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The effect of product substitution and different types of households

Abstract. One of the key problems inherent in fixed-weight consumer price indices is that the most common formula for calculating the price index of consumer goods and services (the Laspeyres formula) ignores the effect of product substitution. Interpreting the scale of the discrepancy between the Laspeyres index and the Törnqvist one as numeric effect of product substitution, it is possible to measure consumers' reaction to price fluctuations and susceptibility to changing of consumption model. It seems that the consumer susceptibility to changing of consumption model is dependent on consumers' financial situation. That is why the paper provides an analysis of product substitution effect for different types of Polish households in years 2001-2010.

Key words: substitution effect, CPI index, CoLI, model of consumption, types of households

Introduction

The problem concerning the measurement of the Consumer Price Index has been existing for decades. In the early 1960s economists knew that the CPI overstated inflation. In the United States already in 1961 the famous Stigler Committee, formed with the objective of preparing a report for the Budget Committee about possibilities of improving national price statistics, drew up statements saying that

the Consumer Price Index calculated using the Laspeyres formula considerably biases upwards the index of the cost of living¹.

However the problem of CPI biases gained real popularity in 1996 after the publication of the Boskin's report, which was constructive criticism concerning the measurement errors of the Consumer Price Index. The report drew attention to such an extent that as a result widespread research work emerged about this topic. Consequently, not only in the United States, but in many countries throughout the world, the supposed biases of the Consumer Price Index, its consequences, and its implications in economic decision making have become an issue.

One of the problem connected with the CPI measured by Laspeyres formula, emphasized in the Boskin's report, is that this index overstates inflation because it does not allow for consumers substitution of lower for higher priced goods when prices change. According to utility theory, along with growth in prices consumers tend to replace more expensive goods with less costly substitutes. The use of expenditure pattern from a base period implies that the Laspeyres index weights too highly those prices, which have risen relatively quickly, so that the bias occurs. According to the Boskin report the overestimation of the price index related to that issue was about 0,15 percentage point. The results were connected only with the overall index, without consideration of different types of households and they were calculated on the basis of superlative indices theory².

A new approach to estimating CPI bias was introduced to the literature in 2001. Using consumer expenditure surveys D. Costa³ and B. Hamilton⁴ applied Engel curves to estimate the CPI bias. The idea of the new approach is base on the Engel law, which states that food's budget share is inversely related to household real income. This suggests that movements in food's budget share might serve as an indicator of movements in real income. If the movement in real income inferred from movements in food's budget share is inconsistent with real-income movements measured directly by nominal income deflated by the Consumer Price Index, then, subject to appropriate caveats, it is possible to use Engel's Law and data on food's budget share to estimate the degree to which the CPI is biased.

¹ G. Stigler, *The Price Statistics of the Federal Government*, Report to the Office of Statistical Standards. Bureau of the Budget. National Bureau of Economic Research, New York 1961, www.nber.org/chapters/c6479.pdf [14.12.2012].

² I. Fisher, *The Making of Index Numbers*, Houghton-Mifflin, Boston 1922, pp. 234-269; W.E. Diewert, *Exact and Superlative Index Numbers*, "Journal of Econometrics" 1976, No. 4, pp. 114-145; W.E. Diewert, *Superlative index numbers and consistency in aggregation*, "Econometrica" 1978, No. 46, pp. 883-900.

³ D. Costa, *Estimating real income in the United States from 1888 to 1994: correcting CPI bias using Engel curves*, "Journal of Political Economy" 2001, No. 109, pp. 1288-1310.

⁴ B. Hamilton, *Using Engel's law to estimate CPI bias*, "American Economic Review" 2001, No. 91, pp. 619-630.

Hamilton offers good arguments for using food, and not other items. Its income elasticity is sufficiently different from unity, it has no durability, it is easily defined and it is plausibly separable from non-food in consumer's utility functions. The method of measurement the CPI bias is based on the almost-ideal-demand-system (AIDS) models, which allow to use different household characteristics data.

