasury bonds);[24] and they try to get rid of shares and other equity. In connection with the households' tendency to get rid of higher-risk assets in the form of shares and other equity we should note that the dividend value paid to households from their shares and other equity was around 85 bn CZK each year in the period 2009–2013, but went down to 77 bn CZK in 2014. In 2014, which confirmed – from the households' viewpoint – a turn to economic growth, accompanied by growing

[23] Consumers' investments are exclusively incurred on apartments and houses.

[24] For example an extraordinary issuance of Czech treasury bonds in 2012.

Figure 4 Net change of receivables in the form of currency and deposits, securities and shares and other equity (mil. CZK, current prices)



Source: <www.czso.cz>, authors' calculations

prices of shares and other equity and offers of advantageous opportunities for financial investments, the households put their free sources into higher-risk assets of higher (even though decreasing) return. The consumers' willingness to invest into higher-risk assets was also supported by very low and even falling interest rates on deposits.

The situation is different for households as entrepreneurs. Their investments into securities and shares and other equity are negligible, nearly nil (hence they cannot be depicted in Figure 4). In comparison with the consumer sub-sector, the changes of entrepreneurs' receivables in the form of currency and deposits may also be viewed as insignificant (see Figure 4). The data about the consumers' financial investments can thus be viewed as the data for the entire household sector.

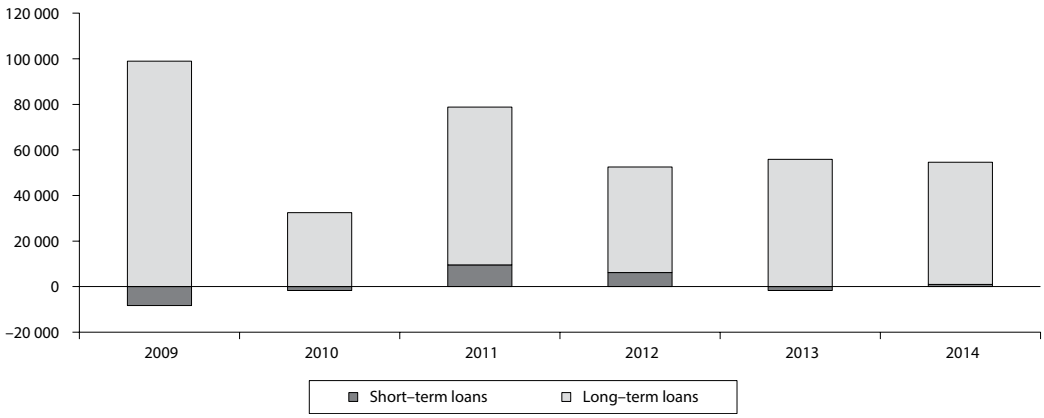
From the viewpoint of the evolution of the changes in liabilities, loans can be considered the most significant component. Figure 5 shows the annual net increments of indebtedness[25] in the form of loans in the consumer sub-sector; it reflects not only the evolution of consumers' demand for long-term (mortgage) loans, as related to the boom of the demand for real estate culminating between years 2007 and 2009, but also the fast response by households to the worsening economic conditions after the beginning of the crisis. An increase in long-term loans in the later years was supported by advantageous interest rates.

The evolution of liabilities is substantially different in the entrepreneur sub-sector, regarding both quantity and quality. While consumers increased their indebtedness (especially in the form of long-term loans) every year, entrepreneurs tried to reduce their debts in the period under assessment, again especially in the area of the long-term loans. This indicates that small-scale producers were not much interested in business loans and their expectations were less optimistic than those of the consumers.

Viewing the sub-sectors' data about the financial operations, we have to observe that consumers represent the dominant subject from the viewpoint of both receivables and liabilities. This fact concerns currency and deposits, net purchase of securities and shares and other equity on the side of receivables and loans on the side of liabilities. Figures 4 and 5 thus more or less reflect the behaviour of the household sector as a whole. However, in the case of loans, a slight difference between the sub-sectors can be pointed out – while entrepreneurs tried to reduce their indebtedness, consumers' new loans amount was higher than the amount paid up; both these observations are in particular true for long-term loans.

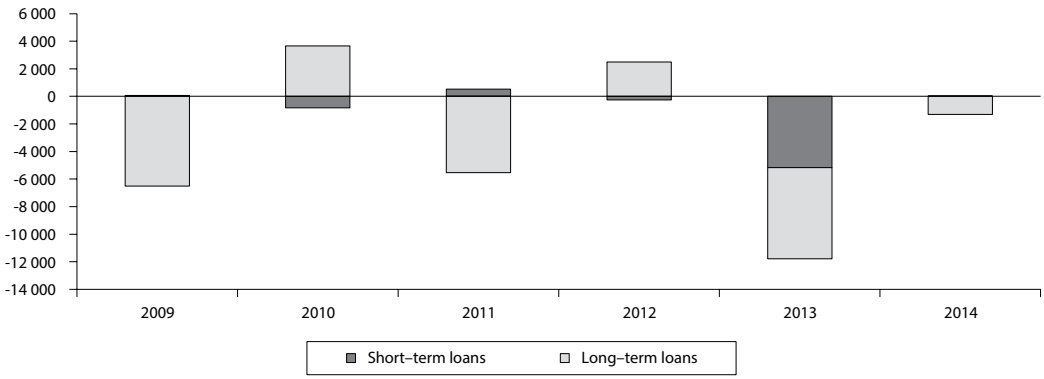
[25] Here the net increase is taken into account, i.e., a difference between the amount of received loans and paid instalments.

Figure 5 Net change in liabilities in the form of loans – consumers (mil. CZK, current prices)



Source: <www.czso.cz>, authors' calculations

Figure 6 Net change in liabilities in the form of loans – entrepreneurs (mil. CZK, current prices)



Source: <www.czso.cz>, authors' calculations

6 ASSETS AND INDEBTEDNESS OF HOUSEHOLDS AND CHANGES THEREOF

Assets and liabilities of households as entrepreneurs and as consumers have, of course, their differences based on differences in their economic behaviour. Consumers have no stock,[26] their fixed assets are limited to dwellings; an important component of the financial assets consists of shares and other equity and life insurance and pension entitlements; the only components of their liabilities are loans and other liabilities. Entrepreneurs' fixed assets include, in addition to dwellings, other buildings and machinery and equipment; and stock is an important item of their non-financial assets. As for the financial assets, currency and deposits are dominant; and financial liabilities also contain securities and financial derivatives. Nonetheless, similar to the flow account, the asset account of households predominantly belongs to consumers.

[26] This is based on an assumption that households as consumers expend all articles of both short- and long-term use (except for dwellings) at the time of the purchase.

Consumers' proportions in the household sector as a whole are significantly higher for non-financial assets (approx. 80%), financial assets (approx. 90–95%), and financial liabilities (approx. 85–90%) – see Table 7. The above-mentioned observations are mainly based on:

a) a high volume of the dwellings, which represents three-quarters of the value of non-financial assets of consumers, and three-fifths of that value of the household sector as a whole;
b) a high volume of currency and deposits – more than one-half of consumers' financial assets, and almost exactly one-half of the assets of households as a whole;
c) a high volume of long-term (predominantly mortgage) loans, amounting to approx. 95% of consumers' liabilities and approx. 90% of financial liabilities of households as a whole.

Table 7 Proportions of consumers' assets and liabilities in the values of the household sector in the Czech Republic as a whole (percentages)

	2009	2010	2011	2012	2013	2014
Non-financial assets	80.6	80.2	79.4	79.5	79.5	79.6
Financial assets	92.6	93.7	93.5	94.3	94.8	94.9
Liabilities	88.1	87.6	89.0	89.1	90.6	90.6

Source: <www.czso.cz>, authors' calculations

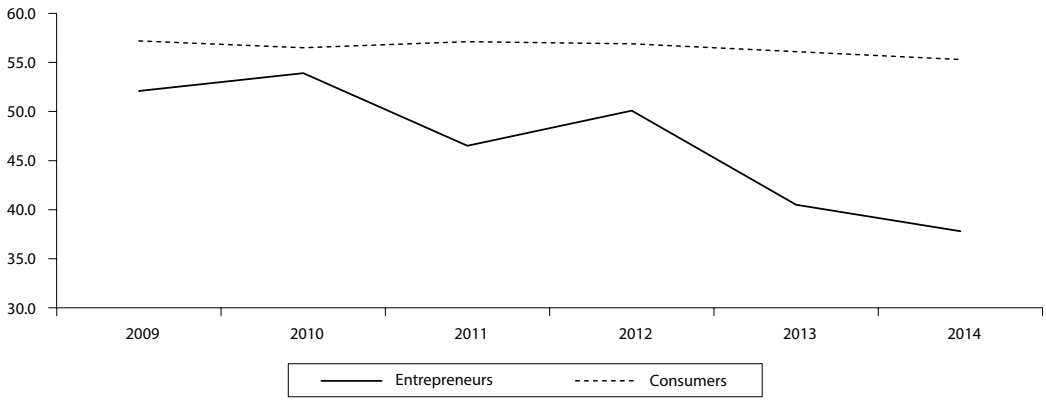
Economic growth is connected, on the one hand, with consumers' efforts to deposit their resources into both financial and non-financial assets. On the other hand, it leads to a "greater courage" to incur debts. The crisis and recession times lead consumers to caution in investing, both financial and non-financial.

In 2007, the economic growth culminated in the Czech Republic, accompanied by a high demand for investments into dwellings. This demand was significantly lower after the beginning of the economic crisis, even though the prices of real estate and the interest rates on mortgage loans were going down. This situation led to increasing financial assets held by consumers in the form of (especially short-term) deposits, and of securities and ownership interests; indebtedness was still growing, but at a lower rate. In the period under assessment (2009 to 2014), the overall increase in consumers' non-financial assets was 8.5%, out of which dwellings amounted to 5.3%; and an increase of financial assets was 32.6%, out of which transferable deposits amounted to 68.9%; and an increase in financial liabilities was 21.6%, out of which long-term loans amounted to 23.1%. In other words, the net financial worth of households as consumers grew by 37.9%, which was 19.5 percentage points higher than the change of the total net worth.

In the case of entrepreneurs, the signs of economic and financial crisis were even more pronounced. The highest increase there was in stock (by 54.6%, out of which the in-stock production amounted to 87.8%); the stock represents about one-quarter of entrepreneurs' non-financial assets. The value of dwellings went down by 3.3%, and that of financial assets by 9.9% (out of which short-term deposits amounted to 19.9%). Entrepreneurs' necessity to incur debts also went down – a decrease in financial liabilities was 6.4%, out of which the indebtedness in the form of short-term loans amounted to 18.4%. Consequently, entrepreneurs' net financial worth went down by 14.2%, while the total net worth went up by 12.4%.

The rate of indebtedness measured as the proportions of loans and deposits as of the end of the year also testifies to the differences in the evolution of the main items of the financial assets and liabilities in the consumer and entrepreneur sub-sectors. The value of this index expresses the extent to which households (both consumers and entrepreneurs) are able to cover their liabilities in the form of loans by their deposits. The data depicted in Figure 7 testify to the above-mentioned significant influence of the crisis on entrepreneurs' economic activities. In the case of consumers, the rate of indebtedness

Figure 7 Rate of indebtedness in the consumer and entrepreneur sub-sectors (percentages)



Source: <www.czso.cz>, authors' calculations

went down in the period under assessment by two percentage points for consumers, while its decrease for entrepreneurs was 14 percentage points.

The long-term evolution in the household sector in the Czech Republic (from 1995) significantly reflected the economic changes that occurred in the given period. The lowest values (around 18%) of the indebtedness rate[27] of Czech households from 1997 to 2001, i.e., the period characterised by uncertainty after the crisis of 1997 and 1998,[28] and the consequent unwillingness to incur debts as well as high interest rates on deposits, which were substantially higher than the average inflation rates in each of the years in question.[29] Another proof is the high proportion of interest amount in the balance of the property income in the said years.[30] In the prosperity years after 2003 the indebtedness rate of Czech households goes up; its highest level occurred in 2009 (57.1 %). After that a decrease followed, analogous to that seen in the consumer sub-sector.[31]

The above-mentioned observations concerning the evolution of the assets and liabilities are based on values of the respective indices in current prices while it is obvious that it is necessary (especially in times of economic turbulence) to distinguish between the influence of the *price* movements (prices going up and down, in particular those of real estate, securities and shares), which is significant in the years of economic changes, on the one hand, and the growing volumes of assets and liabilities related to production activities (the so-called changes implied by *production activity*) and *other* (random or formal) changes on the other hand. The data in Table 8 are related to structural changes in the total values of assets and liabilities.

The data represented above for the consumer sub-sector clearly show the influence of the crisis in the years 2009, 2012, and 2013 (see Table 1) on the price evolution of the non-financial assets;

[27] The rate of indebtedness is expressed as loans as of the end of the year vs. deposits as of the end of the year.

[28] GDP went down by 0.7% in 1997 and by 0.3% in 1998.

[29] The average annual inflation rate was between 8% and 10%, and the interest rates on deposits amounted to values between 20% and 30% p.a. in the years 1997 and 1998.

[30] The balance of interest amounted to more than one-half of the property income balance in 1997 and 1998, and one-third in the period 1999–2011. This proportion currently fluctuates around a value below 10% (since the interest rates on deposits are very low).

[31] The indebtedness rates of consumers and of households as a whole did not differ from each other by more than one percentage point in that period.

Table 8 The structure of the total annual change in the non-financial and financial assets and financial liabilities in the consumer sub-sector (mil. CZK, current prices)

Change in value of	2009	2010	2011	2012	2013	2014
non-financial assets	**–16 374**	**122 831**	**133 701**	**7 939**	**28 550**	**87 014**
out of which – production activity	87 804	107 436	73 085	65 720	64 728	62 187
– other	–2 449	–1 051	9 019	653	–7 105	–28 589
– prices	–101 729	16 446	51 597	–58 434	–29 073	53 416
financial assets	**93 935**	**261 128**	**65 264**	**295 658**	**168 569**	**310 085**
out of which – production activity	144 811	109 869	119 516	174 367	121 916	266 335
– other	–2 938	151 876	–86 081	71 222	–7 558	–845
– prices	–47 938	–617	31 829	50 069	54 211	44 595
financial liabilities	**81 811**	**29 116**	**63 188**	**44 477**	**47 071**	**53 455**
out of which – production activity	46 067	27 423	85 543	71 328	65 815	89 821
– other	28 433	–1 619	–8 381	–23 972	–19 021	–36 317
– prices	7 311	3 312	–13 974	–2 879	277	–49

Source: <www.czso.cz>, authors' calculations

Table 9 The structure of the total annual change in the non-financial and financial assets and financial liabilities in the entrepreneur sub-sector (mil. CZK, current prices).

Change in value of	2009	2010	2011	2012	2013	2014
non-financial assets	**–40 884**	**52 518**	**93 370**	**–672**	**6 660**	**12 729**
out of which – production activity	12 125	9 264	7 439	–1 167	–5 578	–4 459
– other	–13 360	–2 038	10 569	–1 259	5 131	9 504
– prices	–39 649	45 292	75 362	1 754	7 107	7 684
financial assets	**12 266**	**–24 867**	**14 400**	**–16 951**	**–11 622**	**12 687**
out of which – production activity	–4 808	5 076	20 545	–7 711	2 287	–52 982
– other	19 567	–28 485	1 215	–9 048	–7 755	31 152
– prices	–2 493	–1 458	–7 360	–192	–6 154	34 517
financial liabilities	**–8 614**	**10 965**	**–13 256**	**4 520**	**–17 866**	**6 130**
out of which – production activity	–11 572	12 344	–16 425	4 404	–16 924	19 347
– other	5 873	–1 905	1 109	70	–1 131	–448
– prices	–2 915	526	2 060	46	189	–12 769

Source: <www.czso.cz>, authors' calculations

for financial assets, a drop in their prices was only significant in 2009; the evolution of financial liability prices was an insignificant factor. The decreasing prices of the real estate property in 2009 led to a short-lived interest in purchasing such property (while the proportion of loans as financing resources was decreasing), but in the following years the already mentioned observation was true, namely, that consumers restrict their investments into non-financial assets and transfer free resources in favour of financial assets, and the volume of liabilities moderately grows.

Regarding the growing value of entrepreneurs' non-financial assets, its dominant factor was the price evolution in 2009, and the growing values of non-financial assets in 2010 and 2011. The years 2012 and 2013 there was the crisis and the overall values of non-financial assets underwent no significant changes; the influence of the price growth was positive. The evolution of financial liabilities was mainly

affected by the level of economic activities – the decreasing liabilities represent a response to the decreasing creation of value added, while its growth in 2014 brought the necessity to look for other sources of financing. Other and price changes in financial liabilities are not significant (expect for 2014). The evolution of the components of the financial assets indicates that the influence of the price changes was not substantial; however, the year-to-year changes (both total and based on production) are too variable to explain them purely by the changes of the economic cycle.

CONCLUSIONS

The household sector consists of two different types of economic subjects – consumers and entrepreneurs. Their economic behaviour in the economic cycle phases is therefore different. The period from 2009 to 2014, for which data of both sub-sectors are available, was a turbulent period in the Czech Republic – there was a recession in 2009, recovery in the years 2010 and 2011, and the crisis returned in 2012 and 2013; and, finally, economic growth came in 2014. This period is also characterised by a low level of investment activities, low inflation rate, and decreasing interest rates on both deposits and loans, and the controlled weakening of CZK.

Households' proportion in the GDP formation was decreasing in that period, and the full amount of that decrease (by two percentage points) can be ascribed to entrepreneurs. Another manifestation was the decreasing proportion of the mixed income (both based on labour and that from the small-scale businesses) in households' net disposable income "in favour" of the growing balance of social income. Households' disposable income was growing slower than the final consumption expenditure in the period 2009–2014; hence the savings rate of households as a whole was decreasing. An analysis of the evolution of the disposable income for the consumer and entrepreneur sub-sectors seems dubious because these values are substantially influenced by year-to-year changes in Withdrawals from income of quasi-corporations. This index, whose value is not recorded in the household sector as a whole, deforms a view on not only the disposable income of consumers and entrepreneurs, but also their savings and net lending/borrowing. Hence the results of analysing data on non-financial accounts of these sub-sectors are hard to interpret; it is impossible to objectively assess the extent to which the crises and recoveries are reflected in the data recorded for the consumer and entrepreneur sub-sectors.

The data on non-financial and financial investments and on the changes in assets and liabilities of these sub-sectors provide more objective information about the effects of crises and recoveries. Entrepreneurs' non-financial investments (and therefore the investment rate too) were growing until 2011; financial investments were insignificant. Consumers responded to the coming symptoms of the economic crisis as early as 2010 by reducing their liabilities, a moderate decrease of the indebtedness rate, selling ownership interests, focus on securities, and also reduced investments into real estate property. After the recovery in 2014, consumers came back to investing into shares and other equity, mainly due to an expected higher return on such investments.

Our analysis of the growing components of assets and liabilities confirms the observation that consumers reduce their investments into real estate and transfer their free resources to financial assets. After the drop of financial assets' nominal value in 2009 and 2010, their growing prices significantly influenced the value of consumers' financial assets. The crises in the years 2009, 2012 and 2013 brought a falling nominal value of the real estate held by consumers – by tens of billions CZK every year.

The data for the sub-sectors of the household sector indicate certain interesting aspects of activities carried out by these two, mutually distinct, subjects; nevertheless, it turns out that the account of the household sector is predominately determined by the consumer sub-sector. Admittedly, entrepreneurs create about two-thirds of the gross value added of the household sector, but their proportion in the sector as a whole for investments into fixed capital amounts to a mere 25%, in the financial liabilities to one-tenth, and in the balance of the financial assets to one-twentieth. If we therefore view

the economic behaviour of consumers via analysing the data on the household sector account from the level of disposable income formation, we will not run into serious errors in interpretation.

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Regional Price Levels in the Czech Republic – Past and Current Perspectives

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Abstract

Regional price levels represent research topic that is currently under spotlight. Officially published data are focused on national price levels forming only one of the most important inputs for international comparison. Despite this, the national price levels are used to estimate regional indicators in Purchase Power Standard (PPS). Team of researchers from the University of Economics in Prague was dealing with the issue and estimated regional price levels for NUTS 3 regions in the Czech Republic for the year 2007. This estimate should be updated nevertheless the previously applied methodology cannot be used directly under current conditions but has to be adjusted because in the meantime several changes took place.

The aim of the paper is to prepare a methodological background for further computations of renewed regional price levels in the Czech Republic and to introduce the main changes that have occurred since the previous results for the year 2007 were estimated. Impacts of these changes on the results are discussed as well.

Keywords

Regional price levels, methodological issues, Czech NUTS 3 regions, comparison and update

JEL code

E31, R10

INTRODUCTION

Regional price levels represent an interesting and important topic. Very often they are discussed not only inside scientific community, but also in the press in form of different comparative analyses of well-being or living conditions of households in regions. Despite complicated methodology of computation

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of regional price levels, this topic is attractive, because the results are quite clear to the general public. They are often used to compare living conditions or real income across the regions (Coondoo, Majumder and Ray, 2004, p. 51).

Countries and their national price levels are most frequently compared (usually using Purchasing Power Parities), but our paper deals with regional price levels within one country. We focused on NUTS 3 regions in the Czech Republic and our aim was to prepare methodological background for further computations of renewed regional price levels in the Czech Republic and to introduce the main changes that have occurred since the previous results for the year 2007 were estimated (Cadil et al., 2014). The new results are available for the year 2012. Our computation methodology is based on EKS method (see European Commission / OECD, 2012), however, many other approaches can be found in literature. Let us mention e.g. hedonic approach in India (Coondoo, Majumder and Ray, 2004) and in the USA (Aten, Figueroa and Martin, 2011), imputation approach in Germany (Blien et al., 2008) or prediction model in Germany (Roos, 2006). Other attempts to estimate regional price levels can be found e.g. in Spain (Alberola and Marqués, 2001) or in China (Brandt and Holz, 2006). These approaches are always adjusted to the conditions in particular country and available data. Mostly they are very different from ours. On the other hand, the approach of the Office for National Statistics in the UK (Johnston and Bailey, 2011) is based, as well as ours, on EKS method. However, the Office for National Statistics in the UK was also forced to accept some simplifications and assumptions as we were. Some of such simplifications will be explained later. Adjustments needed to be done when estimating regional price levels in 2007 can be found e.g. in Musil et al. (2012).

This research follows the results from the year 2007 as there is a great interest of the public and other researchers in obtaining updated data. However, many things have changed since the previous computation and the methodology of estimate has to be altered for new calculations. The same situation occurs in the Office for National Statistics in the UK.

In our case there are some significant changes. In 2009, the world was affected by financial crisis whose impacts were evident in Czech regions as well. European standard of national accounts changed from ESA 1995 to ESA 2010 and it brought together a new look at e.g. some groups of final households consumption expenditure that are essential for regional price levels computation. Data sources are not the same now either and do not offer the same detail as for the year 2007.

This paper shows the overview of the main methodological changes that need to be done before the computation of regional price levels for 2012 can be carried out. This paper consists of several sections. The next two ones describe changes in methodology and availability of data and are further split into sub-sections, each introducing one change. The third section is dedicated to the renewed results. The fourth section brings the discussion about the possible comparability of results from the years 2007 and 2012. Conclusion summarizes the contents and emphasizes the main findings.

1 CHANGES IN METHODOLOGY BETWEEN 2007 AND 2012

Both our methodological approaches (2007, 2012) are inspired by EUROSTAT / OECD methodology (described in Musil et al., 2012) which is used for international comparison of economic indicators. However, it is not possible to implement this methodology fully to regions, i.e. to replace countries by regions in calculations. Data availability and other conditions should be taken into account. On the other hand, we try to be as close to international methodology as possible in order to ensure comparability of results.

As already stated, several changes occurred in the time period between 2007 and 2012. This section will provide a concise introduction of the main ones. The economy is changing faster and faster and this fact should be reflected in national accounts. Therefore, standards of national accounts have to be updated more frequently. Moreover, consumption habits are changing as well.

1.1 Changes in representatives and consumption basket

During the time, more and more commodities are available through Internet, i.e. their regional indices are equal to 1 (for the same approach in the UK see Johnston and Bailey, 2011, p. 6). This trend contributes to equalization of regional price levels, because the differences in prices are eliminated in case of these commodities. On the other hand, especially non-tradable goods and services cause the main price differences among regions (Jiang and Li, 2006, p. 45). Shopping via Internet or liberalization of energy market leads to reduction of regional differences as the price in the regions may be considered identical. On the other hand, prices of non-negotiable goods and services do not seem to be equalized, moreover, regional differences may increase depending on the structure of local economy, price of labour, etc.

The Czech Statistical Office changed its method of data collection in 2008. Since then prices of more representatives have been collected centrally replacing thus collection of prices directly in the shops. On one hand, this "new" method is cost-effective, on the other hand, availability of regional data decreased. This approach is applied to rents, electricity, cars, railway transportation services, etc. Another reason of changes in data set is that representatives are regularly updated which may cause an interruption of time series.

In 2007, consumer basket contained the total of 729 items with the highest share in the CZ-COICOP[5] sections 01 "Food and non-alcoholic beverages" (22.5%) and 09 "Recreation and culture" (15.5%). In the meantime, for the period of 5 years up to the year 2012, the number of items was reduced by 37 for the total of 692 items. The section 06 "Health" showed the biggest contribution to this decrease (from 47 to 18 items). Detailed overview of changes in the number of items in each section of classification CZ-COICOP presents Table 1.

Table 1 Overview of changes in the number of items and weights in the consumer basket for the years 2007 and 2012

CZ-COICOP	Number of items		Average weight per item (‰)		Sum of weights (‰)	
	2007	2012	2007	2012	2007	2012
01	164	161	0.992	0.931	162.635	149.823
02	20	21	4.086	4.572	81.720	96.008
03	71	65	0.738	0.553	52.427	35.930
04	41	45	6.056	6.230	248.292	280.355
05	82	79	0.708	0.734	58.055	57.972
06	47	18	0.380	1.282	17.864	23.075
07	83	80	1.375	1.313	114.095	105.007
08	3	4	12.911	9.020	38.732	36.079
09	113	110	0.873	0.822	98.657	90.378
10	12	12	0.515	0.649	6.178	7.783
11	43	42	1.358	1.156	58.386	48.561
12	50	55	1.259	1.255	62.957	69.031
Total	**729**	**692**	**1.372**	**1.445**	**1 000.000**	**1 000.000**

Source: Own construction, consumer basket published by CZSO

[5] CZ-COICOP is a Czech version of Classification of Individual Consumption According to Purpose which is used in System of National Accounts (SNA).

Regarding weights of the individual items, in 2007 constant weights of 2005 were used. At that time, the average weight of a single item was the highest in the section 08 "Posts and telecommunication" (12.911‰). Average weight for this section in 2012, when constant weights of 2010 were used, decreased to 9.020‰, but thus remained the highest average weight. The section 04 "Housing, water, electricity, gas and other fuels" shows with its sum of weights the most important area both in 2007 (248.292‰) and in 2012 (280.355‰). Detailed overview of changes in the weights is also given by Table 1.

The number of representatives included in the analysis was 800 in 2007, while only 695 in 2012. The most significant changes were caused by decrease in sections 06 "Health" (31 representatives), 07 "Transport" (27 representatives) and 09 "Recreation and culture" (21 representatives). However, since 2008 some representatives have been replaced by so-called sub-indices. Prices of selected items (e. g. electricity or medical products) are not collected, but their price indices are estimated directly. Usually, model calculation is applied in order to react to changes in legislation or customer behaviour. In fact, one sub-index represents one item in consumer basket even if it replaced several representatives. Therefore comparison of changes of number of representatives should be done carefully.

Among representatives covered in the analysis there are items that are at the same time included in the consumer basket (i.e. with specific weights assigned to them) and their average consumer prices in a given year (2007 or 2012) are available. The list of average consumer prices contains also items not included in the consumer basket (and thus without any weight available). Such items are not considered in our project. Furthermore, there are representatives not included in the consumer basket but considered in our project – narcotics, prostitution and financial intermediation services indirectly measured (FISIM).

Not all the representatives have their prices available for all NUTS 3 regions. Especially in services such items can be found. On the other hand, there are representatives with no values available. In this and previous case the missing values are needed to be estimated by suitable methods. If prices of the representatives are missing just for some regions, they are replaced by weighted arithmetic mean of prices of other regions (Musil et al., 2012). Table 2 lists in addition to the total number of representatives in each section of CZ-COICOP the number of representatives with values known for all regions and number of representatives with values unknown for at least one region. For more detailed overview of changes in the number of items, their weights and in the number of representatives in the two-digit division of CZ-COICOP see Table 6 and Table 7 in the Annex.

Table 2 Number of representatives in 2007 and 2012

CZ-COICOP	Total number of representatives		Number of representatives with known values		Number of representatives with unknown values	
	2007	2012	2007	2012	2007	2012
01	169	161	162	161	7	0
02	23	22	17	21	6	1
03	74	65	71	65	3	0
04	42	45	20	23	22	22
05	91	79	81	74	10	5
06	49	18	41	10	8	8
07	107	80	37	39	70	41
08	4	4	1	1	3	3
09	131	110	85	81	46	29
10	12	12	7	8	5	4
11	44	42	39	37	5	5
12	54	57	35	39	19	18
Total	**800**	**695**	**596**	**559**	**204**	**136**

Source: Own construction based on consumer basket

It is clear that the weight of representatives with missing value(s) has increased. In very few cases current approach is simpler. We did model calculation of regional prices of energy based on price list of regional distribution companies and some assumptions on structure of consumption for the year 2007. As energy market was liberalized in 2012 we took into account just differences in distribution service, whose prices differ regionally. Prices of other components can be supposed to be the same in all regions (contribution to renewables, power electricity, VAT) or can be changed independently to region of consumption.

On the other hand, estimation of regional differences in public transportation is now more complicated. Integrated transport systems have been developed, however, different types of tickets (single tickets for adults, students, pensioners; passes for local transport and for integrated systems), are surveyed in the regions. Several transportation services were defined and the data had to be also obtained from many data sources (CPI survey, annual reports or price lists).

1.2 Transition from ESA 1995 to ESA 2010

Since September 2014 all EU countries are obliged to provide all data in the new standard of national accounts ESA 2010. Major changes are linked to broader concept of assets, research and development, weapon system or small tools are now considered as assets used in production process (Sixta, 2014). Household consumption expenditure is not affected significantly though there are particular changes in insurance services. It should be mentioned that many national statistical institutes took this opportunity to introduce other improvements as well (CZSO, 2014). The Czech Statistical Office has made several improvements that have a significant impact on household consumption.

The main change is a new calculation of output and intermediate consumption of dwelling services. As family houses renting market is very small and unrepresentative, stratification method was replaced by user cost method. It means that output of imputed rent is now based on related cost (especially consumption of fixed capital, intermediates and net operating surplus) instead of market rents. Imputed rent in flats in apartment houses is still estimated using stratification method. Stratification methods allow analysing regional differences, but user cost method does not allow this directly. It means that just prices of rented flats in apartment houses are available. These prices were applied to the whole actual rent and imputed rent in flats in apartment houses. A model approach was used for imputed rent in family houses that is based on prices of buildings which are available from property transfer tax statements. Consumption of fixed capital and net operating surplus constitute the predominant part of imputed rent.

Moreover, estimate of regional baskets has been improved. And finally, new regionalisation keys have been introduced (Kramulová et al., 2013) and they are still being further improved.

1.3 Potential shift in economic performance of regions connected not only with global financial crisis after the year 2009

In the period of the years 2007 to 2012 several changes occurred at the national level that had significant impact on Czech NUTS 3 regions. We have aimed at three most important changes: global economic recession, increase of rates of value added tax (VAT) and amendment of tax assignment. Because of their interconnection, effect of mentioned changes cannot be assessed as a single factor.

Changes affecting economic performance can be demonstrated by time series of selected taxes (see Table 3). Intentionally, the corporate tax was chosen to explain progress respectively the prosperity of business activities. Personal income tax reflects actual level of employment through revenues of income tax. Value added tax as the last describing factor approximates roughly total consumption.

The above mentioned simplification is possible because of consistent low rate of inflation in the described period. The rate of inflation measured by average year on year consumer price index captured the highest values (6.3%) in 2008. Afterwards, the rate of inflation decreased to 1%. The average annual indicator measured in 2010 shows 1.5% and two years later the recorded price growth was 3.3% (CZSO, 2015).

Table 3 Revenues from selected taxes 2007–2012 (in CZK mil.)

Years/Taxes	Corporate tax	Personal income tax	Value added tax
2007	155 674	126 388	235 844
2008	173 590	115 180	254 939
2009	110 543	111 042	253 464
2010	114 746	111 842	269 582
2011	109 312	119 373	275 188
2012	120 461	119 787	278 052

Source: Ministry of Finance (2015), authors' adaption

During the year 2008 the positive trend of economic growth culminated, drown by regions specializing in branches e.g. mining of coal, manufacture of basic metals, manufacture of beverages and tobacco products, financial intermediation and telecommunications (MFCR, 2015). Since 2009 the whole Czech economy has been affected by a financial crisis that hit mostly regions with dominant service industries. Economic crisis could be proved by decrease in collected personal income tax, because employers in regions needed to dismiss staff. On the contrary, we expected decrease of VAT revenues, but it had not appeared in such an amount. The reason lies in a frequent increasing of VAT rate of reduced rate from 5% to 15% respectively standard rate from 19% to 21%.

In connection with the increase of VAT rates, change also occurred in Act No. 243/2000 Coll., on Tax assignment of selected taxes yields to sub-national independent administrations and to certain state funds. This law allocates part of tax revenues to regions, towns and cities (Toth et al., 2014b). Influence on their budgets is important due to the fact that tax revenue exceeds 50% of annual fiscal income (Toth et al., 2014a). Lower income of regions, towns and cities could cause reduction of expenditure; mandatory spending must persist, but other investment could be suspended.

On the contrary, during the above mentioned years the regions have had a unique chance to obtain sources from EU fund (Structural funds and Cohesion fund) support. About CZK 752 billion were allocated in the Programmes 2007–2013 (depending on actual CZK/EUR exchange rate) that is nearly ¾ of the annual Czech budget (Ministry of Regional Development, 2015). Regions used these sources to build, reconstruct and modernize their property or to invest in human resources in order to increase employment, develop human capital and enhance education. This opportunity contributed to the fact that the regions did not fall in economic indicators as much as it was predicted.

The Czech Republic has a highly atomized structure of communities and towns in 13 relatively small heterogeneous regions; the 14th region is the capital city of Prague (see Figure 1). Changes at the national level significantly affect economic performance in particular regions. Partial changes could influence only some regions due to variability of their dominant industries and this has to be taken into account when interpreting the results.

Figure 1 All 14 Czech NUTS 3 regions

Source: Ministry of Transport (2005), authors' adaption

2 CHANGES IN AVAILABILITY OF DATA AND DATA SOURCES

The list of employed data sources will probably be very similar to the previous methodology; however, importance of particular data sources may differ. The survey on CPI remains the main data source though its importance is decreasing. Estimates of dwelling services and regional structure of household expenditure are still based on national accounts data.

Most of the representatives with unknown values remain the same in 2012 as in 2007 in the division 07 "Transport" (41 missing items), in the division 09 "Recreation and Culture" (29 missing items) and in the division 04 "Housing, Water, Electricity, Fuels" (22 missing items).

2.1 Missing items in the division 07

In the division "Transport" the first part of representatives with unknown values form the items representing the subscription of public transport for which we usually know the values of only some NUTS 3 regions. The second part contains the representatives consisting of specific brands and types of automobiles together with related information on prices of petrol, diesel and LPG gas. Specifically, these are the group 7.1 "Purchases of automobiles, motorcycles and bicycles" (16 missing items) and 7.3 "Transportation Services" (18 missing items).

Values of public transport subscription tickets that are not available were traced on the websites of transport companies in individual NUTS 3 regions. Values of automobiles were supplemented by index of 1 due to the fact that it can be assumed that the different types of cars are sold at the same price all over the country. The data on prices of fuels were traced on the website of CCS company that is focused on this activity alongside many others.

2.2 Missing items in the division 09

The majority of representatives with at least one missing value consists of the items from the group 9.5 "Newspapers, Books and Stationery" (13 missing items) related to printed media (newspapers and magazines) and group 9.6 "Package Holidays", i.e. tours to the selected countries. Given that prices are the same nationwide in the Czech Republic, the missing values were replaced with the index of 1.

2.3 Missing items in the division 04

Data on rent are not available in the regional breakdown. Rent is in the consumer basket divided into two parts. The first one represents paid (actual) rent and the second hypothetical rent. Representatives of paid rent are broken down by the number of rooms and size of seat. However, structure of rent is representative for the Czech Republic, but not for the regions. Moreover, the concept of hypothetical rent is a bit different from concept of imputed rent used in national accounts. Therefore, a model approach was applied, for more details see chapter 1.2.

3 RESULTS

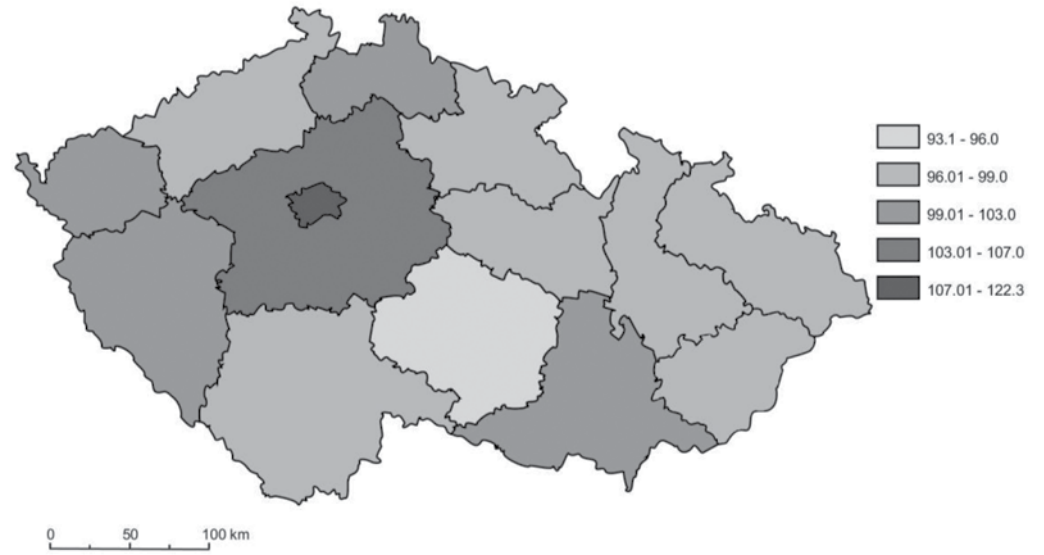
New regional purchase power parities (RPPP) for 2012 were estimated based on the above mentioned methodology. Results are similar to the year 2007, however, some differences can be observed. The highest regional price level is again recorded in the capital city of Prague. Regional price level slightly increased here to 122.3 (see Table 4 and Figure 2); nevertheless, the difference is not huge (1.5 p.p.). Reasons causing that price level in the capital city of Prague is exceptionally higher are still the same. Living costs are significantly higher as well as prices of transportation or personal services. Differences in other regions are not important, the biggest are recorded in Jihomoravský kraj (–4.0 p.p.) and Středočeský kraj (+3.7 p.p.).

Table 4 Comparison of regional price levels in 2012 and 2007

Region	RPPP, 2012, %	RPPP, 2007, %	RPPP, difference, p.p.
Hlavní město Praha	122.3	120.8	1.5
Středočeský kraj	106.3	102.6	3.7
Jihočeský kraj	99.0	97.5	1.5
Plzeňský kraj	100.0	97.1	2.9
Karlovarský kraj	99.9	101.3	–1.4
Ústecký kraj	96.7	94.1	2.6
Liberecký kraj	100.5	100.2	0.3
Královéhradecký kraj	96.7	96.2	0.5
Pardubický kraj	96.2	98.9	–2.7
Kraj Vysočina	93.1	95.1	–2.0
Jihomoravský kraj	100.6	104.6	–4.0
Olomoucký kraj	96.9	96.6	0.3
Zlínský kraj	97.5	100.8	–3.3
Moravskoslezský kraj	97.2	96.9	0.3
Czech Republic	**100.0**	**100.0**	**0.0**

Source: Own construction

Figure 2 RPPPs in the Czech NUTS 3 regions in 2012 (%)



Source: Own construction

Regional price levels can be applied to various indicators in order to recalculate them to the same level. Net disposable income of households represents income in national accounts concept. The main part of it (about 94%) is used for final household consumption expenditure. As our approach is based on final consumption expenditure, the results can be applied to net disposable income as rough approximation of well-being of households. Comparison of net disposable income of households (NDI) per capita in regional purchase power standard is shown in the following Table 5.

Table 5 Comparison of regional net disposable income per capita in 2012 and 2007

Region	2007		2012	
	NDI per capita	NDI per capita in RPPS	NDI per capita	NDI per capita in RPPS
Hlavní město Praha	134.7	111.5	130.8	106.9
Středočeský kraj	108.2	105.4	109.9	103.3
Jihočeský kraj	97.5	100.0	94.7	95.7
Plzeňský kraj	100.8	103.8	101.2	101.3
Karlovarský kraj	88.8	87.7	87.8	87.8
Ústecký kraj	86.8	92.2	87.3	90.3
Liberecký kraj	94.2	94.0	92.4	91.9
Královéhradecký kraj	96.4	100.2	96.8	100.1
Pardubický kraj	93.3	94.3	94.8	98.6
Kraj Vysočina	95.5	100.4	95.1	102.1
Jihomoravský kraj	96.6	92.3	98.3	97.7
Olomoucký kraj	92.0	95.3	90.8	93.8
Zlínský kraj	96.0	95.3	93.1	95.4
Moravskoslezský kraj	88.7	91.5	90.3	92.9
Czech Republic	**100.0**	**100.0**	**100.0**	**100.0**

Source: Own construction, NDI published by CZSO

Regional purchase power standard (RPPS) is an artificial currency and it is calculated as nominal indicator divided by relavant regional purchase power parity. It expresses real value of indicator. NDI per capita in the capital city of Prague has decreased by 4.6 p.p. It was caused partly by the increase of RPPP and also by the decrease of nominal NDI per capita. On the other hand, net disposable income per capita in RPPS in Jihomoravský kraj has increased by 5.4 p.p. due to growth of nominal indicator and decrease of regional purchase parity. Generally, the picture of regions remains more or less the same.

4 DISCUSSION ON POSSIBLE COMPARABILITY OF RESULTS FROM THE YEARS 2007 AND 2012

Also Johnston and Bailey (2011, pp. 9–10) emphasize that their results from 2004 and 2010 cannot be comparable in the United Kingdom. Differences in consumption basket stay as one of the reasons. This also leads to one important conclusion, that it is impossible to estimate trends between the regional price levels and to create time series. Authors believe that it is not possible to create fully comparable time series. However, methodological differences may not be considerable but they should be taken into account when time series are analyzed. Because of above mentioned reasons and severity of the compilation, longer lapse of time between estimates is not necessarily a disadvantage.

Composition of consumption basket of CPI is updated regularly in order to follow changes in consumption habits. This revision has to be taken into account when regional weights are estimated. However, some changes are caused by institutional changes or changes in methodology. System of data collection of prices was transformed in 2008. It had no impact on CPI but availability of regional data decreased. An approach to rents in national accounts has been changed several times as new data sources were available or international recommendations were updated. Within European comparison program these changes do not influence real indicators. However, they may have an impact on regional price levels. In order to perform comparable time series it would be necessary to recalculate previous results using updated methodology that is sometimes not possible as some data were not collected.

Nevertheless, we did not expect significant effect on regional differences. More and more products can be purchased via Internet which leads to elimination of regional differences. However, regions that are supposed to be rich in nominal term fumble with increasing prices of rents, personal services or repair services. In contrast, structurally affected regions offer incredibly low prices of rents. It is clear that there are several effects which are opposed and result in countervailing impacts.

CONCLUSION

The aim of this paper was to prepare methodological background and to carry out estimate of renewed regional price levels in the Czech Republic and to introduce the main changes that have occurred since the previous results for the year 2007 were estimated. This paper emphasized two main groups of changes divided further into different types. They led to the need to adapt the methodology used for the estimation of regional price levels for the year 2007. We also analysed their consequences to new estimates and discussed possible problems in comparability with previous results from the year 2007. We are convinced that even though the comparability is not perfect, it is a good idea to reconstruct the regional price levels in some time span, e.g. in five years. It would be useful to follow this trend also in the future.