Costa and Hamilton employed the Engle law to measure the bias in consumer price indices for the United States. Others have adopted this approach to estimate CPI bias for other countries. T. Beatty and E.R. Larsen⁵ used Engel curves to estimate bias in the Canadian CPI; J. Gibson, S. Stillman, and T. Le⁶ applied the curve to a CPI for Russia, and as did I. de Carvalho Filho and M. Chamon⁷ for Brazil and Mexico.

The knowledge about the problem of imperfections in the construction of the Consumer Price Index and the scale of the bias of the index as a result of ignoring the product substitution seems to be very important. The aim of this paper is to analyze the scale of substitution effect for different types of households. It seems that the consumer susceptibility to changing of consumption model is depended on consumers' financial situation. The scale of substitution effect should be lower if we consider the poorest type of households since their income allow them to buy only the less costly goods and if the prices grow there are no possible substitutes for goods purchased by this type of consumers. It seems that the substitution effect should be also lower for the rich households. Wealthy consumers very often do not need to limit their expenditure even when prices increase.

The method applied to measure the value of the bias connected with the substitution effect is based on the superlative indices theory due to the lack of access to detailed and not aggregated data needed to apply in the approach introduced by Costa and Hamilton.

1. The Laspeyres and Superlative Indices

The Consumer Price Index is a statistical estimate constructed using the prices of a sample of representative items whose prices are collected periodically. Sub-indices and sub-sub-indices are computed for different categories and sub-categories

⁵ T. Beatty, E. Larsen, *Using Engel curves to estimate bias in the Canadian CPI as a cost of living index*, "Canadian Journal of Economics" 2005, No. 38, pp. 482-499.

⁶ J. Gibson, S. Stillman, T. Le, *CPI bias and real living standards in Russia during the transition*, "Journal of Development Economics" 2008, No. 87, pp. 140-160.

⁷ I. de Carvalho Filho, M. Chamon, *The Myth of Post-Reform Income Stagnation: Evidence from Brazil and Mexico*, "International Monetary Fund Working Paper" 2007, No. 08/197, www.imf.org/external/pubs/ft/wp/2006/wp06275.pdf [15.04.2013].

of goods and services, being combined to produce the overall index with weights reflecting their shares in the total of the consumer expenditures covered by the index. In other words, the price movement measurement is weighted by the importance of the item in the spending patterns of the appropriate population group.

The most common formula for calculating the CPI is the Laspeyres formula. The Laspeyres consumer price index is defined as a fixed-quantity price index able to measure the price change in a fixed market basket of consumption goods and services that are purchased by the reference population⁸ and it is given by following formula:

$${}^L I_p = \frac{\sum_{j=1}^n i_{j_p} w_{j_0}}{\sum_{j=1}^n w_{j_0}} = \sum_{j=1}^n i_{j_p} w_{j_0},$$

where:

$$\sum_{j=1}^n w_{j_0} = 1,$$

i_{j_p} – a price index of individual category from a fixed market basket,

w_{j_0} – a weight of individual category in a base period.

The CPI based on Laspeyres formula is the best known and widely used for the measurement of the changes in the cost of living (CoLI). The difference in definitions of CPI and CoLI reveals that the CPI is not in general the CLI. The CPI is a measure of the average price change of a fixed market basket of goods and services purchased by the average household, while the CLI is defined as a ratio of the minimum expenditure required to achieve the same standard of living when consumers faces two different sets of prices.

The Laspeyres index uses fixed quantities from a base period and allows prices to vary. Answering the question: “how much more must the customer spend in a current period to purchase the same quantities that he/she purchased in a base period?” the Laspeyres formula ignores substitution among goods in response to relative price change. The question answered by the cost of living index is: “how much would expenditure from a base period have to change in order to guarantee the consumer the same level of satisfaction in a current period?” Although the answer to this question might appear to require detailed knowledge of a consumer’s preferences and utility theory, it turns out that a great approximation can be obtained by using a superlative index formula instead of the fixed weight CPI index. It had been showed that superlative indices (e.g. the Fisher index, the Törnqvist