The final results showed us that even though between both monitored years (2007 and 2012) the world was affected by huge economic crisis, the conditions of 14 NUTS 3 regions did not significantly change between these two years. For instance, in case of the capital city of Prague its dominance is almost the same (the difference is only 1.5 p.p.). The biggest differences equal to +3.7 p.p. or –4.0 p.p.

When we applied estimated regional price levels to the net disposable income (NDI) per capita, we could see following impact. The highest nominal NDI per capita was observed in the capital city of Prague, about 30% higher in comparison to the average of the Czech Republic. However, when all the data were

transformed to the same price level, this difference decreased to mere 7%. Generally, the differences in NDI per capita in RPPS are lower compared to original figures.

It will be interesting to monitor changes in particular regions and analyse which factor played the main role, since their impact is probably countervailing as we pointed out in the discussion above. In the regions usually more factors affect the resulting regional differences in price levels. Their relations and reasons will be subject to further research and further publications.

ACKNOWLEDGMENT

This paper is prepared under the support of the project "Regional estimates of gross domestic product based on the expenditure approach" of the Czech Science Foundation, project No 13-15771S and by Institutional Support for Long Period and Conceptual Development of Research and Science at Faculty of Informatics and Statistics, University of Economics, Prague.

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ANNEX

Table 6 Overview of changes in the number of items and weights in the consumer basket for the years 2007 and 2012 in the two-digit division of CZ-COICOP

CZ-COICOP		Number of items		Average weight per item (‰)		Sum of weights (‰)	
		2007	2012	2007	2012	2007	2012
1	1.1	148	146	0.983	0.924	145.467	134.909
	1.2	16	15	1.073	0.994	17.168	14.914
2	2.1	12	13	3.353	3.606	40.230	46.881
	2.2	8	8	5.186	6.141	41.490	49.126
3	3.1	54	49	0.738	0.545	39.841	26.716
	3.2	17	16	0.740	0.576	12.587	9.214
4	4.1	10	13	3.527	3.630	35.273	47.198
	4.2	1	1	97.972	108.220	97.972	108.220
	4.3	15	15	0.379	0.294	5.683	4.413
	4.4	5	5	3.888	4.303	19.438	21.517
	4.5	10	11	8.993	9.001	89.926	99.006
5	5.1	20	16	1.069	1.365	21.374	21.847
	5.2	9	8	0.589	1.064	5.303	8.513
	5.3	16	16	0.791	0.615	12.654	9.836
	5.4	12	10	0.404	0.399	4.857	3.987
	5.5	9	9	0.305	0.313	2.748	2.815
	5.6	16	20	0.695	0.549	11.119	10.973
6	6.1	40	8	0.323	1.987	12.902	15.898
	6.2	6	8	0.697	0.707	4.180	5.654
	6.3	1	2	0.781	0.761	0.781	1.522
7	7.1	32	31	1.158	1.169	37.045	36.244
	7.2	27	24	2.194	2.016	59.234	48.377
	7.3	24	25	0.742	0.815	17.816	20.386
8	8.1	1	2	0.745	0.338	0.745	0.677
	8.2	1	1	3.019	1.843	3.019	1.843
	8.3	1	1	34.969	33.560	34.969	33.560
9	9.1	16	19	1.074	0.878	17.184	16.682
	9.2	2	1	0.861	1.596	1.721	1.596
	9.3	34	31	0.641	0.696	21.796	21.576
	9.4	18	16	1.294	1.413	23.299	22.616
	9.5	29	28	0.439	0.325	12.726	9.108
	9.6	14	15	1.567	1.253	21.931	18.800
10	10.1	2	1	0.421	0.900	0.842	0.900
	10.2	1	2	0.498	0.375	0.498	0.751
	10.3	1	1	0.465	0.195	0.465	0.195
	10.4	4	4	0.280	0.581	1.119	2.323
	10.5	4	4	0.814	0.903	3.254	3.613
11	11.1	36	34	1.438	1.200	51.768	40.787
	11.2	7	8	0.945	0.972	6.618	7.774
12	12.1	22	28	1.234	1.250	27.144	34.987
	12.2	x	x	x	x	x	x
	12.3	9	8	0.841	0.794	7.565	6.351
	12.4	2	2	1.863	2.816	3.725	5.633
	12.5	10	10	0,783	0.722	7.826	7.217
	12.6	1	1	12.653	11.752	12.653	11.752
	12.7	6	6	0.674	0.924	4.044	3.092

Source: Own construction based on consumer basket

Table 7 Number of representatives in 2007 and 2012 in the two-digit division of CZ-COICOP

CZ-COICOP		Total number of representatives		Number of representatives with known values		Number of representatives with unknown values	
		2007	2012	2007	2012	2007	2012
1	1.1	153	146	146	146	7	0
	1.2	16	15	16	15	0	0
2	2.1	13	13	10	13	3	0
	2.2	9	8	7	8	2	0
	2.3	1	1	0	0	1	1
3	3.1	57	49	54	49	3	0
	3.2	17	16	17	16	0	0
4	4.1	10	13	0	0	10	13
	4.2	1	1	0	0	1	1
	4.3	15	15	15	15	0	0
	4.4	5	5	1	1	4	4
	4.5	11	11	4	7	7	4
5	5.1	20	16	20	16	0	0
	5.2	10	8	9	7	1	1
	5.3	22	16	16	13	6	3
	5.4	12	10	12	10	0	0
	5.5	9	9	9	9	0	0
	5.6	18	20	15	19	3	1
6	6.1	42	8	38	6	4	2
	6.2	6	8	3	4	3	4
	6.3	1	2	0	0	1	2
7	7.1	55	31	13	15	42	16
	7.2	27	24	18	17	9	7
	7.3	25	25	6	7	19	18
8	8.1	2	2	0	0	2	2
	8.2	1	1	1	1	0	0
	8.3	1	1	0	0	1	1
9	9.1	32	19	16	17	16	2
	9.2	2	1	2	1	0	0
	9.3	35	31	34	31	1	0
	9.4	19	16	15	13	4	3
	9.5	29	28	14	15	15	13
	9.6	14	15	4	4	10	11
10	10.1	2	2	1	1	1	1
	10.2	1	1	1	1	0	0
	10.3	1	1	1	1	0	0
	10.4	4	4	0	1	4	3
	10.5	4	4	4	4	0	0
11	11.1	37	34	35	32	2	2
	11.2	7	8	4	5	3	3
12	12.1	23	28	22	27	1	1
	12.2	1	1	0	0	1	1
	12.3	9	8	8	8	1	0
	12.4	2	2	2	2	0	0
	12.5	10	10	0	0	10	10
	12.6	2	2	0	0	2	2
	12.7	7	6	3	2	4	4

Source: Own construction based on consumer basket

Model of Water Needs for Energy Production

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Abstract

Thermoelectric power plants need large amounts of cooling water. The energy sector is responsible for the largest annual volume of water withdrawals in the Czech Republic. The issues related to water demand and its determinants were considered in several earlier studies of thermoelectric water use. For regression model determinants describing the natural, operational and socio-economic conditions were selected. In this study, we used econometric models of water needs for energy production in thermoelectric power plants in the Czech Republic. The main purpose was to obtain a model suitable for predictions. Annual data on electricity and heat production and on water use were available for sample of 33 operational units.

Keywords

Linear regression model, water consumption, water withdrawals, energy production

JEL code

C30, Q25, Q49

INTRODUCTION

Energy production is very water-intensive. Meeting ever-growing demands for energy will generate an increasing stress on freshwater resources with repercussions for other users, such as agriculture and industry. Since these sectors also require energy, there is room to create synergies as they develop together (WWAP, 2015, p. 4). The largest water users in the energy sector are thermoelectric power plants and hydropower plants which generally require large quantities of water. Thermoelectric power generation is a broad category of power plants consisting of coal, nuclear, oil, natural gas, and the steam portion of gas-fired combined cycles (Feeley III et al., 2008). Approximately 90% of global power generation is water intensive. Water is used directly for hydropower generation as well as for all forms of thermal power generation schemes (WWAP, 2014, p. 33). Water is required not only in thermoelectric power plants but also for production of nearly all forms of energy. For primary fuels, water is used in resource extraction, irrigation of biofuel feedstock crops, fuel refining and processing, and transport. In power generation, water provides cooling and other process-related needs at thermoelectric power plants; hydropower facilities harness its movement for electricity production (IEA, 2012, p. 505).

Globally, about 4 000 km3 of fresh water is withdrawn each year for human use. Of that, about 70% is withdrawn for agriculture and around 10% for the power industry (Williams, Simmons, 2013, p. 10). There is a completely different situation in the Czech Republic. As shown in the annual report on water

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management in the Czech Republic in the period 2004–2013, the energy sector withdrew an average of 45% of all withdrawals from water resources in the Czech Republic and 56% if observing only surface waters.

The issues related to water demand and its determinants were considered in several earlier studies of thermoelectric water use. Examples of these studies can be found for example in Dziegelewski, Bik (2006). The group of operational conditions can include, in particular, the technology of boilers, type of cooling systems and the means of dealing with fly ash and its transport. Because in conventional power plants half or more of the produced heat gets lost as waste heat (WWAP, 2014, p. 51), most power plants operate in a combined heat and power mode in the Czech Republic. And, conversely, most heating plants use power generation to maintain optimal operating conditions of boilers in periods of reduced heat demand. For this paper, we use the term "power plant" for a classic power plant and also for a heating plant with power generation.

The design of a cooling system and its operational condition is the most important factor for water withdrawals and water consumption in thermoelectric power generation. Generally, higher withdrawals and lower consumptions of water per produced energy unit are typical for power plants with once-through (open loop) cooling systems. Conversely, lower withdrawals with higher consumption per energy unit are typical for recirculating (close loop) cooling systems (Macknick et al., 2012). The third cooling system with the pond is not used in the Czech Republic.

In the group of natural conditions, we can include water availability, temperature, air humidity, etc.

Social and economic conditions are very important in a longer perspective because they form the basis for investment decisions on the improvement of technology of current plants, the design of new plants, etc. The influence of indirect factors cannot be expressed exactly, but we can use econometrics tools to answer "how much" questions using theory and data from economics, business, statistics, as well as social and natural sciences (Hill et al., 2012). Econometrics come into play either when we have an economic theory to test or when we have a relationship in mind that has some importance for policy decisions or analyses (Wooldridge, 2013, p. 2).

1 DATA AND METHODOLOGY

1.1 Data

In our study we focused on models of the operational phase of power generation, thus excluding water usage in other stages of the life cycle (Fthenakis, Kim, 2010; Williams, Simmons, 2013).

For the study presented in this paper, we collected data from the evidence of water balance under Decree no. 431/2001 Coll. In most cases we examined permitted withdrawals and discharges in the IPPC licence. For the next solution, we selected plants for which there were data on withdrawals and discharges. Some power plants must be grouped into the operational units because only data about withdrawals and discharges for operational units are available. For these power plants, we obtained data on the production of electricity (MWe) and heat energy (MWt) and additional data from individual operators of these power plants. For the study 33 operational units with complete data were selected (see Table 2). The study included power plants with a wide range of installed capacity of the order from tens of MW (MWe + MWt) up to units of GW. The data availability determined the time period of the study to the decade 2004–2013.

For operational units for which the data are only available on net electricity production, gross electricity generation was imputed by using average ratio gross and net electricity generation from records with both data.

Records, which are not used for the direct production of energy, were excluded from the withdrawals and discharges data. Typically, they include remediation pumping, cases of watercourse flowing through ash landfills, water supply to other users, etc.

1.2 Model

We assumed that water demand per energy unit is a function of direct and indirect determinants (explanatory variables). These explanatory variables could describe different conditions specified in the introduction herein. Overview of the selected variables is given in Table 1.

As explanatory variables describing natural conditions, we selected average annual temperature and the average temperature from June to September representing the summer period with most intensive demand on cooling. We used regional data from Czech hydrometeorological institute (CHMI, 2014). The average temperature from June to September was calculated as the average value of monthly temperature in this period each year.

As the explanatory variables describing operational conditions, we selected the amount of produced energy, heat energy to total energy production ratio, capacity factor – electricity, capacity factor – heat, and type of cooling equipment. We used data provided by Energy Regulatory Office. The amount of produced energy includes both electrical and heat energy. The capacity factor – electricity (resp. heat) of an operation is the ratio of its actual electricity (resp. heat) output over a period of time, to its potential electrical (resp. heat) output if it were possible for it to operate at full electric (resp. heat) generation capacity (also known as nameplate capacity) continuously over the same period of time.

As the explanatory variable describing the socio-economic conditions, we selected payments for water withdrawals. Payment for water withdrawals is one of the typical instruments of management and sustainable way of managing water resources. Other instruments are discussed in Slavíková et al. (2012). For this variable, we collected data from Reports on water management in the Czech Republic (MoA, 2015).

The type of cooling equipment was the only (purely) qualitative determinant and we grouped the operational units accordingly. The remaining seven determinants are quantitative and served as explanatory variables in the regression analysis described below.

Table 1 Summary of explanatory variables used in models

Explanatory variable	Units of measurement	Expected sign
Avg. temperature: June-Sept.	°C	+
Avg. annual temperature	°C	+
Energy production	MWh / year	-
Heat energy to total energy	<0 ; 1>	-
Capacity factor–electricity	<0 ; 1>	?
Capacity factor–heat	<0 ; 1>	?
Price for withdrawal	CZK / m3	-

Source: Own computation

As the main target of the study is the connection between the thermoelectric sector as a whole and water withdrawal, we also took into account the relative energy production of individual operational units. That means that each operation received a weight equal to its share on the sum of energy produced by all operational units included in the relevant model. This approach contributes to the (total) error reduction of prediction when trying to predict the total amount of water withdrawn in a certain future year. In practice, a possible expected error of, for example, 0.1 m^3/MWh gets more weight concerning large operational units than 0.1 m^3/MWh concerning small operational units. However, we also tried to estimate the effect of the explanatory variables without weighting the individual observation. This approach can be useful for predicting the withdrawals of smaller operational units, either individually or when grouped. The determinant amount of produced energy, mentioned in the previous paragraph as an explanatory variable, may be useful for more accurate prediction of individual withdrawals and serves rather as a feature of an individual operation. Using the size of an operation as an explanatory variable does not interfere with weighting the observations by practically the same variable.

The operational units listed in Table 2 were divided into three groups. The first group represents operational units with the once-through cooling system. The second group represents operational units with the recirculating cooling system, and the third represents hybrid cooling systems. This study

Table 2 Summary of operational units – average data for period 2004–2013

Operation	Cooling system	Gross energy generation [MWh/year]	Ratio between power and heat generation	Water withdrawals [m^3/MWh]	Water consumption [m^3/MWh]
HPs Brno Sever+Špitálka	R	825 510	0.168	1.337	0.798
HP České Budějovice	R	1 024 075	0.193	1.321	1.175
HP Dvůr Králové	OT	154 163	0.132	21.584	2.399
HPs Energetika Třinec	R	2 166 807	0.449	4.983	2.622
HP Kolín	OT	415 099	0.135	18.443	0.616
HP Krnov	R	187 789	0.185	1.238	No data
HP Liberec	R	280 130	0.101	1.181	0.992
HP Náchod	R	211 293	0.334	2.575	No data
HP Olomouc	OT+D	832 410	0.319	0.539	0.388
HP Ostrov	R	123 615	0.105	3.105	2.086
HP Otrokovice	R	780 256	0.360	1.207	0.914
HP Písek	R	155 836	0.099	0.437	0.372
HP Planá nad Lužnicí	R	337 921	0.871	2.873	2.486
HP Plzeň	R	1 576 252	0.634	1.658	1.402
HP Přerov	R	672 558	0.687	3.643	3.031
HP Strakonice	OT	365 548	0.483	13.915	0.625
HP Trmice	R	1 439 117	0.407	3.626	1.411
HP Varnsdorf	R	74 440	0.079	5.370	2.156
HP Zlín	R	683 066	0.411	1.004	0.918
PPs Alpiq Kladno	R	2 188 569	2.675	2.163	1.011
PP Dětmarovice	R	2 646 007	14.048	2.043	1.346
PP Hodonín	OT	607 782	1.793	114.772	0.424
PP Chvaletice	R	3 125 041	60.779	3.082	2.104
PP Ledvice	R	2 338 291	6.091	3.281	1.352
PP Mělník	OT+R	7 637 173	1.887	53.242	1.602
PP Opatovice	OT	3 514 978	1.529	50.719	0.503
PP Počerady	R	6 699 537	143.422	2.475	1.934
PP Poříčí	R	1 098 995	1.323	2.066	0.930
PPs Prunéřov	R	8 803 992	20.030	2.341	1.841
PP Tisová	R	1 869 319	4.533	2.342	0.841
PP Tušimice	R	4 021 132	19.425	2.032	1.674
PP&HP Komořany	R	1 520 382	1.122	1.778	1.106
PP&HP Vřesová	R	7 057 527	1.043	1.805	0.581
NP Dukovany	R	14 426 350	108.981	3.376	2.079
NP Temelín	R	13 295 602	86.429	2.553	1.979

Abbreviations: HP – heat power plant, NP – nuclear power plant, PP – fossil (coal or nature gas) power plants, OT – once through, R – recirculation, D – dry cooling system.
Source: Own computation based on Water balance evidence data and data from the Energy Regulatory Office

focuses only on the first two groups because there were only two operation units with a hybrid system. So we got a group of 28 records in annual steps for operational units with recirculating cooling systems and 5 records for once-through cooling system. These two groups of records were analysed with SPSS statistical software (SPSS, 1999). For each group, we tried to find the best model using weighted least squares regression and the best model using least squares regression without weighting. Therefore, we searched for four models, each of them suitable for a different purpose or type of cooling.

Besides (not-) weighting the observations, the process of searching for the best model was the same for all four segments. The dependent variable was water withdrawal per energy produced and the examined explanatory variables were always the seven quantitative variables mentioned in the first paragraph of this section. We used the traditional linear regression model for an operation unit in a given year in the form:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_n X_n + \varepsilon\,, \tag{1}$$

where Y is the dependent variable (water withdrawals), β_i are regression coefficients, X_i are independent variables and ε is a random component (white noise). The models were generated with the procedures known as forward selection, backward selection and stepwise selection (Zvára, 2008, p. 110). Multicollinearity of individual explanatory variables was tested by variance inflation factor (VIF). Multicollinearity of an explanatory variable is high when VIF of the given variable is higher than 10.

For each model, we estimated the Akaike information criterion (AIC) of the model and in the next step only examined models with the lowest AIC in the particular segment and with appropriate signs of the regression parameters. We require positive dependence for both temperatures and negative dependence for energy production, heat energy to total energy and for price of withdrawals. We are not sure about the required signs of the regression parameters of the variables capacity factor – electricity and capacity factor – heat. Both signs were, therefore, acceptable for us. The proposed models showed the lowest AIC of the models which we examined in each segment and which met the signs requirement.

The first group included 10 observations (each observation for the particular year of the period 2004–2013) for each of the 28 operational units with recirculating cooling. Therefore, the regression parameters related to the already mentioned explanatory variables were estimated from 280 observations during the regression analysis. The second group included 10 observations for each of the 5 operational units, making the size of the sample including 50 observations.

2 RESULTS

The results of analyses of operational water withdrawals and consumption for energy generation shown in Table 2 are similar to the published results of other studies. Macknick et al. (2012, Table 2 and 3) processed the information from several studies and states that real observed water consumption is between 1.491 and 4.164 m^3/MWh for coal power plants with recirculating cooling systems, and between 0.242 and 1.200 m^3/MWh for coal power plants with once-trough cooling systems. The value interval of water consumption for nuclear power plants with recirculating cooling system is between 2.199 and 3.199 m^3/MWh. Water withdrawal is between 1.775 and 5.485 m^3/MWh for coal power plants with recirculating cooling systems, between 75.708 and 189.271 m^3/MWh for coal power plants with once-trough cooling systems, and between 3.028 and 9.842 m^3/MWh for nuclear power plants with recirculating cooling system.

For each category of cooling systems, we identified three best-weighted models and three best no weighted models with lowest AIC. Only for category of recirculating cooling – weighted by energy production of individual operational units we found best five models because the best three models contained the variable price for withdrawal and its parameter's interferes with its expected sign. Table 3 shows the statistics of the models as a whole. The p-values of the F-tests of all of the models listed in table 3 are <0.02.

Table 3 The statistics of the models as a whole for best models in all categories

Model	Number of explanatory variables	R^2_{adj}	Std. Error of the Estimate	RSS	AIC
Recirculating cooling – weighted by energy production of individual operational units					
5re,w,f	5	0.204	0.042	0.474	–1 776.8
4re,w,b	4	0.201	0.042	0.478	–1 776.7
6re,w,f	6	0.204	0.042	0.472	–1 775.8
3re,w,f	3	0.195	0.042	0.483	–1 775.4
5re,w,b	3	0.194	0.042	0.484	–1 775.1
Recirculating cooling – equal weight assigned to each of the operational units					
1re,f	1	0.023	1.181	387.7	93.1
2re,f	2	0.024	1.181	386.0	93.9
3re,f	3	0.025	1.180	384.4	94.8
Once-through cooling – weighted by energy production of individual operational units					
3ot,w,b	5	0.944	0.931	38.2	–3.5
6ot,w,f	6	0.943	0.941	38.1	–1.6
7ot,w,f	7	0.941	0.952	38.1	0,4
Once-through cooling – equal weight assigned to each of the operational units					
2ot,b	6	0.964	7.448	2385.5	205.3
1ot,b	7	0.963	7.536	2384.9	207.2
3ot,b	5	0.960	7.765	2652.8	208.6

Abbreviations in model name: re – recirculating cooling system; ot – once through cooling system; w – weighted by energy production of individual operational units; f – forward selection; b – backward selection.
Source: Own computation

2.1 Operation units with recirculation cooling

Table 4 shows the estimated regression parameters, standard error of the estimation, standardised coefficients, t value of relevant variable and its statistical significance and collinearity statistics VIF. The first three best models (using the AIC) in the recirculating cooling category contained the variable price for withdrawal and its parameter's sign was positive according to the regression analysis. The model with the lowest AIC in the category exhibits AIC equal to 1776.8 which is close to the AIC of the models 3re,w,f and 5re,w,b that are the models with fourth and fifth lowest AIC. These models contained three explanatory variables each and none of their regression parameters interferes with its expected sign. The values of R^2_{adj} indicate that the models 3re,w,f and 5re,w,b could have slight to moderate predictive power.

Table 5 shows the best three models and their parameters if the operational units receive equal weight. We can see that the models again include the capacity factor of electricity production and also of heat production. The signs of the regression parameters are the same as in the weighted regression case. On the other hand, the R^2_{adj} of the models are low. As a result, the values of R^2_{adj} and F Significance are empirical evidence why (for the whole sector prediction) the models mentioned in Table 5 (i.e. models which take into account the size of individual operational units) should be preferred. This may be confirmed by the lower values of AIC in weighted regression models; however it is a question whether AIC is the best criterion for comparison of the model estimated from equally weighted observations with the model estimated from differently weighted observations.

Even though the VIFs (Variance Inflation Factor) of the explanatory variables are relatively low, the models are not suitable for quantification of the influence of individual variables because the R^2_{adj} is low.

Table 4 Summary of analysis for best five models in the category recirculating cooling – weighted by energy production of individual operational units

Model	Explanatory var.	Unstandardized Coeff.		Stand. Coeff.	t	Sig.	VIF
		β_i	Std. Error				
5re,w,f	(Constant)	0.021	1.04		0.02	0.984	
	capacity factor–electricity	1.946	0.36	0.462	5.33	0.000	2.6
	avg. temperature: June-Sept.	0.088	0.06	0.084	1.43	0.153	1.2
	capacity factor–heat	–1.369	0.57	–0.194	–2.41	0.017	2.3
	total energy production	–3.2E-08	1.64E-08	–0.210	–1.96	0.051	4.0
	price for withdrawal	0.067	0.05	0.085	1.49	0.138	1.1
4re,w,b	(Constant)	1.464	0.26		5.68	0.000	
	price for withdrawal	0.083	0.04	0.105	1.89	0.059	1.1
	capacity factor– electricity	1.962	0.37	0.466	5.37	0.000	2.6
	capacity factor–heat	–1.603	0.55	–0.227	–2.94	0.004	2.1
	total energy prod.	–3.9E-08	1.56E-08	–0.259	–2.53	0.012	3.7
6re,w,f	(Constant)	–0.230	1.07		–0.22	0.830	
	capacity factor– electricity	2.006	0.37	0.477	5.42	0.000	2.7
	avg. temperature: June-Sept.	0.101	0.06	0.097	1.61	0.109	1.3
	capacity factor–heat	–1.633	0.63	–0.231	–2.59	0.010	2.8
	total energy production	–2.9E-08	1.66E-08	–0.191	–1.75	0.082	4.2
	price for withdrawal	0.056	0.05	0.071	1.20	0.231	1.2
	heat e. to total energy	0.240	0.25	0.081	0.97	0.331	2.4
3re,w,f	(Constant)	–0.657	1.00		–0.66	0.511	
	capacity factor– electricity	1.553	0.28	0.369	5.49	0.000	1.6
	avg. temperature: June-Sept.	0.141	0.06	0.135	2.46	0.015	1.0
	capacity factor–heat	–0.786	0.47	–0.111	–1.67	0.097	1.5
5re,w,b	(Constant)	1.713	0.22		7.71	0.000	
	capacity factor– electricity	1.990	0.37	0.473	5.42	0.000	2.6
	capacity factor–heat	–1.662	0.55	–0.235	–3.03	0.003	2.1
	total energy production	–3.7E-08	1.56E-08	–0.245	–2.39	0.018	3.6

Abbreviations in model name: re – recirculating cooling system; w – weighted; f – forward selection; b – backward selection.
Source: Own computation

2.2 Operation units with once-through cooling

All of the three models for once-through cooling systems by energy production of individual operational units with the lowest AIC had the signs of their regression coefficients in accordance with our expectation (without considering the capacity factors). Apparently, the values of the regression parameters of the same variables are very similar in the models 3ot,w,b and 6ot,w,f, which suggests that the explanatory variables, at least in the 3ot,w,b, could be very significant in the once-through cooling segment. Table 6 indicates that both models exhibit very high R^2_{adj}. According to the values of AIC (see the third part of Table 3) we recommend the model 3ot,w,b.

Table 7 shows the best three models and their parameters in case the operational units receive equal weight. The regression parameter of the variable average annual temperature of the second best model exhibited a minus sign, however, in the next step, this variable was eliminated because of its low significance (0.922). The elimination of average annual temperature resulted in the model 2ot,b. Model

Table 5 Summary of analysis for best three models in the category recirculating cooling – equal weight assigned to each of the operational units

Model	Explanatory var.	Unstandardized Coeff.		Stand. Coeff.	t	Sig.	VIF
		β_i	Std. Error				
1re,f	(Constant)	1.935	0.18		10.77	0.000	
	capacity factor– electricity	0.927	0.33	0.164	2.78	0.006	1.0
2re,f	(Constant)	2.169	0.28		7.79	0.000	
	capacity factor– electricity	0.760	0.37	0.135	2.07	0.039	1.2
	capacity factor–heat	–0.881	0.80	-0.072	–1.10	0.271	1.2
3re	(Constant)	2.512	0.43		5.91	0.000	
	capacity factor– electricity	0.695	0.37	0.123	1.87	0.063	1.2
	capacity factor–heat	–1.113	0.83	–0.090	–1.34	0.180	1.3
	price for withdrawal	-0.082	0.08	–0.065	–1.07	0.287	1.1

Abbreviations in model name: re – recirculating cooling system; f – forward selection.
Source: Own computation

Table 6 Summary of analysis for best three models in category once-through cooling – weighted by energy production of individual operational units

Model	Explanatory var.	Unstandardized Coeff.		Stand. Coeff.	t	Sig.	VIF
		β_i	Std. Error				
3ot,w,b	(Constant)	160.74	42.32		3.80	0.000	
	price for withdrawal	–41.02	7.65	–0.253	–5.36	0.000	1.9
	avg. temperature: June-Sept.	5.741	1.88	0.142	3.05	0.004	1.9
	heat e. to total energy	–216.48	11.07	–1.323	–19.6	0.000	4.0
	capacity factor– electricity	–87.11	21.45	–0.429	–4.06	0.000	9.7
	total energy production	–1.19E-05	1.96E-06	–0.614	–6.05	0.000	9.0
6ot,w,f (2ot,w,b)	(Constant)	163.38	43.83		3.73	0.001	
	capacity factor–heat	24.90	90.84	0.028	0.27	0.785	9.2
	price for withdrawal	–39.73	9.04	–0.245	–4.40	0.000	2.7
	heat energy to total energy	–221.95	22.88	–1.356	–9.70	0.000	16.7
	total energy production	–1.22E-05	2.28E-06	–0.630	–5.34	0.000	11.9
	capacity factor– electricity	–90.69	25.30	–0.446	–3.59	0.001	13.3
	avg. temperature: June-Sept.	5.618	1.96	0.139	2.87	0.006	2.0
7ot,w,f (1ot,w,b)	(Constant)	163.90	44.69		3.67	0.001	
	capacity factor–heat	27.95	97.43	0.032	0.29	0.776	10.4
	price for withdrawal	–39.38	9.88	–0.243	–3.99	0.000	3.1
	heat energy to total energy	–222.58	24.09	–1.360	–9.24	0.000	18.1
	total energy production	–1.21E-05	2.33E-06	–0.628	–5.21	0.000	12.2
	capacity factor– electricity	–91.66	27.62	–0.451	–3.32	0.002	15.5
	avg. temperature: June-Sept.	5.49	2.38	0.136	2.31	0.026	2.9
	avg. annual temperature	0.19	2.04	0.005	0.09	0.925	2.2

Abbreviations in model name: ot – once through cooling system; w – weighted; f – forward selection; b – backward selection.
Source: Own computation

2ot,b is the model with the lowest AIC (see last part of Table 3) in this segment and the signs of its regression parameters are in accordance with the expectations.

Table 7 Summary of analysis for best three models in the category once-through cooling – equal weight assigned to each of the operational units

Model	Explanatory var.	Unstandardized Coeff.		Stand. Coeff.	t	Sig.	VIF
		β_i	Std. Error				
2ot,b	(Constant)	124.24	47.23		2.63	0.012	
	price for withdrawal	–51.46	7.54	–0.306	–6.82	0.000	2.7
	avg. temperature: June-Sept.	7.492	2.14	0.157	3.50	0.001	2.7
	heat energy to total energy	–185.40	18.85	–1.092	–9.83	0.000	16.6
	capacity factor– electricity	–54.23	23.84	–0.225	–2.27	0.028	13.2
	capacity factor–heat	–130.83	59.60	–0.146	–2.20	0.034	5.9
	total energy production	–1.13E-05	1.88E-06	–0.369	–5.99	0.000	5.1
1ot,b	(Constant)	123.45	48.45		2.55	0.015	
	price for withdrawal	–51.64	7.84	–0.307	–6.59	0.000	2.9
	avg. temperature: June-Sept.	7.64	2.64	0.160	2.89	0.006	4.1
	avg. annual temperature	–0.21	2.12	–0.004	–0.10	0.922	2.4
	heat energy to total energy	–185.19	19.19	–1.091	–9.65	0.000	16.8
	capacity factor– electricity	–53.75	24.62	–0.223	–2.18	0.035	13.7
	capacity factor–heat	–131.63	60.85	–0.147	–2.16	0.036	6.1
	total energy production	–1.13E-05	1.93E-06	–0.370	–5.86	0.000	5.3
3ot,b	(Constant)	172.64	43.55		3.96	0.000	
	price for withdrawal	–44.59	7.15	–0.265	–6.23	0.000	2.2
	avg. temperature: June-Sept.	5.530	2.03	0.116	2.73	0.009	2.2
	heat energy to total energy	–220.76	10.21	–1.300	–21.6	0.000	4.5
	capacity factor– electricity	–94.61	15.82	–0.392	–5.98	0.000	5.3
	total energy production	–1.19E-05	1.94E-06	–0.390	–6.15	0.000	5.0

Abbreviations in model name: ot – once through cooling system; w – weighted; f – forward selection; b – backward selection.
Source: Own computation

For the quantification of individual explanatory variables the model 3ot,b could be used because of relatively low VIFs of its all considered variables and high statistical significance of each of its explanatory variables.

DISCUSSION AND CONCLUSIONS

For circulation plants, it is not possible to recognise from the available water balance data what was actually used for energy production. If there are no data on technological or hot water delivery to other water consumers, then the processed data can be significantly overstated. For example, an unadjusted sampling of water supplies to third parties at the Planá nad Lužnicí heating plant causes an increase in demand for water per 1 MWh by 68.7% and water consumption by 79.4%. Collecting information about hot water supplies to the third parties is unfortunately very complicated.

The results of the regression analysis suggest that the created models seem to be rather partially successful for the recirculation cooling category of operation and much more successful for the once-through cooling category. For most models with optimal or close to optimum values of AIC, the expected signs

of the estimated coefficients of explanatory variables were in accordance with the *a priori* expected signs. We suggest using the models from a group of weighted models with lowest (or close to lowest) AIC, the statistical significance of all explanatory variables lower than 0.05 and with expected signs of the estimated coefficients of explanatory variables. Model 3ot,w,b meets this conditions in the once-through cooling category and in the recirculation cooling category it is model 5re,w,b. For significantly higher prediction power of the models with non-equal weights than models with equal weights in the recirculating segment we cannot find other explanation than this is due to failure to meet the assumption of constant weights of individual observations.

Table 8 Comparison of the values of coefficients in the in both cooling categories – weighted models

Explanatory var.	Model	Unstandardized Coeff.		Model	Unstandardized Coeff.	
		β_i	Std. Error		β_i	Std. Error
(Constant)	5re,w,f	0.021	1.04	3ot,w,b	160.743	42.32
	4re,w,b	1.464	0.26	6ot,w,f	163.376	43.83
	6re,w,f	–0.230	1.07	7ot,w,f	163.898	44.69
	3re,w,f	–0.657	1.00			
	5re,w,b	1.713	0.22			
Avg. temperature: June-Sept.	3re,w,f	0.141	0.06	3ot,w,b	5.741	1.88
	5re,w,f	0.088	0.06	6ot,w,f	5.618	1.96
	6re,w,f	0.101	0.06	7ot,w,f	5.494	2.38
Avg. annual temperature				7ot,w,f	0.192	2.04
Capacity factor– electricity	6re,w,f	2.006	0.37	3ot,w,b	–87.114	21.45
	3re,w,f	1.553	0.28	6ot,w,f	–90.686	25.30
	5re,w,b	1.990	0.37	7ot,w,f	–91.664	27.62
	4re,w,b	1.962	0.37			
	5re,w,f	1.946	0.36			
Capacity factor–heat	5re,w,f	–1.369	0.57	7ot,w,f	27.950	97.43
	4re,w,b	–1.603	0.55			
	6re,w,f	–1.633	0.63			
	3re,w,f	–0.786	0.47			
	5re,w,b	–1.662	0.55			
Heat energy to total energy	6re,w,f	0.240	0.25	3ot,w,b	–216.480	11.07
				6ot,w,f	–221.950	22.88
				7ot,w,f	–222.579	24.09
Price for withdrawal	5re,w,f	0.067	0.05	3ot,w,b	–41.019	7.65
	4re,w,b	0.083	0.04	6ot,w,f	–39.733	9.04
	6re,w,f	0.056	0.05	7ot,w,f	–39.381	9.88
Total energy production	4re,w,b	–3.9E-08	1.56E-08	3ot,w,b	–1.19E-05	1.96E-06
	5re,w,f	–3.2E-08	1.64E-08	6ot,w,f	–1.22E-05	2.28E-06
	6re,w,f	–2.9E-08	1.66E-08	7ot,w,f	–1.21E-05	2.33E-06
	5re,w,b	–3.7E-08	1.56E-08			

Abbreviations in model name: re – recirculating cooling system; ot – once through cooling system; w – weighted by energy production of individual operational units; f – forward selection; b – backward selection.
Source: Table 4 and Table 6

On another side, the values of β_i coefficients in the once-through cooling category are significantly different from the same explanatory variables in recirculating cooling technology (see Table 8). We see a logical explanation only for two of the explanatory variables. For average temperature from June to September, we can assume that this is caused by the relatively stable temperature of cooling water in recirculating systems against the fluctuating temperature of water withdrawn from rivers during a year. The second remarkable variable is the price. While in the recirculating segment its regression parameters are close to 0 (which is confirmed by the low statistical significance of the variable), in the once-through segment the price was statistically very significant with its parameter around –40. That means that for the range from 0.4 to 1.22 CZK/m^3 (i.e. the range corresponding to the real minimum and maximum price for the 1 m^3 withdrawn from the surface water for the once-through cooling purposes in the investigated period) making the water more costly by 0.01 CZK/m^3 we can expect a decrease in water withdrawal by 0.40 m^3/MWh.

Possible reasons for a relatively low prediction power of the models for recirculation cooling category include:

- more heterogeneous category (while once-through cooling uses the water just once, the number of times the water is used in the recirculation system is not the same for all operational units with a recirculation system);
- not sufficiently complex statistical model;
- only annual data are available (while the electricity and heat production and temperature exhibits strong monthly seasonality).

ACKNOWLEDGEMENTS

The study presented within this paper was carried out as part of the project TD020113 funded by the Technological Agency of the Czech Republic. The authors would like to thank the staff of the Energy Regulatory Office, Czech Statistical Office, United Energy and ČEZ for sharing their knowledge and for providing the necessary data for this study. The authors would like to thank all unnamed colleagues from TGM WRI for their inspiring suggestions and comments. The authors also would like to thank the anonymous referees for their valuable comments which helped to improve the manuscript.

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Selection of Unit Root Test on the Basis of Length of the Time Series and Value of AR(1) Parameter

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Abstract

An important task in econometric modelling is to determinate the integration order of analysed time series through unit root tests. Statistical theory offers a wide range of tests where the most common are Dickey-Fuller tests, Phillips-Perron test, KPSS test, and their modifications ADF-GLS test and Ng-Perron test. The choice of an appropriate one depends primarily on a subjective judgement of the analyst. If we wish to avoid the subjective choice, we need to find an objective criterion that clearly defines which test is the most suitable for specific types of time series. The goal of the article is to answer this question by a simulation study and to provide the recommendations which test is possible to use. The conclusions will be applicable for time series of lengths $T = 25, ..., 500$ and positive values of the autoregressive parameter AR(1).

Keywords

Unit root test, augmented Dickey-Fuller test, Phillips-Perron test, KPSS test, ADF-GLS test, NGP test, simulation, power of test, time series analysis

JEL code

C12, C15, C22, C51

INTRODUCTION

Statistics and econometrics use a single-equation or multi-equation regression models of time series for modelling economic variables and their interrelations. These models are based on the Box and Jenkins methodology (Box, Jenkins, 1970) and the fundamental assumption for their use is time series stationarity or their linear combinations stationarity in the case of multi-equation models. In practice, however, this condition is often not met because most of economic time series are non-stationary. These time series are denoted as integrated of order d when they are after the d-differentiations stationary.

Therefore, analytic models construction requires identification of the order of integration or the order of differentiation d. Econometrists employ several approaches to determine this order. The simplest method is an assessment of the time series graphs. The original time series is compared with time series

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of the first and second differences. Although this method has a subjective character, it is very effective in many cases, especially for experienced analysts. The shape of sample autocorrelation (ACF) and partial autocorrelation (PACF) functions (Box, Jenkins, 1970) is another simple method providing sufficient results. If the ACF is slowly decreasing, roughly at a linear rate, the PACF has a very high first value, the time series should be differentiated (the assumption is, that the time series does not contain the outliers, whose presence can change the shape of both functions and it is necessary to remove it before the analysis). In case the time series is classified as non-stationary, then its first differences are analysed. Similarly, if the time series of first differences is non-stationary, the time series of second differences is analysed. The above approach, however, suffers by the over-differencing risk. Therefore, it is convenient to approach this problem formally and to use appropriate statistical tests to determine the order of differentiation.

The determination and verification of the order of integration is a quite wide area that includes an extensive list of tests known as unit root tests, where the most commonly used are Dickey and Fuller's DF-test and ADF test (Dickey and Fuller, 1979), Phillips-Perron test (Phillips and Perron, 1988), KPSS test (Kwiatkowski, Phillips, Schmidt and Shin, 1992), also less frequently used ADF-GLS test (Elliot, Rothenberg and Stock, 1996) and NGP test (Ng and Perron, 1995 and 2001).

Consequently, there is a wide range of unit root tests that are usually integrated in statistical and econometric software. A question the analysts face is which one of them should be used as the most suitable test for the respective time series. The aim of this article is to solve this dilemma and advise which one of them to use under specific criteria. The recommendations concluded from this article are suitable for short and medium-long time series of lengths from 25 to 500 values and for positive values of parameter ϕ_1 of the autoregressive process AR(1).

1 REVIEW OF SELECTED UNIT ROOT TESTS

1.1 Dickey-Fuller tests (DF test and ADF test)

Dickey-Fuller test (Dickey, Fuller, 1979) is one of the best known and most widely used unit root tests. It is based on the model of the first-order autoregressive process (Box, Jenkins, 1970):

$$y_t = \phi_1 y_{t-1} + \varepsilon_t, \qquad t = 1, \ldots, T \tag{1}$$

where ϕ_1 is the autoregression parameter, ε_t is the non-systematic component of the model that meets the characteristics of the white noise process.

The null hypothesis is H_0: $\phi_1 = 1$, i.e. the process contains a unit root and therefore it is non-stationary, and is denoted as I(1), alternative hypothesis is H_1: $|\phi_1| < 1$, i.e. the process does not contain a unit root and is stationary, I(0).

To calculate the test statistic for DF test, we use an equation that we get if y_{t-1} is subtracted from both sides of the equation (1):

$$\Delta y_t = \beta y_{t-1} + \varepsilon_t, \tag{2}$$

where $\beta = \phi_1 - 1$. The test statistic is defined as:

$$t_{DF} = \frac{\hat{\phi}_1 - 1}{s_{\hat{\phi}_1}}, \tag{3}$$

where $\hat{\phi}_1$ is a least square estimate of ϕ_1 and $s_{\hat{\phi}_1}$ is its standard error estimate. Under the null hypothesis this test statistic follows the Dickey-Fuller distribution, critical values for this distribution were obtained by a simulation and have been tabulated in Dickey (1976) and Fuller (1976).

Model (1) can be expanded by a constant or a linear trend:

$$y_t = \beta_0 + \phi_1 y_{t-1} + \varepsilon_t, \tag{4}$$

$$y_t = \beta_0 + \beta_1 t + \phi_1 y_{t-1} + \varepsilon_t. \tag{5}$$

In the case when a non-systematic component in DF models is autocorrelated, so-called Augmented Dickey-Fuller test is constructed (Dickey, Fuller, 1981). Model (1) is then transformed as:

$$y_t = \phi_1 y_{t-1} + \sum_{i=1}^{p-1} \gamma_i \Delta y_{t-\mathrm{i}} + \varepsilon_t \tag{6}$$

and the following equation is used to calculate the test statistic of the ADF test:

$$\Delta y_t = (\phi_1 - 1) y_{t-1} + \sum_{i=1}^{p-1} \gamma_i \Delta y_{t-i} + \varepsilon_t \ . \tag{7}$$

A practical problem of this test is the choice of lags p. The next steps are the same as in the case of DF test. Schwert (1989) suggests choosing the maximum lag $p_{max} = 12(T/100)^{1/4}$, because if p is too low, the test will be affected by autocorrelation and if p is too large, the power of test will be lower. Model (6) can be expanded by a constant, or linear trend as well. Then, tests based on the following model are used:

$$y_t = d_t + \phi_1 y_{t-1} + \sum_{i=1}^{p-1} \gamma_i \Delta y_{t-i} + \varepsilon_t \ , \tag{8}$$

where $d_t = \sum_{i=0}^{p} \beta_i t^i$, for $p = 0, 1$, contains deterministic parts of the models mentioned above.

The limiting distribution of test statistics is identical with the distribution of DF test statistics and for $T \to \infty$ is tabulated in Dickey (1976) and MacKinnon (1991).