⁸ R. Turvey, *CPI Manual. True Cost of Living Indexes*, 2002. [www.ottawagroup.org/Ottawa/ottawagroup.nsf/home/Meeting%2B5/\\$file/1999%205th%20Meeting%20%20Turvey%20Ralph%20%20True%20Cost%20of%20Living%20Indexes%202nd%20Edition.pdf](http://www.ottawagroup.org/Ottawa/ottawagroup.nsf/home/Meeting%2B5/$file/1999%205th%20Meeting%20%20Turvey%20Ralph%20%20True%20Cost%20of%20Living%20Indexes%202nd%20Edition.pdf) [21.01.2013].

index) numerically approximate each other⁹, and they closely approximate the true cost of living index¹⁰. It also had been proved that the true cost of living index is bounded from above by the Laspeyres index¹¹.

Superlative indices require the same information on prices and quantities as the Laspeyres or Paasche indices and involve interpolating between two periods rather than treating one of them as the base period. One of them, the Fisher index, is the geometric mean of the Laspeyres and Paasche indices¹²:

$${}_F I_p = \sqrt{{}_P I_p \times {}_L I_p}.$$

The other one, the Törnqvist index, is the geometric average of the growth rates in prices weighted by the arithmetic average of the weights in the two periods¹³:

$${}_T I_p = \prod_{j=1}^n \left(i_{j_p} \right)^{\frac{1}{2}(w_{j_0} + w_{j_1})},$$

where:

- i_{j_p} – a price index of individual category from a fixed market basket,
- w_{j_0} – a weight of individual category in a base period,
- w_{j_1} – a weight of individual category in a measured period.

Since the superlative indices provide a satisfactory approximation to the true cost of living index, it is possible to measure the extent of substitution bias comparing the Laspeyres index with one of the superlative indices. When interpreting the scale of the discrepancy as numeric effect of product substitution it is possible to measure consumer reaction to price fluctuations and susceptibility to changing of consumption model in this way.

It is worth stressing that the extent of measured bias depends on the level at which the measurement is undertaken. Aizcorbe and Jackman¹⁴ and G en ereux¹⁵,

⁹ W.E. Diewert, *Superlative index numbers and consistency in aggregation*, "Econometrica" 1978, No. 46, pp. 883-900.

¹⁰ W.E. Diewert, *Exact and Superlative Index Numbers*, "Journal of Econometrics" 1976, No. 4, pp. 114-145.

¹¹ A.A. Konus, *The Problem of the True Index of the Cost of Living*, "Econometrica" 1939, No. 7, pp. 10-29.

¹² I. Fisher, *The Making of Index Numbers*, Houghton-Mifflin, Boston 1922, pp. 234-269.

¹³ L. T ornqvist, *The Bank of Finland's Consumption Price Index*, "Bank of Finland Monthly Bulletin" 1936, No. 10, pp. 1-8.

¹⁴ A.M. Aizcorbe, P.C. Jackman, *The commodity substitution effect in CPI data, 1982-91*, "Monthly Labour Review" 1993, Vol. 116, No. 12, pp. 25-33.

¹⁵ P.A. Genereux, *Impact of the Choice of Formulas on the Canadian Consumer Price Index*, in: *Price Level Measurement* (Ottawa: Statistics Canada), eds. W.E. Diewert, A. Montmarquette, 1983, pp. 489-535.

observed that the more detailed levels of the index are taken into account to make comparisons, the strength of substitution bias increases. Thus, the potential for bias at the upper level is constrained.

It seems that the consumer susceptibility to changing of consumption model is depended on a current market situation. The substitution effect should be stronger especially when prices increase. The intuition described by the following estimation¹⁶:

$${}_L I_p - {}_F I_p \cong 0,5(1+i)Var(\varepsilon)$$

where:

- i – the rate of inflation measured by the Laspeyres index,
- $Var(\varepsilon)$ – the variance of relative price changes,

was confirmed by the results of the substitution effect analysis in Poland in years 2001-2010¹⁷. It follows from the formula that the higher the variance of relative price changes is, the higher the substitution bias is. It may appear obvious, that bias arising from the substitutability of goods increases in line with the level of inflation, because as the rate of inflation increases, so does the variance of relative price changes, however there is no exact proof of this intuition.