1.2 Phillips-Perron test (PP test)

In the unit root testing of time series generated by the process with autocorrelated and heteroscedastic non-systematic component, there is often a problem of selection of lag p in the regression model. Phillips and Perron (1988) were dealing with this problem and instead of describing the autocorrelation structure of the generating process by the corresponding autocorrelation models, they used standard Dickey-Fuller test with non-parametrically modified test statistics.

This test is also based on the models (1), (4) and (5) with the difference that the linear trend in the last model is replaced by a centred time variable.

Nevertheless, the next steps differ from Dickey-Fuller tests. This test is not using the differentiated equations for the test statistics calculation, but it derives it directly from the equations (1), (4) and (5).

The test statistics Z for model with a constant are written as follows (Pesaran, 2015):

$$Z_\phi = T(\hat{\phi}_T - 1) - \frac{1}{2} \frac{T^2 s_{\hat{\phi}}^2}{s_T^2} (s_{LT}^2 - s_T^2) \tag{9}$$

$$Z_T = \left(\frac{s_T}{s_{LT}}\right) t_{DF} - \frac{1}{2}(s_{LT}^2 - s_T^2)\frac{1}{s_{LT}}\frac{Ts_{\hat{\phi}}}{s_T}, \tag{10}$$

where:

$$t_{DF} = \frac{\hat{\phi}_T - 1}{s_{\hat{\phi}}}, \quad s_T^2 = \frac{1}{T}\sum_{t=1}^{T}\hat{\varepsilon}_t^2, \quad s_{LT}^2 = s_T^2 + 2\sum_{j=1}^{q}(1 - \frac{j}{q+1})\hat{\gamma}_{j,T} \quad \text{and} \quad \hat{\gamma}_{j,T} = \frac{1}{T}\sum_{t=j+1}^{T}\hat{\varepsilon}_t\hat{\varepsilon}_{t-j},$$

t_{DF} is the test statistics of DF test, s_T^2 is the OLS estimator of the non-systematic component variance, $\hat{\gamma}_{j,T}$ is the maximum likelihood estimator of the non-systematic component covariance and q is a number of lag of covariates.

If ε_t is not autocorrelated, then $\hat{\gamma}_{j,T} = 0$, for $j > 0$, and $s_{LT}^2 = s_T^2$, the limiting distribution of the test statistics t is therefore not dependent on autoregressive parameters of ε_t process. The test statistics Z are consequently reduced to t_{DF} test statistics. Dickey-Fuller test is thus a special case of non-parametric tests.

1.3 ADF-GLS test

ADF-GLS test, also known as ERS test (Elliot, Rothenberg and Stock, 1996), is another modification of Augmented Dickey-Fuller test. Before the unit root testing, the ADF-GLS test utilizes the detrending transformation (i.e. transformation that removes trend from time series).

The constant in model (4) is estimated based on the generalised least squares method (GLS) using the transformation:

$$\begin{aligned} &\tilde{y}_1 = y_1, \tilde{y}_t = y_t - \rho y_{t-1}, && t = 2, \ldots, T, \\ &x_1 = 1, \; x_t = 1 - \rho, && t = 2, \ldots, T, \end{aligned} \tag{11}$$

where $\rho = 1 + \bar{c}/T$ and $\bar{c} = -7$,[3] based on the equation:

$$\tilde{y}_t = \beta_0 x_t + \varepsilon_t. \tag{12}$$

Subsequently, parameter $\tilde{\beta}_0$ is estimated by the least squares method and used to remove constant from the time series y_t

$$y_t^* = y_t - \hat{\beta}_0. \tag{13}$$

In the last step, the ADF test is calculated based on the transformed time series given by:

$$\Delta y_t^* = \phi_1 y_{t-1}^* + \sum_{i=1}^{p}\gamma_i \Delta y_{t-i}^* + \varepsilon_t. \tag{14}$$

[3] The value $\bar{c} = -7$ (resp. −13.5, in the case of a model with a linear trend) was deduced for $\alpha = 0.05$ by Elliot, Rothenberg and Stock (1996) based on power envelope. For given T and when the relevant deterministic components are present the power envelope in this point reaches 50% (i.e., that the tests are optimal at the 50% power).

The trend in models with the linear trend is estimated by GLS. Transformation (11) is extended by $z_1 = 1$, $z_t = t - \rho(t-1)$, where $\rho = 1 + \bar{c}/T$, where $\bar{c} = -13.5$. Estimates of parameters are calculated based on equation:

$$\tilde{y}_t = \beta_0 x_t + \beta_1 z_t + \varepsilon_t \tag{15}$$

and estimated parameters $\tilde{\beta}_0$ and $\tilde{\beta}_1$ are then used to remove trend from the time series y_t

$$y_t^* = y_t - (\hat{\beta}_0 + \hat{\beta}_1 t). \tag{16}$$

Finally, the ADF test is applied on the transformed time series, i.e. the test statistic is obtained from the following equation:

$$\Delta y_t^* = \beta_0 + \phi_1 y_{t-1}^* + \sum_{i=1}^{p} \gamma_i \Delta y_{t-i}^* + \varepsilon_t . \tag{17}$$

The critical values for the ADF-GLS test obtained on the basis of simulation in Elliot, Rothenberg and Stock (1996) show that for models without constant they are the same as in the case of the ADF test. For the remaining models, critical values of the ADF-GLS test are used as indicated in Elliot, Rothenberg and Stock (1996) as well.

1.4 NGP test

Ng and Perron (1995, 2001) built on detrended data y_t^* obtained from the ADF-GLS test and modified the Phillips-Perron PP test.

Based on the equation (8) the test uses test statistics Z from the PP test that had been modified by Ng and Perron into form:

$$\overline{MZ}_\phi = (T^{-1} y_t^* - s_{AR}^2)\left(2T^{-2}\sum_{t=1}^{T} y_{t-1}^*\right)^{-1}, \tag{18}$$

$$\overline{MSB} = \left(T^{-2}\sum_{t=1}^{T}\frac{y_{t-1}^*}{s_{AR}^2}\right)^{1/2}, \tag{19}$$

$$\overline{MZ}_T = \overline{MZ}_\phi \cdot \overline{MSB}, \tag{20}$$

where $s_{AR}^2 = \left(\sum_{t=p+1}^{T} \varepsilon_t^2\right)\left((T-k)(1-\sum_{i=1}^{p}\hat{\beta}_i)^2\right)^{-1}$, and marked as M tests.

Although the NGP test is considered as an effective modification of unit root tests, it is not included in many statistical software.

1.5 KPSS test

All the tests mentioned above are testing the null hypothesis that the time series y_t is integrated of order one, I(1). The opposite case, i.e. testing the null hypothesis that the time series y_t is I(0), is described by the KPSS test (Kwiatkowski, Phillips, Schmidt and Shin, 1992).

Kwiatkowski, Phillips, Schmidt and Shin built on the idea that the time series is stationary around a deterministic trend and is calculated as the sum of a deterministic trend, random walk and stationary random error. It is based on model:

$$\begin{aligned} y_t &= d_t + r_t + \varepsilon_t, \\ r_t &= r_{t-1} + u_t, \end{aligned} \tag{21}$$

where $d_t = \sum_{i=0}^{p} \beta_i t^i$, for $p = 0, 1$, contains deterministic parts of the model (constant or deterministic trend), ε_t are iid $N(0, \sigma_\varepsilon^2)$, r_t is a random walk with variance σ_u^2 and u_t are iid $N(0, \sigma_u^2)$.

KPSS test is based on LM test of the hypothesis that the random walk has a zero variance, i.e. H_0: $\sigma_u^2 = 0$, which means that r_t is a constant, against the alternative H_1: $\sigma_u^2 > 0$. The test statistic is written as:

$$LM = \sum_{t=1}^{T} s_t^2 \; / \hat{\sigma}_\varepsilon^2 \;, \tag{22}$$

where $s_t = \sum_{t=1}^{T} \hat{\varepsilon}_t$, $t = 1, 2, \ldots, T$, and $\hat{\sigma}_\varepsilon^2$ is the estimate of variance $\hat{\sigma}_\varepsilon^2$ of process ε_t from the equation (21). Critical values were derived by a simulation and are listed in Kwiatkowski, Phillips, Schmidt and Shin (1992).

1.6 Problems associated with unit root tests

Pesaran (2015) and Zivot (2006) state that a problem of all the above-mentioned unit root tests subsists in their dependence on the length of analysed time series. In the case of the ADF test the authors Dickey and Fuller (Dickey, Fuller, 1979) are aware of this fact from the outset. The description of other tests mentioned above indicates that their construction reacts to this fact and attempts to eliminate the disadvantages of the ADF test.

The Phillips-Perron test represents the most common alternative to the ADF test. Its main advantage is that it is a non-parametric test. Thus, it is not necessary to specify the model and lagged parameter in the test regression. On the other hand, PP test is based on an asymptotic theory, i.e. it is designed to test the unit roots in long time series. Unfortunately, this assumption is often not met in reality. Pesaran (2015) shows that PP and ADF tests are asymptotically equivalent.

Both Pesaran (2015) and Zivot (2006) also point out another problem that occurs in a situation where the parameter ϕ_1 in the autoregressive process (1) is close to one. Both tests have in this case low power and the invalid null hypothesis is not rejected, i.e. time series is classified as non-stationary, type I(1), while it is actually stationary, type I(0), and the alternative hypothesis applies. According to Caner and Killian (2001) even the KPSS test suffers from a similar drawback. Moreover, it was proved that the power of these tests is lower in the case where a linear deterministic trend is included in the model of test regression. In contrast, the ADF-GLS and NGP tests should eliminate this problem. Nevertheless, complicated construction and also the fact that they are practically not represented in statistical and econometric software make their application difficult.

2 SIMULATION STUDY

A simulation study based on Fedorová (2016) shows the impact of the length of time series and the value of parameter ϕ_1 on the results of the unit root tests. This comparative study is according to our information quite unique, since a study that would contain similar list of analysed unit root tests has not been found in any available sources. A comparison of some tests can be found e.g. in Park (1990), Park, Fuller (1995), Schwert (1989). Traditionally, simulation studies verifying the properties of specific unit root tests are presented in the original papers by Dickey, Fuller (1979), Phillips-Perron (1988), Kwiatkowski, Phillips, Schmidt and Shin (1992), Elliot, Rothenberg and Stock (1996) and Ng, Perron (1995 and 2001).

First, 297 000 times series were generated by a stationary autoregressive process AR(1) without a constant, in the form $y_t = \phi_1 y_{t-1} + \varepsilon_t$, where $\varepsilon_t \sim N(0, 1)$, for positive values of the parameter ϕ_1, i.e. $\phi_1 = 0.01, 0.02, \ldots, 0.99$, which fulfil the condition of stationarity of the process. The number of replications is $n = 3\,000$. The length of time series $T = 500$ was chosen as a base from which the time series of lengths $T = 25$, 50 and 100 were derived. These lengths were chosen both with regard to the length of real time series and also to verify the assumption of rapid growth in the power of these tests with increasing T.

The second step assumes that the above described unit root tests were applied on these time series. The criterion for comparison of their effectiveness is their power, i.e. one of the fundamental characteristics observed in the statistical hypothesis testing. The power of the test, denoted as $(1 - \beta)$, is the probability of rejecting the null hypothesis when it is false.

In the results evaluation we monitor in how many cases a test rejects the null hypothesis H_0: $\phi_1 = 1$. To yield the probability β, a sum of these cases is divided by a number of test replications. We plot the calculated values of the power of tests, i. e. the value $(1 - \beta)$ in the form of so-called power functions. An exception from the above is the KPSS test, whose hypotheses are defined reversely. In this case we plot the ratio of number of non-rejections of null hypothesis of stationarity and number of replications, i. e. the probability $(1 - \alpha)$.

For the sake of completeness, a simulation, where the generating process contains a unit root, i.e. $\phi_1 = 1$ (it is the non-stationary process), was performed. It was examined in how many cases a test did not reject the null hypothesis H_0: $\phi_1 = 1$, and the size of the test (probability of type I error α) was calculated for each test (except KPSS test).

All tests were conducted on a chosen 5% significance level. The simulation study was performed in the statistical software R, R Development Core Team (2008).

2.1 Power comparison of selected unit root test

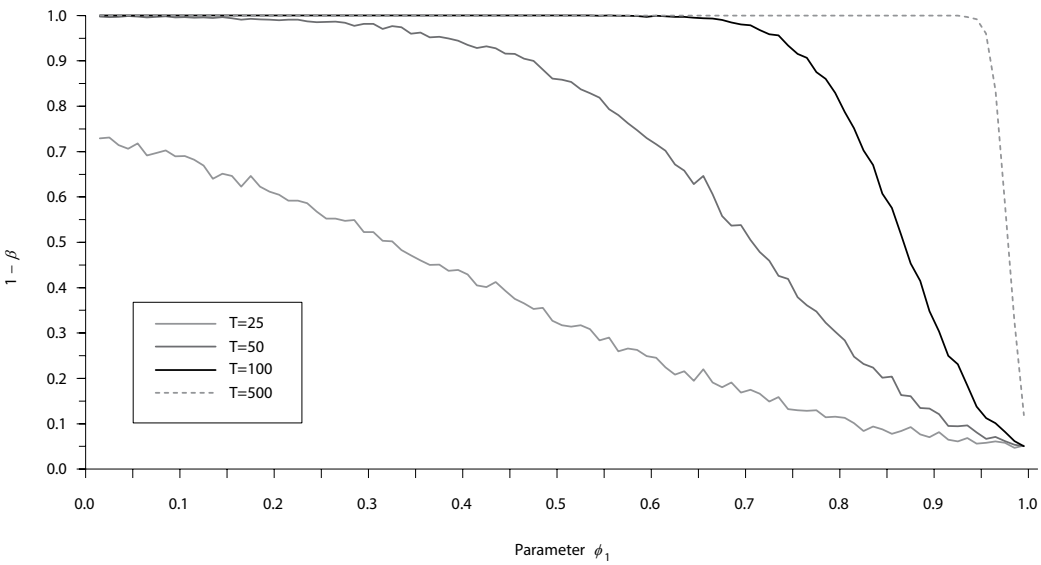
ADF test

Based on the assumptions, the ADF test is considered to have a very low power. This appears particularly in the case where the parameter ϕ_1 is close to 1.

For very short time series ($T = 25$) the power of the test gradually decreases inversely to the value of parameter ϕ_1. More importantly, as is evident from Fig. 1, the test is not able to prove the stationarity even for low values of this parameter. The test achieves maximum success, approximately 70%, for very small values of ϕ_1 ($0.01 < \phi_1 < 0.15$). For values $\phi_1 > 0.3$ is the test more likely to not reject the non-stationarity of time series despite the fact of its stationarity.

The test properties improve for time series of length $T = 50$ and the results of the ADF test are approaching 1 for $\phi_1 < 0.2$. Again, the power of the ADF test gradually decreases for higher values of this parameter. In the case of time series of length $T = 100$ the power of the test increases; it reaches 1 until the value $\phi_1 = 0.6$ and then begins to decrease. It seems clear that the power of the test increases along with the growing length of time series, but even in the case of time series with 500 observations, which

Figure 1 Power functions (1 – β) of ADF test for simulated time series of lengths T = 25, 50, 100, 500 and number of replications n = 3 000, α = 0.05



Source: Authors' calculation

uniquely identifies the test stationarity for $\phi_1 < 0.9$, its power function drops sharply for higher values of parameter ϕ_1.

The sizes of the test α (Figure 10) are 4.6% for T = 25, 4.9% for T = 50, 4.7% for T = 100 and 4.8% for the length of time series T = 500. The sizes of the test (probability of the type I error) are for all lengths almost at the given 5% significance level.

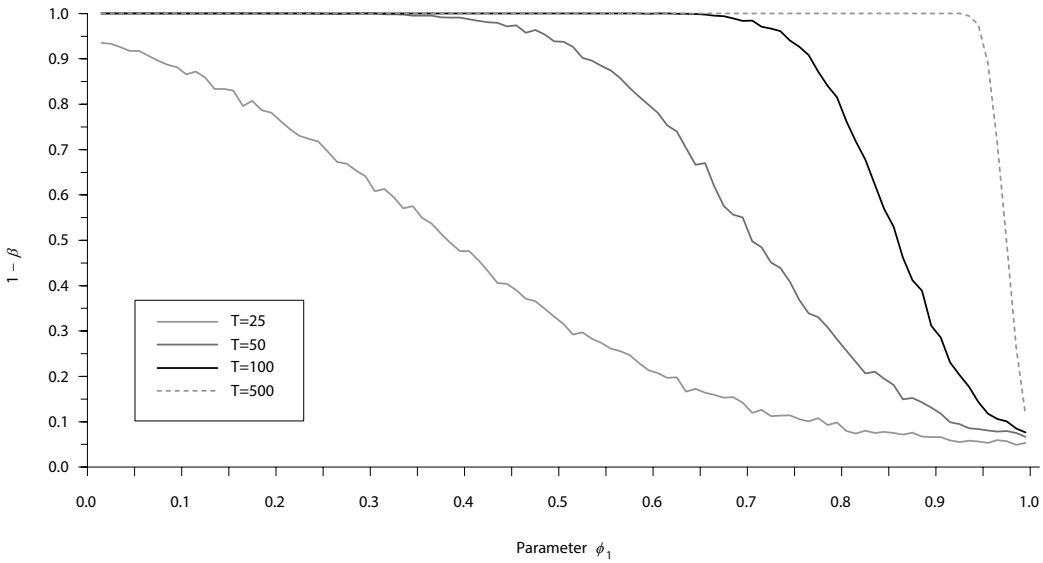
PP test

The PP test uses non-parametrically adjusted test statistics. Compared to the ADF test this fact should increase the power of tests and improve test results.

Noticeable smoothing of power functions with increasing number of replications can be seen also in this case. For time series of length T = 25 the power of the test remains very low; the results are good only for the smallest values of parameter ϕ_1 where the power of the test for $\phi_1 < 0.2$ is above 80%. For T = 50 the test reaches almost 1 in the case of values $\phi_1 < 0.4$ and then decreases rapidly. If the time series is of length T = 100, the power of the test is significantly higher. Namely, it reaches the maximum value for $\phi_1 < 0.7$ and only after this value the power begins to decline. The test becomes very reliable in the case of lengths T = 500. Nevertheless, similarly as for the ADF test, the power of the test rapidly declines for values of ϕ_1 close to 1.

The sizes of the test α (Figure 10) are 3.8% for T = 25, 5.8% for T = 50, 6.6% for T = 100 and 6.4% for the length of time series T = 500. For the length T = 25, this test is a conservative test as the size of the test α is notably lower than set 5% significance level, what might result in a smaller power of test. On the contrary, if time series is longer, this test is liberal as the sizes of the test are higher than the given 5% significance level up to 1.6 percentage points.

Figure 2 Power functions (1 – β) of PP test for simulated time series of lengths T = 25, 50, 100, 500 and number of replications n = 3 000, α = 0.05



Source: Authors' calculation

ADF-GLS test

The power functions of the ADF-GLS test, also called "efficient unit root test", are shown in Figure 3.

The ADF-GLS test shows a noticeable increase in power with a raising number of observations as well. The shape of the power functions is, however, different at first glance; in comparison with the previous tests it is very low for small T and ϕ_1. For T = 25 the power is below the 40% threshold, therefore, this test is not sufficient. Even though, also in this case the power of test increases with the growing length of the time series, for T = 50 it does not reach even the 70% threshold and with the increasing value of the parameter ϕ_1 it slowly drops. In the case of lengths T = 100 the power of the test fluctuates around 80% for $0.01 < \phi_1 < 0.7$, then it begins to fall again. For the time series of length T = 500, we can observe greater ability to reject the null hypothesis of the unit root also for higher values of the parameter ϕ_1. The power of the test is approaching 1 even for the values around $\phi_1 = 0.9$. It, however, declines sharply after this value.

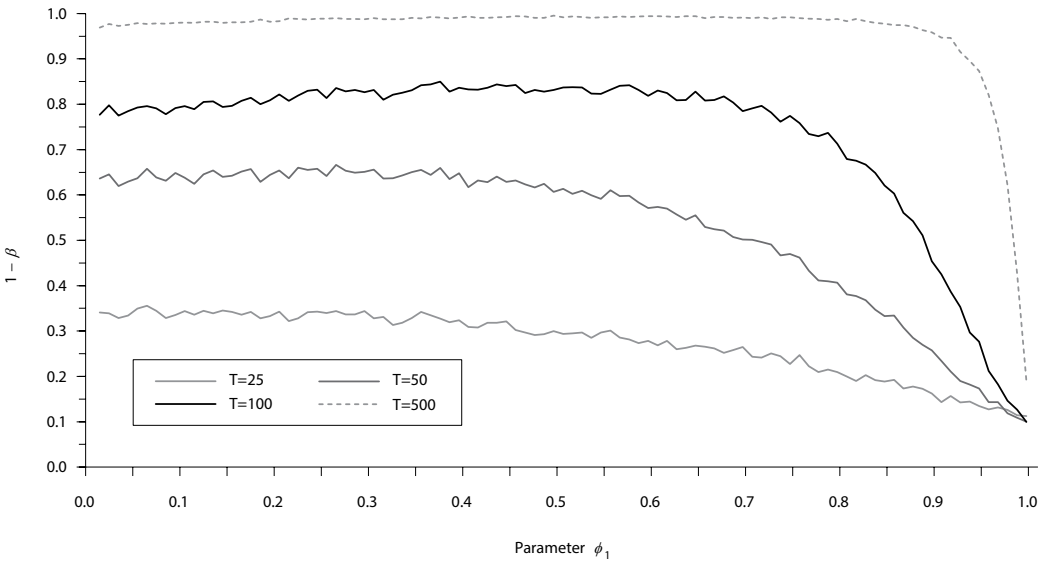
The sizes of the test α (Figure 10) are 10.0% for T = 25, 8.9% for T = 50, 6.9% for T = 100 and 5.9% for the length of time series T = 500. In this case, the type I errors exceed 5% significance level for any length of time series. This test is liberal for all analysed lengths of time series. For short time series, the difference reaches up to 5 p.p., it declines for longer time series. In the case of very long time series, with more than 500 observations, we can assume that the size of the test will be approaching the given 5% significance level.

NGP test

The NGP test is assumed to have high power in the case of ϕ_1 close to 1.

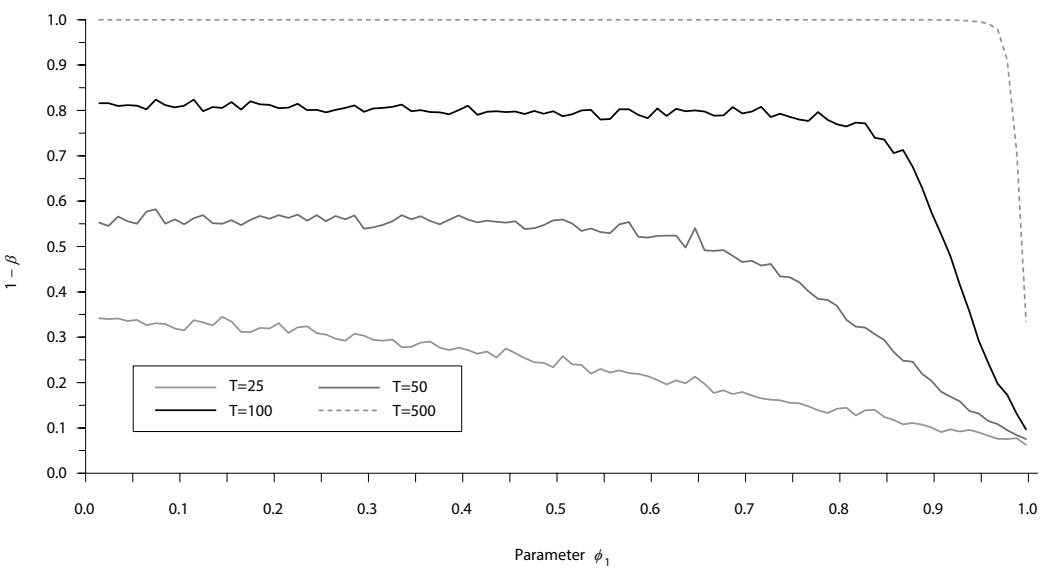
As before, the power of the test is very low for T = 25, for $\phi_1 < 0.3$ it reaches only about 30% and slowly decreases. For T = 50 it fluctuates above 50% until $\phi_1 = 0.6$ and then decreases after this point. In the case

Figure 3 Power functions (1 – β) of ADF-GLS test for simulated time series of lengths T = 25, 50, 100, 500 and number of replications n = 3 000, α = 0.05



Source: Authors' calculation

Figure 4 Power functions (1 – β) of NGP test for simulated time series of lengths T = 25, 50, 100, 500 and number of replications n = 3 000, α = 0.05



Source: Authors' calculation

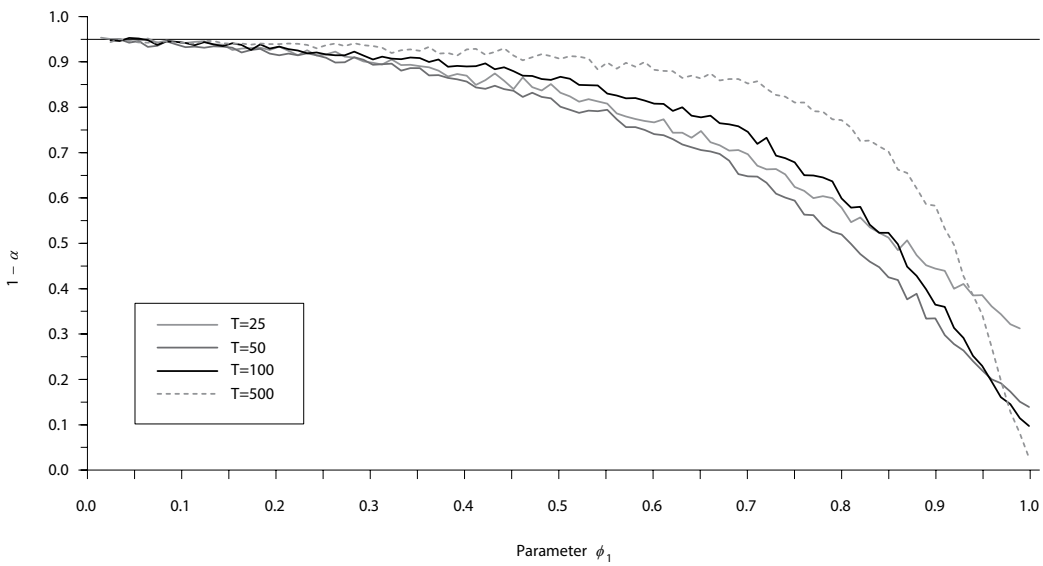
of lengths $T = 100$, the power of the test oscillates around 80% and declines from the value of parameter $\phi_1 = 0.8$. In the case of $T = 500$, the power reaches 1 for $\phi_1 < 0.95$ and falls sharply just before ϕ_1 close to 1.

The sizes of the test α (Figure 10) are 4.0% for $T = 25$, 3.4% for $T = 50$, 3.2% for $T = 100$ and 4.6% for the length of time series $T = 500$. The sizes of the test are for all lengths below the 5% significance level and the test is sufficiently valid. This test is conservative for the lengths $T = 25$, 50 and 100 as the sizes of the test α are notably lower than given 5% significance level, by up to 1.8 p.p., in the case of long time series $T = 500$ is the size of test approaching the 5% significance level.

KPSS test

KPSS test, unlike the other tests mentioned above, is not a unit root test, but a test of stationarity of the time series. Therefore, instead of the power functions, Figure 5 shows the probability $(1 - \alpha)$, i. e. the probability of not rejecting the null hypothesis when it is true.

Figure 5 Probability $1 - \alpha$ of KPSS test for simulated time series of lengths $T = 25$, 50, 100, 500 and number of replications $n = 3\,000$, $\alpha = 0.05$



Source: Authors' calculation

For the values of the parameter $\phi_1 < 0.2$ the results of the KPSS test for individual lengths are very similar and the probability $(1 - \alpha)$ fluctuates around the selected 95% (see the line at 0.95 level in the graph). For higher values of the parameter ϕ_1 the envelopes rapidly decline.

Interesting fact to note is that for T = 25 the probability $(1 - \alpha)$ is higher than this probability for T = 50 and for the value $\phi_1 = 0.8$ and bigger values it is higher than for T = 100. For $\phi_1 > 0.9$ and for shorter time series the probability $(1 - \alpha)$ becomes higher than in the case of longer time series.

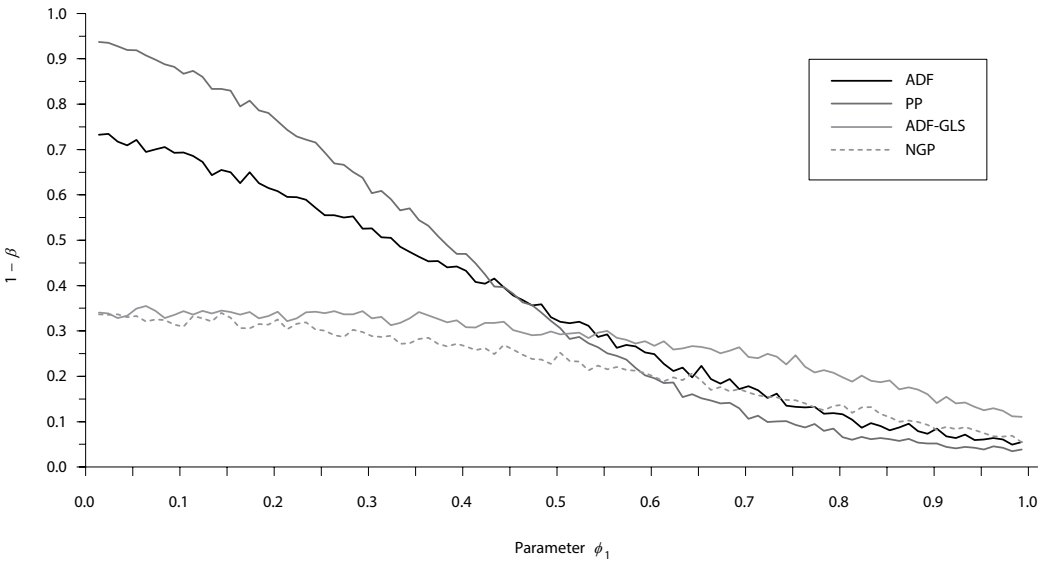
The KPSS test is therefore considered as a suitable complement for unit root tests not only due the fact that it directly tests the stationarity, but especially because it can be used for shorter time series.

2.2 Comparison of selected unit root tests

Now, let us compare individual tests according to their ability to determine the presence of unit root or stationarity for different lengths of time series. The results of KPSS test will not be presented, the comparison will be made based on the findings of the previous section.

Very short time series (T = 25)
At first, the tests for time series of lengths $T = 25$ will be compared.

Figure 6 Comparison of power functions of selected tests for time series length $T = 25$, $\alpha = 0.05$



Source: Authors' calculation

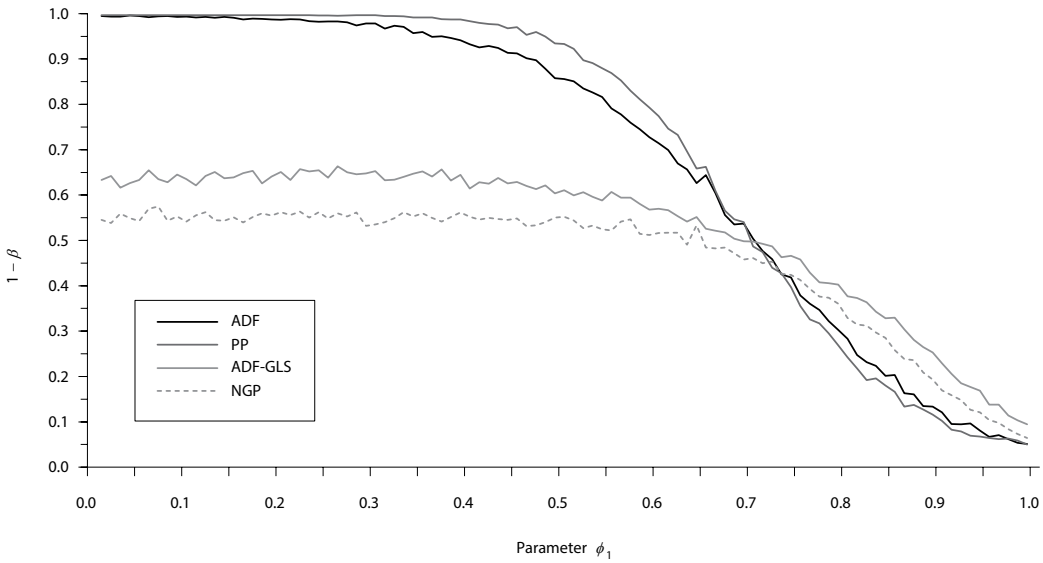
It is clear from Figure 6 that the power of most of the tests appears to be very low. For $\phi_1 < 0.5$ is the order of the tests according to their power as follows – PP, ADF, the power of the other tests is very low. In the interval of $0.5 < \phi_1 < 0.7$ the power functions intersect and for higher values of this parameter is the order of the tests as follows - ADF-GLS, NGP, ADF and PP test. In the case of stationarity tests for this length (Figure 5) and lower values of the parameter ϕ_1, the KPSS test achieves very good results and therefore is considered to be a suitable complement in this situation.

Medium-long time series (T = 50)
Figure 7 shows the power of the tests for $T = 50$.

For this length, some of the tests reach the values close to 1. It is the case of the ADF and PP tests. The power functions of these tests are again very similar and decline rapidly from the value of parameter $\phi_1 = 0.4$. At first, better results are achieved by the PP test, but the order changes at $\phi_1 = 0.7$ and slightly better results are observed for the ADF test.

The power of the ADF-GLS and NGP tests is again not very high for small values of the parameter ϕ_1. For $\phi_1 > 0.7$, however, their power reaches comparable or even better results than the other tests.

Figure 7 Comparison of power functions of selected tests for time series length $T = 50$, $\alpha = 0.05$



Source: Authors' calculation

The power functions intersect around this value and for higher values of this parameter is the order of the tests as follows – ADF-GLS, NGP, ADF and PP. The conclusion is therefore the same as for $T = 25$. KPSS test can be used as a complementary test also for this length.

Long time series (T = 100)

The power of the tests increases with the increasing length of time series (see Figure 8).

As for the shorter lengths, also in this case the ADF and PP tests reach the best results for small values of parameter ϕ_1. The power of both tests equals 1 for $\phi_1 < 0.6$. Afterwards, it sharply declines. KPSS test can be also used.

The power of ADF-GLS and NGP tests is for $\phi_1 > 0.8$ even higher when compared to ADF and PP. The advantages of modifications of classic unit root tests, i. e. NGP and ADF-GLS, can already be observed.

Very long time series (T = 500)

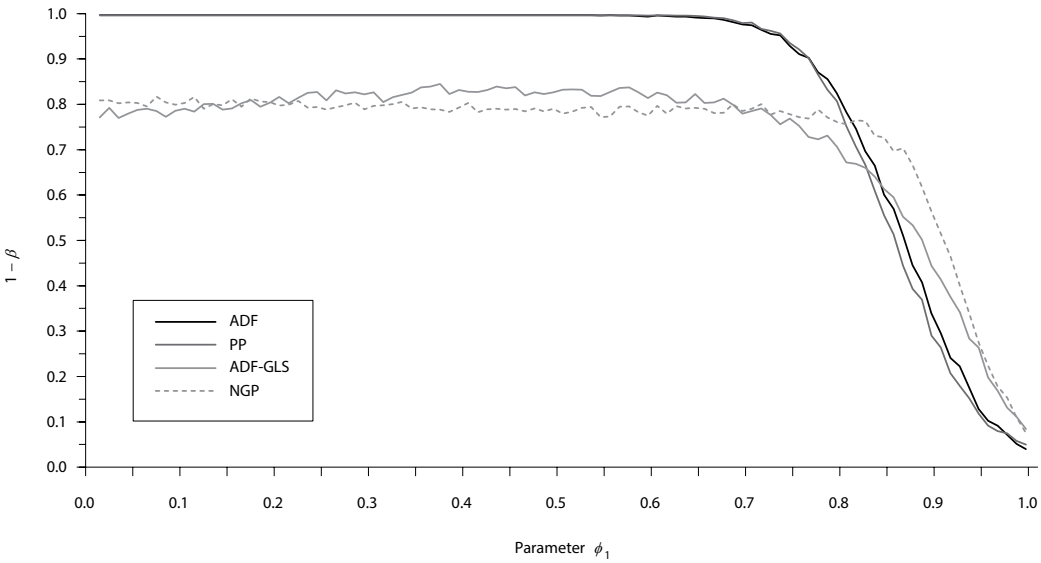
The results of all tests for time series of length $T = 500$ are very good and the power functions have much similar shape.

The results of the ADF and PP tests are in this case almost undistinguishable; their power reaches 100% for $\phi_1 < 0.9$ and then it suddenly and sharply declines.

The values of power of the ADF-GLS test fluctuate below the level of 100 %. In this case a steep decline of power function occurs already for $\phi_1 > 0.8$. The NGP test shows considerably better results than for shorter time series. It reaches 100% for $\phi_1 < 0.95$ and its power for ϕ_1 close to 1 is still the highest in comparison with other tests.

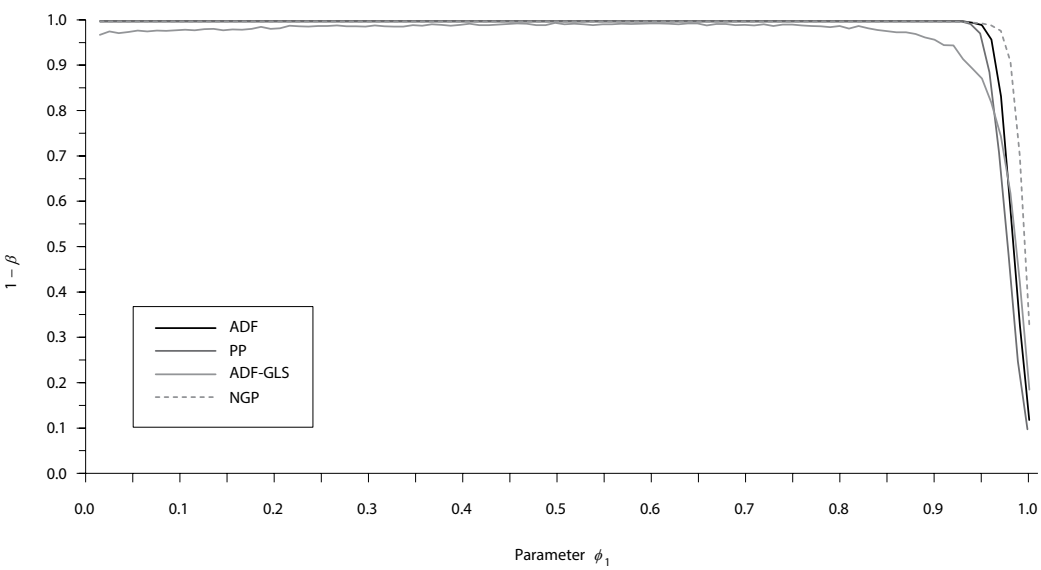
The order of the tests according to their power for ϕ_1 close to 1 is as follows – NGP, ADF-GLS, ADF, PP, KPSS test cannot be recommended for this length.

Figure 8 Comparison of power functions of selected tests for time series length $T = 100$, $\alpha = 0.05$



Source: Authors' calculation

Figure 9 Comparison of power functions of selected tests for time series length $T = 500$, $\alpha = 0.05$

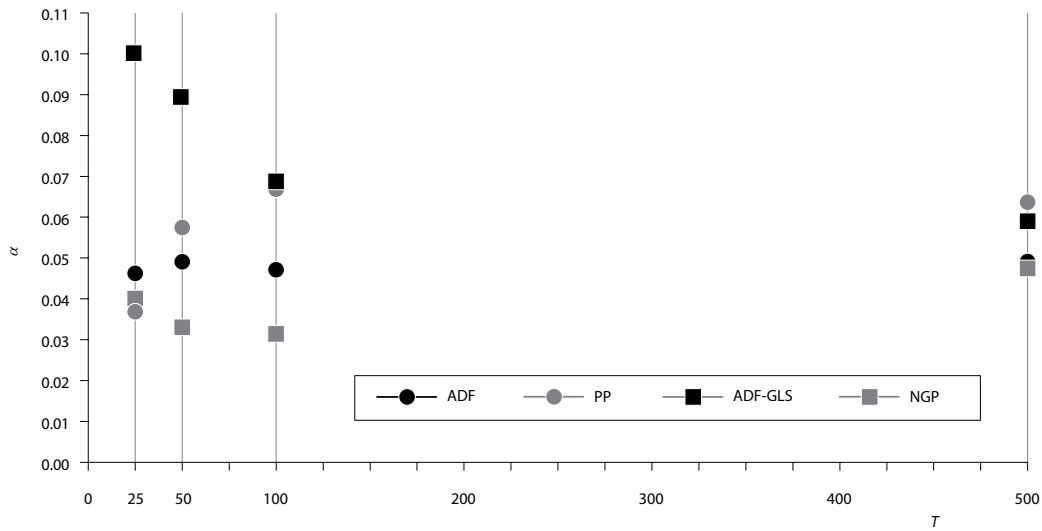


Source: Authors' calculation

Special case $\phi_1 = 1$, for $T = 25, 50, 100$ and 500

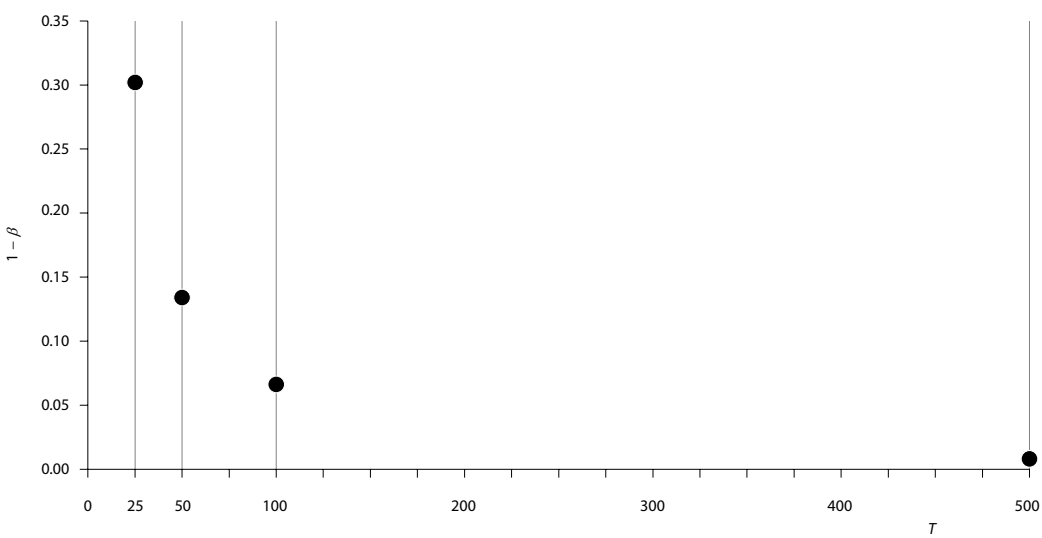
So far we have considered only the stationary process AR(1) with parameters $\phi_1 = 0.01, \ldots, 0.99$, i.e. the process without a unit root, for data generating. To complete the study, let us now consider a situation

Figure 10 Estimations of type I error of selected tests for $\phi_1 = 1$ and series lengths $T = 25, 50, 100$ and 500



Source: Authors' calculation

Figure 11 Power of KPSS test for $\phi_1 = 1$ and simulated time series lengths $T = 25, 50, 100, 500$



Source: Authors' calculation

where the generating process contains a unit root, i.e. $\phi_1 = 1$, therefore we speak about a non-stationary random walk process.

Figure 10 shows the estimates of probabilities of the type I. errors of individual tests (without KPSS test) for $T = 25$, 50, 100 and 500. This figure shows that valid tests for the length $T = 25$ are PP, NGP and ADF that are below 5% of the nominal significance level, in contrary ADF-GLS test is notably above this level and therefore is not suitable for this length. For the same reason only the ADF and NGP tests can be used for lengths $T = 50$, 100 and 500.