2. The substitution effect and different types of households

In this part of this paper we provide an analysis of product substitution effect for different types of Polish households in years 2001-2010, due to the fact that their reaction may vary in response to relative price changes. Household groups representing the basic socio-economic groups of the population were established on the basis of the exclusive or main (predominate) source of maintenance, i.e.:

- 1) households of employees – income from hired work,
- 2) households of the self-employed – income from self-employment, i.e., from conducting economic activity, other than farming, from practising a learned profession (e.g., artists, lawyers),
- 3) households of farmers – income from the use of a private farm in agriculture,
- 4) households of retirees and pensioners – retirement pay and pensions¹⁸.

¹⁶ W.E. Diewert, *Index Number Issues in the Consumer Price Index*, "Journal of Economic Perspectives" 1998, Vol. 12. No. 1, pp. 47-58.

¹⁷ E. Mela-Owczarek, *Efekt substytucji a przeszacowanie wskaźnika CPI w Polsce w latach 2001-2010*, „Zeszyty Naukowe WSB we Wrocławiu” 2013, No. 2(34), pp. 327-336.

¹⁸ Statistical Yearbook of Poland (2001-2011), Warsaw, GUS.

According to recommendations included in the Boskin report we measure the substitution bias by comparing the Laspeyres index with the Törnqvist one. We use the annually updated system of weights based on the structure of Polish households' expenditure.

On the basis of yearly data coming from publications of Central Statistical Office (GUS) – Statistical Yearbook of the Republic of Poland (2001-2011)¹⁹ two chained indices were calculated, the Laspeyres and the Törnqvist one. The results we obtained for annual indices for different types of households are presented in the table 1.

Table 1. The Laspeyres index and the scale of discrepancy between the Laspeyres and Törnqvist indices divided by the types of households in years 2001-2010

Households	Values	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Household of employees	Laspeyres	105,44	101,97	100,81	103,23	102,00	100,84	102,32	104,02	103,32	102,50
	Laspeyres – Törnqvist	0,05	0,03	0,03	0,05	0,05	0,05	0,06	0,09	0,05	0,04
Household of the self-employed	Laspeyres	104,96	101,82	100,78	103,19	101,90	100,77	102,14	103,54	102,94	102,50
	Laspeyres – Törnqvist	0,06	0,01	0,02	0,04	0,04	0,04	0,06	0,07	0,05	0,04
Household of farmers	Laspeyres	104,60	101,30	100,50	104,10	102,10	100,50	102,20	104,40	103,00	102,40
	Laspeyres – Törnqvist	0,08	0,03	0,04	0,04	0,04	0,05	0,07	0,08	0,06	0,03
Household of retirees and pensioners	Laspeyres	106,00	102,20	101,00	103,80	102,30	101,40	103,00	104,90	104,20	102,80
	Laspeyres – Törnqvist	0,03	0,01	0,02	0,02	0,01	0,02	0,02	0,03	0,01	0,01

Source: own research on the basis of Central Statistical Office data – Statistical Yearbook of Poland (2001-2011), Warsaw, GUS.

When analyzing the gap between the Laspeyres and the Törnqvist indices related to presented types of households we may draw a conclusion that in all cases the differences between these indices in adequate periods of time have similar tendency. Thus, considering all types of households, years in which the gap between the Laspeyres and the Törnqvist indices increases are: 2001, 2004 and 2008, i.e. in periods when Poland's economy showed features of recession (2001), when Poland accessed to the European Union and when one of the highest point in an economic expansion occurred (2008, in Poland's economy the visible results of the financial crisis appeared in 2009). The same character of differences between indices calculated for various types of households may confirm the intuition that the consumer susceptibility to changing of consumption model is depended on current market situation. It is easy to notice that the tendency of the scale of

¹⁹ Statistical Yearbook of Poland (2001-2011), Warsaw, GUS.

discrepancy between the Laspeyres and the Törnqvist indices in all periods is similar to the tendency of inflation level. The scale of discrepancy is relatively larger in years with higher rate of inflation, what may confirm the intuition following from the Diewert estimation. This may point to the rational behavior of Polish consumers who match their consumption model in accordance with changing prices in such way that they in place of more and more expensive goods look for cheaper alternatives.