To complete the results Fig. 11 has been created to show the power of KPSS test.

2.3 Results summary

It is evident that it is impossible to choose the only test that could be generally described as the best for unit root testing in time series for any length T and any value of the parameter ϕ_1 at the same time. Table 1 shows the summary of the results of our simulation study and recommendations which tests are appropriate for given length T and value of the parameter ϕ_1. We have taken into consideration three basic aspects – power of the test, its validity and ease of use.

Table 1 Overview of appropriate tests for different lengths of time series and values of parameter ϕ_1, $\alpha = 0.05$

ϕ_1	T			
	25	**50**	**100**	**500**
(0; 0.5>	PP, ADF, + KPSS	PP, ADF, + KPSS	ADF, PP	ADF, PP, NGP
(0.5; 0.7>	PP, ADF, + KPSS	PP, ADF, + KPSS	ADF, PP	ADF, PP, NGP
(0.7; 0.9>	ADF, NGP, PP	ADF, NGP, PP	ADF, NGP	ADF, NGP
(0.9; 1>	PP, NGP, ADF	ADF, NGP	ADF, NGP	ADF, NGP

Source: Authors' calculation

The most suitable tests for very short time series are the ADF and PP tests, the best results were obtained for length $T = 25$. KPSS test can be used for refinement in the case of lower values of parameter ϕ_1. For higher values of parameter ϕ_1, the NGP test is also suitable.

The best results for time series of lengths $T = 50$ were obtained by ADF test. For lower values of parameter ϕ_1 the PP and KPSS tests are sufficient, in contrary, NGP test can be used for $\phi_1 > 0.7$.

The most appropriate test for values $\phi_1 > 0.8$ and length $T = 100$ was the ADF test, a suitable complement for $\phi_1 < 0.7$ is the PP test and for $\phi_1 > 0.7$, the NGP test.

In the case of very long time series, i.e. in our case for $T = 500$, the results of all the analysed tests were very similar. The best results for $\phi_1 < 0.9$ were achieved by the NGP, ADF and PP tests, for $\phi_1 > 0.9$ by the ADF-GLS and NGP tests.

CONCLUSION

Unit root testing in time series is one of the fundamental steps in the construction of univariate and multivariate econometric models. As the theory offers several possible unitroot tests, the aim of this paper was to make recommendations to analysts which test to choose based on given parameters. The results were obtained from a simulation study where the criteria were the length of time series and value of the parameter ϕ_1 in the autoregressive process AR(1) without drift.

Table 1 was created based on the results of the simulation study and it gives clear recommendations which tests should be used based on the length of time series and the value of the parameter ϕ_1. The highest

power for shorter time series was achieved the ADF and PP tests. KPSS test, which tests the stationarity is suitable for very small values of the parameter ϕ_1, we do not recommended to use it independently, but only as complementary test during the unit root testing of shorter time series. The ability of other tests to reject the null hypothesis of the unit root increased with the increasing length of time series. Significantly better results were achieved by the ADF and PP tests especially for lower values of the parameter ϕ_1. Very good results for higher values of this parameter were achieved by the modified NGP test.

The results show that the ADF test is a reliable option for unit root testing, its results are very good especially in the case of time series with bigger number of observations. PP test is a suitable substitute for very short time series, or another recommendation could be a simultaneous use of KPSS test. However, despite this lack, the ADF test is and will be one of the most commonly used unit root test since its crucial advantage lies in its simple construction and feasibility.

Despite the fact that our simulation study is relatively rare, we do realize its rather narrow focus (resulting from the use of the autoregressive process AR(1), with positive values of the parameter ϕ_1 only) and the possibility to extend it quite significantly in the future. This extension would be possible not only for the negative values of the parameter ϕ_1, but also for autoregressive processes with deterministic components (constant and linear trend), for autoregressive processes of higher order, for processes that contain a combination of autoregressive process and process of moving averages, for different significance levels α and even for longer time series.

ACKNOWLEDGEMENTS

This paper was written with the support of the Czech Science Foundation project No. P402/12/G097 DYME – *Dynamic Models in Economics.*

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ISTAT's New Strategy and Tools for Enhancing Statistical Utilization of the Available Administrative Databases

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Abstract

This paper presents ISTAT's[4] new strategy to enhance the statistical utilization of administrative databases, aimed at: (i) disseminating information about the existence and accessibility of administrative databases to all potential statistical users; (ii) disseminating standard documentation about the information content and the quality of the available administrative databases to all potential statistical users.

Our purpose is to supply a proper utility to all institutions and people who wish to use administrative databases for statistics, including the owner institutions themselves, which may take advantage from the availability of tools to evaluate the quality and usability of their own databases.

This goal requires a massive activity of collecting information about the existence, the content and the quality of administrative databases. For this purpose we are currently undertaking a set of related activities, ranging from surveys of the administrative databases owned by local administration agencies to dedicated inquiries on the most important administrative databases, which are managed by central administration agencies.

Keywords

Administrative databases, quality documentation, quality database

JEL code

C10, Z19

INTRODUCTION

ISTAT is undertaking a general strategy that aims at making administrative data sources as serviceable as possible for statistical purposes by means of defining proper activities and dedicated tools, and levering forms of collaboration with owner institutions (UNECE, 2011).

In order to exploit administrative data sources for statistical purposes, the first step is to characterize their content in terms of collectives, which may be of interest to statisticians, and their features.

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For this purpose, it is necessary to examine their administrative procedures as data collecting tools and characterize their collected data as pieces of information about real-world observable items, which may assume a potential interest for statistical users. The aim is to determine what can be statistically used in a given administrative data source, independently of any current utilization, from a strictly documentation viewpoint. This requires an appropriate description of the administrative data source's information content, namely the definition of the administrative data source's ontology. This goal implies the capability of specifying the content of the administrative data source in terms of several collectives with their features, taking into account that an administrative data source generally observes both populations and sets of events that occur in time.

The more the statistical users exploit existing data sources, in particular administrative data sources, the more it becomes relevant for the description of the ontology of these sources to be standard and understandable, independently of any further particular statistical use. Moreover, statistical users need an accurate and comparable assessment of the data source's quality, which should exactly concern those collectives and features they are interested in.

ISTAT's strategy is carried out through (i) activities that aim at specifying the information content of each administrative data source, and analysing and measuring its quality, and (ii) ISTAT's supervision on those changes and innovation projects, which involve administrative data sources and administrative forms. In particular, the specification of each administrative data source's content and quality is attained by means of investigation on administrative data sources and their related administrative forms. An investigation is an analysis and documentation activity that employs standard tools, and is undertaken by ISTAT in collaboration with the owner institution. In order to support such activities, ISTAT is building methodological and information management tools, namely the DARCAP system and the Quality Assessment Framework for Administrative Data Sources.

DARCAP (Documenting ARChives of Public Administrations) is the web-based information management system to support investigations on administrative data sources and other documentation initiatives in order to provide potential users with structured documentation of their content and features. This tool also supports administration institutions in sending ISTAT their communications about innovation initiatives that concern administrative data sources or administrative forms. Furthermore, DARCAP supports ISTAT experts in producing structured documentation on the new information content of the administrative data sources that are involved in innovation projects, and in defining ISTAT's recommendations.

The *Quality Assessment Framework for Administrative Data Sources* is ISTAT's methodological tool to support statistical users in evaluating the quality of the available administrative data sources.

1 DOCUMENTING THE CONTENT AND THE QUALITY OF THE AVAILABLE ADMINISTRATIVE DATA SOURCES

The investigation on administrative data sources is performed by analyzing the available documentation and interviewing the source's experts belonging to the owner institution, as well as the source's users. The collected documentation is then organized according to DARCAP's database structure in order to be stored into such a database.

Firstly, we specify the denomination and the main characteristics of the administrative data source, the owner and the other managing institutions, the information flows and sets of administrative forms that are used to feed the administrative data source with data. Furthermore, the administrative data source's content is also documented; in particular, the main observed populations, which correspond to those collectives that are the target of the administrative procedure, and their related sets of events, each one with its definition. We also document the main characteristics of the single elements belonging to the specified collectives with their definitions, and the associated classifications (list of modalities) for qualitative characteristics. This work of conceptual description of the administrative data source's

content produces a specific source ontology that encompasses the following elements: the main collectives (which may be populations or sets of events), the main characteristics of these populations or sets of events, and the relationships that link populations and sets of events. The first result of this work is a network of main populations or sets of events, linked by 1-1 or 1-N relationships, in which every collective has its own definition and characteristics. A further analysis of the administrative data source helps determine more populations or sets of events that have associated their distinguished characteristics and relationships and are linked with the main collectives by means of subset relationships.

In terms of the investigation on administrative data sources, we also produce a first evaluation of their quality. More precisely, we ask the source's experts for information concerning each population or set of events. For each population, we document the entry and exit events, and the way by which their registration influence the population's coverage. For each set of events we document the way by which the single events are recorded into the source and the time distribution of events, as well as the coverage problems due to some of the following elements: registration scope (namely the capability of effectively registering all the single expected events) registration systematic distortion related to the purposes of the administrative registration procedure and registration timeliness (namely the time lag between the occurrence of the event and its registration). The main problems and the possible interventions concerning: the collectives' definitions, the suitability of the used classifications and their correspondence with standard classifications and the identification codes which may be used to link with other data sources are also evaluated. For the administrative data source as a whole, the main problems and the possible interventions concerning its statistical usability and its diffusion timeliness are also evaluated together with the related innovation strategies.

In order to perform a deeper analysis of the quality of administrative data sources it is useful and necessary to calculate standard quantitative indicators. As described in the next dedicated section, the Framework of quality indicators for administrative data sources defines concepts, methods and specific indicators for such an in-depth quality evaluation.

The investigation activity may suggest how to improve the content and the quality of the investigated sources. Moreover, in order to enable ISTAT to realize a more direct intervention on the existing administrative data sources we are now launching another activity, namely the supervision on changes and innovation projects related to the observed administrative data sources. To accomplish this task, ISTAT is asking a first group of administrative data sources' owner institutions to inform it about any kind of innovation project concerning their administrative forms and data sources in order to receive a technical and scientific evaluation. DARCAP provides a suitable environment to collect such communications (which may concern occasional as well as periodic changes), analyzing them to a certain extent, storing the extra documentation related to the communicated innovation projects and on the whole analysis process, and releasing opinions and recommendations.

All of the above activities are coordinated by a *Committee for Harmonizing Administrative Forms* whose members are nominated by ISTAT and the most important administrative data sources' owner institutions, which is supported by a *Network of experts*.

2 DOCUMENTING THE CONTENT OF ADMINISTRATIVE DATA SOURCES: THE CONCEPTUAL MODEL

The documentation activity aims to produce a standard, and therefore comparable, specification of the content of the available administrative data sources in terms of observed real-world objects, namely an ontology of the documented administrative data sources.

An ontology of an administrative data source is a structured description of its information content based on a standard conceptual model. In order to define such a conceptual model, we've analyzed the life-cycle of the administrative data and identified the different kinds of real-world objects to which they are referred. We've put such objects into correspondence with those objects to which any statistic

is currently referred, namely collectives and variables. Our conceptual model is oriented towards supporting the statistical exploitation of the administrative data sources, but it can be easily translated into other general-purpose conceptual models and languages for ontology specification (D'Angiolini, 2013). In the following section, we briefly introduce its main features.

Administrative data sources collect information about several kinds of real-world objects in order to support administrative activities (Brackstone, 1987, pp. 28–43). Firstly, any administrative activity entails collecting data about those entities which the activity addresses. Such entities are subsets of two general populations of persons, on one hand, and entities which perform economic activities, on the other hand. They may also be subsets of related populations such as households or territorial units. Moreover, information is collected about those particular sets of events that may involve these entities and are of interest for the purposes of the administrative activity. The observed *populations* and *sets of events* are linked by *relationships*. For both observed populations and sets of events proper information is collected about their characteristics, which may change in time. As an example, the Ministry for Public Education continuously collects information concerning students, schools and universities with their characteristics, as well as various sets of events such as degree course enrolments, examinations and degree earnings with their characteristics.

Therefore, inside an administrative data source we find two kinds of linked collectives: *populations* and *set of events*. Populations are subsets of the two most general populations of persons on one hand, and entities which perform economic activities on the other hand, or subsets of their related populations. Sets of events can be instantaneous (such as an examination) or durable (such as a degree course enrolment), and they may connect elements belonging to different populations. For example, any degree course enrolment event connects a student with a degree course. Each element of these collectives has *qualitative* or *quantitative characteristics*, such as a date of birth, residence, date of enrolment, examination score, as well as relationships with elements in other collectives.

According to a widespread ontology specification paradigm, in our conceptual model, a qualitative or quantitative characteristic is regarded as a relation that links an element belonging to a collective with an item belonging to a proper *classification*, or with a number in a numerical domain respectively. From a statistical viewpoint, quantitative characteristics and qualitative characteristics, together with their associated classifications, are regarded as variables. New variables can be defined as combinations of relationships and characteristics by means of logical and numerical operators. This is the reason why it is important to document the relationships among collectives. Finally, an administrative data source's ontology is a network of populations and sets of events that are linked by 1-1 or 1-n relationships and have associated quantitative or qualitative characteristics, the latter ones with their associated classifications.

Often some characteristics or relationships are associated with only a part of the elements of a collective. In this case, it is worth defining another collective that is a subset of the main collective, whose elements have associated such characteristics or relationships. More precisely, we distinguish between *subset relationships* and *partition relationships*. A subset relationship simply links two collectives when one gathers a part of the elements of the other. A partition relationship links a collective with many collectives which jointly partitions it, that is: each element of the partitioned collective belongs to one and only one of the partitioning collectives.

3 ASSESSING THE QUALITY OF ADMINISTRATIVE DATA SOURCES: BUILDING THE FRAMEWORK OF QUALITY INDICATORS FOR ADMINISTRATIVE DATA SOURCES

Trends such as the open data vision, the widespread development of data warehouses and the increasing usage of administrative data sources for statistical purposes not only by NSOs, but also by other organizations including their owner organizations' themselves, are all factors that are enlarging the scope of the quality assessment activity. In this scenario, NSOs should take responsibility for a new methodological

coordination task, namely to define rich and flexible sets of standards and repeatable quality assessment procedures for administrative data sources, as they currently do for surveys (UNECE, 2011). In order to meet such requirements, we have based our Framework on a careful analysis of the particular goals and features of the administrative data collection process and their effects on the quality of the collected data for each one of the different kinds of observed objects, which set up any data source's ontology (D'Angiolini et al., 2013).

Our Framework is organized according to the structure that has been proposed by Statistics Netherlands (Daas, 2009), which distinguishes three different views on quality, namely the Source view, the Metadata view, and the Data view. To each of these views, called "hyperdimension", is associated a number of dimensions, quality indicators and methods.

In the Source *hyperdimension*, the quality aspects relate to the administrative data source as a whole, the data set keeper, and the delivery conditions. The *Metadata hyperdimension* specifically focuses on the metadata related aspects of the administrative data source. It is concerned with the existence and the adequacy of the documentation, and the kind and structure of the identification codes. The *Data hyperdimension* focuses on the quality aspects of the data in the administrative data source. For the Source and Metadata hyperdimensions, we propose a set of qualitative indicators. As it has been mentioned above, in addition to requiring the administrative data owners to certify the availability of proper metadata, we also provide them with a standard tool for metadata specification: the DARCAP system.

As for the indicators in the Data hyperdimension, according to our approach, we aim to define a rich and well-reasoned quality indicators' frame in order to drive anyone outside or inside an NSO, particularly the administrative data source's owners themselves, in calculating and interpreting each indicator. Therefore, *the quality indicators are defined on the basis of the data set's ontology specification* and *the Data hyperdimension, which includes both qualitative and quantitative indicators.*

As we have seen, the qualitative indicators in the Data hyperdimension are specified by asking the data set experts a first qualitative assessment concerning some preliminary aspects of the data quality, such as the coverage and influence of registration delay on the coverage, distinctly for each collective (populations and set of events) in the administrative data source. As to the quantitative indicators, namely those indicators that are calculated from data and therefore require the availability of the data set, they must be calculable by the administrative data owner as well as by the NSO when it acquires the data set. The best scenario is when a collaborative calculation procedure is applied.

In order to define such quantitative indicators, first we have discriminated between possible errors, on one hand, and ways of checking them, on the other hand. The possible errors are defined in terms of those objects that may be present in an administrative data source's ontology in the following way.

For each object in an ontology, namely a collective, a characteristic or a relationship, we can build belonging statements concerning observed elements. More precisely, we can assert that a single observed element belongs to a set or that a couple of elements belongs to a characteristic or a relationship. In logical terms, statements concerning populations and sets of events correspond to a single variable predicate, statements concerning characteristics and relationships correspond to two variable predicates. Such statements will be true or false.

As an example, let us suppose we have an administrative data source whose ontology encompasses:

- Student (x), Degree_course (x), Examination (x) and Enrolment (x) which are collectives, more precisely Student (x) and Degree_course (x) are populations, Examination (x) and Enrolment (x) are set of events;
- Residence (x y), a characteristic that links each element x of the population Student (x) with an item y in the classification Town_codes (y);
- Examination_Student (x y) a relationship that links each element x of the set of events Examination (x) with an element y of the population Student (x);

- Enrolment_Student (x y) and Enrolment_Course (x y), two relationships that link each element of the set of events Enrolment (x) with an element y of the population Student (x), or Degree_course (x) respectively.

Examples of belonging statements, which involve observed elements are:

- the person identified by the fiscal code n is a student, namely Student (n);
- this person lives in Milan, namely Residence (n, Milan);
- there is an event i belonging to the set of the Examination events that concerns such a person, namely Examination (i), Examination_Student (i, n);
- there is an event i belonging to the set of the Enrolment events that concerns such a person and the degree-course Statistics, namely Enrolment (i), Enrolment_Student (i, n), Enrolment_Course (i, Statistics).

However, our conceptualization is more complex because the above statements have also time references as parameters, which are single moments for instantaneous events such as Examination, or (possibly open) periods for elements of populations such as Student, or durable events such as Enrolment.

The administrative data sources continuously collect and store data, which are in fact proper combinations of such belonging statements. Referring to the above example, for each new student, a new record is stored in the Student register which combines the statement Student (n) with the statement Residence (n, Milan) and other similar statements. Furthermore, another new record is stored in the Student register too, which combines the statement Enrolment (i), with the statements Enrolment_Student (i, n), Enrolment_Course (i, Statistics) and possibly other statements.

Each administrative data source has its own data collection procedure, which consists in accepting or not accepting such combinations of belonging statements inside the data source. As a result, at any time, any administrative data source stores a collection of belonging statements for each collective, characteristic or relationship in its ontology. It may happen that some of these statements are false, and that some true statements are not in the data set.

Therefore, at any given time we may have in the administrative data source:

- *Inclusion errors:* false statements (definitely or temporarily) accepted in the data source;
- *Exclusion errors:* true statements (definitely or temporarily) excluded from the data source.

Other errors may concern *wrong identification of the involved elements* due to problems in the identification code system, such as: syntactical errors in identifiers, identifiers for non-existing elements, lack of identifiers for existing elements, more than one identifier for each element and elements that share identifiers.

For *each collective* (population or set of events) the inclusion or exclusion errors correspond to the well-known *over-coverage* and *under-coverage* errors respectively. Therefore, when combining them with identification errors, we obtain a specification of all possible errors that concern belonging to the collective.

For *each mandatory characteristic* we may have an exclusion error, which corresponds to a nonresponse error. We may also have a combined exclusion and inclusion error if the element is linked with a wrong item in the classification or a wrong numerical value, which corresponds to a *measure error*. In terms of non-mandatory characteristics, we may have inclusion errors too. Identification errors may affect the observed characteristics when a change in a characteristic is registered for an element that is already in the data set, such as a new residence town for a student.

Errors that may concern relationships are specified in a similar way.

The available *quality check methods* are mainly: searching evident errors such as duplicate identification codes, linking with other data sources, using logical constraints (mandatory or incompatible combinations

between various belonging statements), calculating time lags between the moment of the events' occurrence and the moment of their registration.

Until now, we have defined a quality indicators' frame concerning the collectives' coverage and the elements' identification by means of properly combining possible errors and quality check methods. We are now analyzing the possible errors on characteristics and relationships in order to define two other quality indicators' frames concerning all kinds of nonresponses, measure errors and relationship errors. Obviously, in such indicators' frames, each quantitative indicator refers to several kinds of possible errors. Therefore, the quality evaluator will exploit the collected qualitative information about the nature and the respective relevance of the different kinds of errors in order to choose those quantitative indicators that are worth calculating and properly interpret them. Note that *our proposed indicators are distinctly calculable for each collective, characteristic and relationship in the administrative data source's ontology, in order to effectively support any statistical usage of the collected information.*

CONCLUSION

After a one year of testing activity, *we are now ready to start the investigation activity and the supervision activity on innovation projects concerning administrative data sources at operating speed*. Thanks to the work done in this first experimentation year, it has been possible to improve the investigations' supporting tools and the applied work procedures in collaboration with the administrative data sources' owner institutions.

We are now carrying out the work of specifying indicators in the Data hyperdimension on the basis of a careful analysis of possible errors anchored to the objects which may be present in an administrative data source's ontology. We plan to integrate the existing indicators, such as the BLUE-ETS indicators (Daas et al., 2011), in our indicators' framework as summaries of these more detailed indicators. Finally, the *Framework of Quality indicators for Administrative Data Sources* will contain *qualitative indicators for a preliminary quality assessment* in the Source and Metadata hyperdimensions together with *a rich set of both qualitative and quantitative indicators for an in-depth and customizable quality assessment* in the Data hyperdimension, which can be summarized in a more limited frame for a first overall certification task.

Moreover, in our opinion, an important advantage of our approach is that it gives foundations for *future research aimed at building a generalized probabilistic frame for the quality assessment activity* by means of properly reformulating the task of assessing the quality of any data collection as a problem of evaluating and composing the probabilities of all the possible errors.

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Quality in Statistics – from Q2001 to 2016[1]

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Abstract

The paper considers the main developments in quality work and their impact on statistics since the first European conference on quality in statistics in 2001. In addition to the establishment of quality frameworks, the developments comprise a change of focus from quality assessments to assurance and from product quality to processes. In data collection, focus has changed from surveys to administrative registers and new data sources. National statistical institutions are not the sole producers of official statistics, and there is more attention on the whole statistical systems than before. Together with technological improvements and more use of administrative data sources, this has resulted in more statistics produced more efficiently with improved timeliness. New data sources provide new possibilities, but also challenges for quality assurance. Reflecting on these developments may guide the way forward, on creating and maintaining a culture for continuous improvement in European and national statistics.

Keywords

Quality, quality assurance, quality development, continuous improvement

JEL code

C10

INTRODUCTION

Quality has been on the agenda in National Statistical Institutes (NSIs) and Eurostat the last 20 years. The first European conference on quality in statistics, Q2001 in Stockholm, was an important milestone. The basis for this conference was the work and conclusions from the Leadership Expert Group (LEG) on Quality. Later international cooperation initiatives in this area have set the terms for the next Q-conferences, which after 2004 have taken place each second year.

The paper considers the main developments in quality work and their impact on statistics since Q2001. Seeing the developments in a longer term perspective may guide the planning of new initiatives. What can we learn that is relevant for the future of quality work in statistics?

Developments in quality work must be seen in relation with the development of society and statistics in general, characterized and driven by globalization, technological developments and political changes. Quality work and its results are difficult to distinguish from improvements due to other causes. An example illustrating this is the obvious improvements in accessibility of statistics following the development of the Internet.

[1] The paper is based on a presentation at the European Conference on Quality in Official Statistics (Q2016) in Madrid, 1–3 June, 2016.

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1 Q2001

The first European quality conference, Q2001 in Stockholm was structured around the recommendations from the Leadership Group (LEG) on Quality (Eurostat, 2002). These recommendations were based on current thinking on quality management, typically principles from Total Quality Management (TQM), and a survey of quality practices in NSIs (Japec, 2001). According to this survey, only a few NSIs had adopted a systematic approach on quality work at that time.

The LEG on Quality formulated 22 recommendations. These dealt with the need for a systematic approach to quality improvement, measurements of product and process quality, quality reporting and other quality management tools, documentation, training and the relationships with data suppliers and users. Accomplishment of regular Q-conferences was one of the recommendations. These issues were covered in Q2001, which in addition had sessions on metadata and methodology, and some on more general issues in statistics like data collection and business statistics.

The main message from the LEG was that quality is a multi-dimensional issue, covering not only accuracy but several components. Statisticians today agree that these can be described by relevance, accuracy and reliability, timeliness and punctuality, coherence and comparability, accessibility and clarity.

The main aspects of the development of quality work since Q2001 are considered below.

2 MAIN DEVELOPMENTS IN QUALITY WORK

2.1 From TQM to a variety of frameworks

A quality framework or management system consists basically of some definitions, principles and a model linking the principles together. General quality frameworks comprise Total Quality Management (TQM), Six Sigma, European Foundation for Quality Management (EFQM), Common Assessment Framework (CAF), ISO and Lean or Lean Six Sigma. These systems are to a large extent based on a common set of definitions (e.g. quality as "fit for use") and principles (such as user and process orientation, improvements based on measurements and participation by all), first formulated within TQM. But they differ with respect to main focus and degree of formalisation. In EFQM and ISO emphasis is for example put on rating and certification in addition to improving processes, whereas Six Sigma focuses on quality control applying statistical methodology. Lean emphasizes improved efficiency by the reduction of waste. One of the recommendations from the LEG on Quality was that all ESS organisations should adopt a systematic approach to quality improvement and use the EFQM model as a basis, except for those already using a similar model.

However, there is a set of values and principles of official statistics which go beyond the principles of these systems. This, in particular, regards independence, impartiality and protection of data on individuals. Such requirements to official statistics were first formulated jointly in the ten UN principles of official statistics adopted in 1994 (UN, 1994).

The European Statistics Code of Practice (CoP) which was established in 2005 is a milestone in European work on quality in statistics. It was revised in 2011 and followed up by peer reviews in 2006–2008 and 2013–2015 (Eurostat, 2011).

The revised version of CoP contains a quality declaration for the European Statistical System (ESS) as a preamble, stating that the members of the ESS strive for joint cooperation and continuous interaction with users according to the principles of the European Statistics Code of Practice and general quality management principles including commitment of leadership, partnership, staff satisfaction and continuous improvement, in addition to integration and harmonization. Hence, some principles from general quality management frameworks such as TQM have been added to CoP as a common quality framework for the ESS. In addition, a "Quality Assurance Framework (QAF)" with good statistical practices is linked to the CoP principles and indicators (Eurostat, 2015). Compared to the first version of CoP, the 2011 revision also strengthened the principle on quality commitment and its indicators,

and added a few more indicators, in particular to reinforce professional independence, better cover statistics based on administrative data, and to promote standardisation and communication of quality.

A proposal for a new and modified quality declaration for the ESS is being discussed (summer 2016). CoP will in any case remain the cornerstone of the ESS common quality framework.

During the last years a series of other similar principles and frameworks for statistics have been developed by international organisations, for example the UN National Quality Assurance Framework (NQAF) (UN, 2013a). IMF and OECD also have their quality frameworks, and OECD has recently developed a recommendation on good statistical practice (OECD, 2015).

During the last 10 years, risk analysis has been implemented in the public sector in many countries, also in statistics and in international organisations. In some NSIs this has been integrated in their quality work.

NSIs in almost all the 32 countries exposed to European peer reviews in 2013–2015 follow some sort of systematic approach to quality management. In addition to CoP, TQM is used by many NSIs and EFQM and Lean by some. Some NSIs are certified according to ISO. In spite of this, most countries got recommendations on improvements in this area, often to enhance quality management and elaborate and publicise quality guidelines on their web sites.

2.2 From assessment to assurance

Almost all 22 recommendations from the LEG on Quality addressed measurements and analyses (of quality dimensions, processes, user and staff satisfaction) and documentation. It was followed by a LEG on Quality Implementation Group. This group initiated work on a series of handbooks with descriptions of good practices in the use of quality assessment tools in statistics.

The main results were summed up in a Handbook on Data Quality Assessment Methods and Tools (DatQAM) (Eurostat, 2007) covering quality reports and indicators. Sæbø (2014) has carried out an assessment of later experiences with these tools.

There has been a development from quality assessment to quality assurance during the later years. As pointed out by Sæbø (2006) stand-alone self-assessments do not necessarily provide a correct picture. But they constitute a convenient tool as a part of preparations for reviews and audits. They have been used prior to the European peer reviews, and in preparation for internal quality reviews carried out in several countries.

The extent of quality reviews has increased. At Q2001 reviews and audits were almost absent from the agenda, not to speak about experiences in his area. At Q2012 and Q2014 several examples of experiences with such reviews or audits were given. The last European peer review identified such reviews in several countries, like in Austria, France, Greece, Italy, UK and Norway. Some of these were judged as innovative practices by the peer review teams. In some cases audits are carried out with the purpose of certification. However, what is crucial is that reviews and audits result in improvement actions that are followed up regularly.

On the level of statistical systems or institutions there has been a large increase in assessments outside Europe, for example light peer reviews or adapted global assessments.

2.3 From products to processes

To obtain improved product quality it is necessary to work on improving the production processes. There is no doubt that there is more focus on processes in statistics today than 15 years ago. This development has been supported by the introduction of the Generic Statistical Business Process Model (GSBPM) (UNECE, 2013). Such a model is a reference for the NSIs' work on improving the processes, in particular by implementing standardized systems and methodology. In the last European peer review more than half of the countries stated that they had implemented a statistical business process model, and most of the remaining countries had done it partly (Eurostat, 2016a).

In Statistics Norway we have used the business process model both for structuring documentation, standardization, risk analyses and as a basis for our improvement work with internal quality reviews and within a Lean framework.

There is also a potential for better use of analyses of process variables. Sæbø (2014) points out that use of such variables other than resource inputs is still limited in official statistics, often confined to analysing response rates and managing interviewers. Editing and the effect of this is one area where this methodology should be suitable. This process normally counts for a relatively high share of resources used for the production of statistics.

2.4 From surveys to big data

The first Q-conferences were characterized by survey methodology to a larger extent than the latter ones. This was reflected in the name of the conferences in 2004 and 2006, including methodology and survey statistics explicitly in the title which for the other conferences have been "European conference on Quality in Official Statistics".

There has been a trend from quality issues in traditional surveys (sampling, questionnaires, non-response etc.) to administrative registers, and during the latest conferences new data sources and big data.

While Q2001 treated quality of administrative registers only in a session on business registers and macroeconomics, there were 5 sessions devoted to this in Q2014. In addition there were 2 sessions on big data and one on multi-source data production. In Q2016 there are 3 sessions both on administrative and big data and one on multi-source statistics. In addition, both administrative and big data are treated in other sessions.

Nordbotten (2012) gave a keynote speech at Q2012 in Athens on the developments in statistics before Q2001 and after 2012. He mentions major developments in the 20th century such as the introduction of punched cards even before the century started, the scientific development of sampling theory after the World War II, electronic processing in the 1950ties and the use of administrative registers for statistics from the 1960ties. The latter was boosted by the introduction of unique identification numbers, first for the population in the Nordic countries. After that registers have become increasingly important and used as a source for statistics, also supplemented or linked to by data from other sources including survey data.

Big data are frequently discussed as a new source for statistics, even if they are not much used for official statistics so far. Big data are characterized by the size and complexity of the data sets, but also by being real-time or very timely data. Examples are data from social media on Internet, mobile telephone data, data from global positioning systems (GPS) and traffic data from automatic registrations. They often originate from an unknown population and represent methodological challenges. But all of them are not new, even if the notation came around 2005. Just think about data from satellite images to some extent used for statistics 30 years ago.

Statistics Norway today collects some data from Internet (web-scraping) for the consumer price index (e.g. flight prices). Another example of use of new and in this case big data will be data from automatic measurements of electricity consumption based on meters which will be installed at all consumers in 2017.

New data sources have challenged quality work and the tools that have been applied for sample surveys. The quality frameworks such as CoP/QAF have the end users of statistics as the point of departure. Users demand statistics with quality components such as accuracy and timeliness. The same components are valid for input data, but here the scope is the fitness for use by the statistics producer. A quality framework for input data, from registers or other sources, will therefore be different from CoP or others mentioned above, and should not be confused with these. Work has been done on developing indicators for both administrative registers and big data, see for example BLUE-ETS (2011) and UNECE (2014). In addition to the same or similar indicators as those used for quality of statistics, additional indicators comprise completeness and integrability (possibility to link data).

2.5 From NSIs to statistical systems

NSIs are not sole producers of official statistics, even if the NSIs normally have a coordination role that comprises quality assurance. The European Statistical System currently consists of Eurostat, 32 NSIs and 335 other producers who submit data to Eurostat.[3] Representatives of the latter have participated in the Q-conferences, but these have been dominated by participants and contributions from the NSIs, academics and international statistical organisations. At the European peer reviews completed last year coordination was an issue, and up to 3 other producers of European statistics or so called Other National Authorities (ONAs) filled out self-assessments and were interviewed. Out of 707 improvement actions for the NSIs, 121 were linked to their coordinating role (Eurostat, 2016b). Some of these dealt with quality issues, for example on reviewing the quality of statistics produced by other institutions.

The peer reviews also covered cooperation and integration in Europe, thus dealing with the quality of European initiatives. In the Vision 2020 for European statistics quality work is focused (Eurostat, 2016c).

International quality work and cooperation have played an important role in supporting work on quality within the NSIs. Now quality of both the National and European Statistical Systems have come into focus, and this represents a challenge for our quality work that was not the same 15 years ago, or at least not thought about in the same way.

3 HAVE STATISTICS IMPROVED?

There is no doubt that there is a higher consciousness about quality in statistics today than 15 years ago. That quality consists of several components which have to be balanced vs. each other and costs is common sense today. Use of tools such as self-assessments and internal quality audits are widespread.

The development has been facilitated by international work on quality, in Europe in particular linked to the establishment of CoP, the peer reviews and the follow up of improvement actions. It is believed that the Q conferences have contributed as well.

But has this led to improved quality in statistics? Marker (2015) has considered this. His obvious answer is yes, due to some of the same developments in quality work discussed in this paper. However, our users and their requirements change, so do the technological possibilities, and there is always a demand for new statistics and better timeliness. Changes after Q2001 in the product quality components of statistics as given in CoP are considered briefly in the following, and some challenges are mentioned. Changes in the quality of processes and the institutional environment are considered summarily.

3.1 Relevance

New statistics have been produced in several areas, in Europe in particular due to new EU regulations believed to improve relevance. More statistics have been adapted to the needs of the general public also due to technological developments with internet and social media. New developments linked to globalization are addressed, but represent challenges to the coverage of economic statistics and our ability to describe migration, such as statistics on refugees. A recent challenge is how to describe and eventually follow up the Sustainable Development Goals. Official statistics is by nature a bit conservative, also to secure comparability over time.

3.2 Accuracy and reliability

The question is not to provide statistics that are as accurate as possible, but as accurate as needed for the purpose. There is more focus on this now than before, and corresponding to user needs accuracy has probably decreased for some statistics, for the benefit of timeliness.

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[3] According to Eurostat web site: <http://ec.europa.eu/eurostat/documents/747709/753176/List_ONAs_BG_PT_15042016/96c133ff-c8d8-4401-9620-a679cf322b2f>.

More use of administrative data systems may improve accuracy, but accuracy of statistics based on sample surveys has probably decreased due to decreasing response rates linked to respondents' unwillingness to participate and difficulties to trace them. Statistics Norway has experienced reduced response rates for important voluntary surveys such as EU-SILC over a long period and it costs more to keep it up on a reasonable level. New data based on bar codes, electronic traces and information on web are believed to be an alternative for some of these surveys, but peoples' attitudes are difficult to measure without asking.

3.3 Timeliness and punctuality

Timeliness has improved, by using more administrative data, better technology, more preliminary figures and just by measuring and publishing timeliness at least internally. This has in particular been the case for annual statistics, to a less extent for short term statistics. Measuring punctuality according to international standards (with release calendars) has probably led to improvements in this area as well.

3.4 Coherence and comparability

In this area there is room for improvements. The internal quality reviews in Statistics Norway (Sæbø and Byfuglien, 2013; Sæbø, 2014) have revealed a need for better coherence in published statistics, i.e. comparison of similar statistics covering the same area, from both Statistics Norway and other statistics producers. There has been an increase of other producers which represent a challenge in our coordination and quality work. More use of administrative data systems for statistics may also represent a challenge if these systems are not based on statistical standard definitions and classifications.

3.5 Accessibility and clarity

There is no need to justify that accessibility has improved a lot since 2001, due to the development of Internet and the possibilities for communication it has created. The web has developed from representing only a supplement to traditional channels for distribution of statistics at the time of Q2001, to the main if not the only channel for this now. Output databases where users can download statistics for free are widespread (the few possibilities that existed 15 years ago were often pay services). Use of APIs (Application Programming Interfaces) for bulk downloading of tables from the data banks of statistical institutions is an example of recent developments. This enables the users to utilise the statistics in their own environment and applications. Statistics Norway has just released this type of service in full scale. Microdata for research are available to a greater extent than before, but there are challenges linked to cover an increasing demand. In general there is still a need for better and simpler metadata and explanations for the users.

3.6 Statistical processes

Improved processes are a prerequisite for improved products, and there are reasons to believe that processes have improved accordingly. Key words are more and easier use of administrative data and more standardised systems driven by or in addition to technological improvements. While electronic dissemination basically was established before 2001 (though developed a lot since then), there has been a breakthrough for electronic data collection since that time. For example, the share of data submitted electronically from industries to Statistics Norway has increased from close to zero to more than 90 percent during this period. However, there are challenges linked to the structure of data and metadata accompanying them, a prerequisite for efficient use of data for statistics, as well as for the understanding of the disseminated results. The best solution is to extract data directly from registers and administrative systems such as accounting systems of the data providers.

3.7 Institutional environment

As for the institutional environment, there is little doubt that the introduction and use of frameworks such as the CoP, supported by the peer reviews and following up by the international statistical organisations,

have led to improved compliance with the principles on professional independence, objectivity and impartiality in addition to quality commitment in the NSIs. Equal access to statistical releases for all users at the same time are focused and supported by advance release calendars (first promoted by the IMF in 1996, and later emphasised in the CoP). Dissemination policy documents, which to an increasing extent seem to be available on the NSI web sites, will often describe this, as well as for instance principles on treatment of errors and of revisions. The UN (2013b) carried out a global assessment on the compliance with its Fundamental Principles of Official Statistics comparing 2003 and 2011. It was found that full compliance with the principles linked to independence had increased significantly in this period (for example from 44 to 60 per cent for the principle on relevance, impartiality and equal access).

CONCLUSIONS – LESSONS LEARNT AND THE WAY FORWARD

The message from Q2001 that quality has several dimensions is now common knowledge in statistics, well established in CoP and other quality frameworks. Balancing quality components and costs is a main issue when it comes to quality work, making statistics fit for purpose. Also developing quality assurance fit for purpose (differentiating in accordance with needs), in line with discussions in the work on implementing the Vision 2020 for European statistics, will be useful.

However, the explosion of quality frameworks and systems in general and for statistics might create some confusion, even if these are based on much of the same principles. Outside statistical institutions this development is driven by consultants, since it is a built-in feature of their business to promote new initiatives. Different international statistical organisations have also developed separate quality frameworks, though with many common aspects. There are differences in scope and target groups, and establishing new frameworks and indicators is important for ownership to these, but it may also imply double work. For a statistical institution that needs continuity, is it essential to keep values and principles over time, also their wording. Deming's and TQM's principle constancy of purpose is just as valid today as when it was formulated more than 30 years ago (Deming, 1982). Future quality work must build on what has been successful in the past. Better coordination between initiatives taken by international statistical organisations is needed.

Exploiting new data sources is not new to statistics, but is more on the agenda than ever, also because traditional sources may be more difficult to use and due to competition from other actors. New sources challenge quality work, since quality of input data largely is uncontrolled or even unknown. There is a need to develop or rather agree on quality components for input data used for statistics, like it has been done for output or product quality. This does not presuppose completely new quality frameworks, and should not be confused with quality frameworks for a statistical institution or for output quality.

Quality assurance presupposes improvement actions that are followed up. Quality reviews and audits resulting in recommendations and actions which are followed up really make a difference and should be pursued.

There is room for more and better use of the business process model and analyses of process variables as a basis for improvements.

Things take time. Even if there have been developments in quality work and improvements in quality of statistics since Q2001, many of the same challenges persist, and there is still room for doing more following the recommendations from the LEG on quality. This for example regards improving relationship with both data suppliers and users, and developing, recommending and in particular implementing good or best methods and practices linked to the most common processes.

Quality constitutes a key factor in the Vision 2020 for European statistics. An exercise to map quality elements of the Vision 2020 projects to CoP provides input to the next round of modifications of the code, together with the experiences from the last peer review round. It is already foreseen that the CoP may need to be extended to cover coordination and possibly innovation (better). The last area comprises big data.

Quality assessment and assurance in their nature are conservative, dealing with controlling and improving existing processes. However, user orientation and new data and technology require and render possible new solutions. Quality work is a continuous task and not only about doing things right, but also about doing the right things.

International cooperation will still play an important role supporting national quality work in statistics, and there will be no lack of issues for future Q-conferences.

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Recent Publications and Events

New publications of the Czech Statistical Office

Expeditures and consumption of households included in the household budget survey in 2015. Prague: CZSO, 2016.
Household income and living conditions in 2015. Prague: CZSO, 2016.
Inovační aktivity podniků v ČR 2012–2014. Prague: CZSO, 2016.

Conferences

The 22nd International Conference on Computational Statistics (COMPSTAT 2016) took place at the Conference Centre of **Oviedo, Spain, during 23–26 August 2016**. The conference aims at bringing together researchers and practitioners to discuss recent developments in computational methods, methodology for data analysis and applications in statistics. The conference is organized by the University of Oviedo. More information available at: *http://www.compstat2016.org*.

The 19th International Scientific Conference Applications of Mathematics and Statistics in Economics (AMSE 2016) was held in **Banska Stiavnica, Slovakia, from 31st August to 4th September 2016.** These conferences are organized each year by three Faculties of three Universities from three countries – University of Economics, Prague, Czech Republic, Matej Bel University in Banska Bystrica, Slovakia, and Wrocław University of Economics, Poland. More information available at: *http://amse.umb.sk*.

The 34th International Conference on Mathematical Methods in Economics (MME 2016) took place in **Liberec, Czech Republic, during 6–9 September 2016**. The conference is a traditional meeting of professionals from universities and businesses interested in the theory and applications of operations research and econometrics. Conference is held under auspices of the Technical University of Liberec, Czech Republic, Czech Society for Operations Research, Slovak Society for Operations Research and the Czech Econometric Society. More information available at: *http://mme2016.tul.cz*.

The 24th Interdisciplinary Information Management Talks (IDIMT 2016) was held in **Poděbrady, Czech Republic, from 7th to 9th September 2016**. More information available at: *http://www.idimt.org*.

The 10th International Days of Statistics and Economics (MSED 2016) took place in **Prague, Czech Republic, during 8–10 September 2016**, organized by the Department of Statistics and Probability and the Department of Microeconomics, University of Economics, Prague, Czech Republic, Faculty of Economics, Technical University of Košice, Slovakia, and Ton Duc Thang University, Vietnam. The aim of the conference is to present and discuss current problems of statistics, demography, economics and management and their mutual interconnection. More information available at: *https://msed.vse.cz*.

The 19th ROBUST 2016 Conference was held in **Jeseníky, Czech Republic, from 11th to 16th September 2016**. More information available at: *https://robust.nipax.cz*.

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List of References
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Design: Toman Design
Layout: Ondřej Pazdera
Typesetting: Chráněná grafická dílna Slunečnice, David Hošek
Print: Czech Statistical Office

96th year of the series of professional statistics and economy journals of the State Statistical Service in the Czech Republic: ***Statistika*** (since 1964), ***Statistika a kontrola*** (1962–1963), ***Statistický obzor*** (1931–1961) and ***Československý statistický věstník*** (1920–1930).

Published by the Czech Statistical Office
ISSN 1804-8765 (Online)
ISSN 0322-788X (Print)
Reg. MK CR E 4684