The positive values of the discrepancy between the Laspeyres and the Törnqvist indices in all cases are in line with the Konus theorem. Thus, the Laspeyres index is an upper bound for the cost of living index measured by the Törnqvist formula. The scale of discrepancy for every type of households does not exceed 0.1 percentage point (the highest obtained value is 0.0939 and it is related to households of employees).

The results obtained for different types of households are in line with the intuition that the consumer susceptibility to changing of consumption model is depended on consumers' financial situation. The smallest differences between Laspeyres and Törnqvist indices occur in the case of retirees and pensioners, as they have the lowest income at their disposal. Lack of significant differences between the Laspeyres and the Törnqvist indices may arise, therefore, in the absence of the possibility of replacing the already consumed goods and services because they are the cheapest. If we compare the adequate results for other types of households (i.e. employees, households of the self-employed and households of farmers) we may draw a conclusion that the values of the gap between Laspeyres and Törnqvist indices are similar, just slightly lower for households of self-employed. The very cautious interpretation of this fact could be as follows – the self-employed are probably the richest group among those which was taken into account in our analysis, so they do not need to reduce their expenditure on a scale comparable with others.

Conclusions

When analyzing the scale of the discrepancy between the Laspeyres and the Törnqvist indices interpreted as a numeric effect of product substitution in Poland in years 2001-2010 there can be observed that consumer reaction to price fluctuations and susceptibility to changing of consumption model in all types of households depends on current market situation. The gap between the Laspeyres and the Törnqvist indices is relatively larger in years with higher rate of inflation resulting from accommodative monetary policy conducted by the central bank authority

during expansion periods. Growing rate of inflation make consumers match their consumption model in accordance with increasing prices in such way that they, in place of more and more expensive goods, look for cheaper alternatives and thus the relatively significant bias appears.

The only difference is in the strength when comparing the gap between the Laspeyres and the Törnqvist indices in adequate periods. The lowest values of substitution bias are obtained for the household of retirees and pensioners. These lead to a conclusion that different types of households suffer from the effects of inflation in different way. This is because of the discrepancies in the pattern of consumer goods and services consumption. Characteristic of poor societies is the fact that a substantial part of income is devoted to buying food and keeping a place of stay. Therefore, the most vulnerable groups of the population will share this model of consumption. In Poland, this applies to retirees and pensioners. The indices of consumer goods and services and cost of living calculated for these groups most difficultly submit to the effect of substitution.

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Efekt substytucji a typy gospodarstw domowych

Streszczenie. Jednym z kluczowych problemów związanych z indeksami cenowymi o stałych wagach jest to, że powszechnie stosowana formuła indeksu – formuła Laspeyresa – nie uwzględnia efektu substytucji. Przeszacowanie z tym związane można zmierzyć porównując wartości indeksu Laspeyresa z analogicznymi wartościami indeksu Törnqvista. Interpretując skalę rozbieżności między analogicznymi wartościami tych dwóch indeksów jako liczbową miarę efektu substytucji, możliwy staje się pomiar reakcji konsumentów na fluktuacje cenowe i ich skłonności do zmiany modelu konsumpcji. Zakładając racjonalne zachowanie konsumentów, jeśli ceny rosną, powinni oni być bardziej skłonni do zastępowania droższych dóbr tańszymi zamiennikami. Wydaje się, że skłonność ta powinna zależeć od sytuacji finansowej danego gospodarstwa domowego, dlatego w artykule przedstawiono analizę wielkości przeszacowania wartości ogólnego wskaźnika CPI, mierzonego formułą Laspeyresa, na skutek nieuwzględnienia w jej konstrukcji efektu substytucji w podziale na różne typy gospodarstw domowych. Analizą objęto okres 2001-2010.

Słowa kluczowe: efekt substytucji, indeks CPI, indeks CoLI, model konsumpcji, typ gospodarstwa domowego