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PRICE VOLATILITY IN MACROECONOMIC STRUCTURE OF PRODUCTION IN POLAND

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ABSTRACT

In this article an empirical analysis of price volatility was conducted, on the basis of Polish macroeconomic data from 2010–2016 and theoretical framework proposed by Austrian School of Economics. The research was carried out using a number of statistical methods used on price indices representing different stages of production. The analysis allowed to establish conclusions about differing degree of price movements throughout Polish economy and its sectors, where prices of goods produced at the beginning of the structure were characterised by higher volatility than those produced in other branches. No statistically significant difference in price volatility was noted between consumer goods and intermediate goods stage.

Key words: structure of production, price volatility, Austrian School, statistical mathematics, macroeconomics

INTRODUCTION

Price changes in the economy are inherently linked to the market relations between the individuals within society. Indeed, it is the market economy which allows entrepreneurial activity that manifests itself in demand and supply market forces allowing for price determination. In centrally planned economy one cannot speak of prices as a result of voluntarily conducted transactions. The concept of prices in such conditions is nothing less than misleading; such "prices" (imposed by central planning) would lack what is perhaps one of the most important feature of price formation in the economy namely transmission of information [Huerta de Soto 2011]. Price theory presented in this paper is based on tradition of Austrian School of Economic Thought. In general the most distinguishing difference between neoclassical economics and Austrian approach is the lack of distinction between micro- and macroeconomics [Huerta de Soto 2008]. Austrians[1] view economic activity as an uniform process encompassing individuals, markets and whole economies alike, human action axiom being the common thread. Austrians prove that this axiom is sufficient for creating complex economic theories, as the one examined in this article.

Having stated that, it might be confusing why it was decided to use the term "macroeconomic" in the title of this paper. Firstly, as much as Austrian methodology leads to some of the most original and accurate conclu-

[1] This term is nowadays used in relation to all representatives of Austrian School who not necessarily come from Austria. Moreover, most of contemporary Austrian economists come from United States and are concentrated around Mises Institute operating in Auburn, Alabama.

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sions, many of its representatives, especially in the past century, relied almost exclusively on theoretical tools without conducting empirical research. The author of this paper believes that while praxeology[2] is absolutely sufficient when considering less complex economic phenomena and theories, more complicated matters (such as the theory of the structure of production) require additional empirical considerations, especially in spite of availability of proper data. Secondly, the structure of production concept can be viewed as a direct attempt at countering neoclassical and Keynesian models [Butos 2001]. Thirdly, the title of this paper points out to the use of macroeconomic data, on which this research was based.

MACROECONOMIC STRUCTURE OF PRODUCTION

While considering macroeconomic structure of production one can speak of transmission of information via prices in the economy. Based on the theory of capital firstly introduced by Bohm-Bawerk [1930], macroeconomic structure of production concept is the result of the work of later generations of Austrian economists, as well as contemporary adherents of the theory. As Garrison [2002] mentions, general idea behind the concept is to "allow the time to enter the theory [of macroeconomics – note of the author] in a fundamental yet concrete way". Therefore, one can depict production side of the economy as an intertemporal capital structure which outlines how raw resources are being transformed into consumable output in time.

On Figure 1 an exemplary depiction of macroeconomic structure of production is examined, representing disaggregated neoclassical model of circular flow of income. It has to be mentioned, that there is no canonical way of depicting macroeconomic structure of production. Throughout the years, many authors used different methods; dating back to Bohm-Bawerk's "concentric circles" [Bohm-Bawerk 1930] through "Hayek's triangles" [Hayek 2008] and modern depictions as seen in Huerta de Soto [2006]. These were however mostly used as a basis of theoretical framework and were meant to ease the comprehension of the concept. For the purpose of this research an authorial structures[3] was used which is not only consistent with the discussed theory but can also be used as foundation for empirical research.

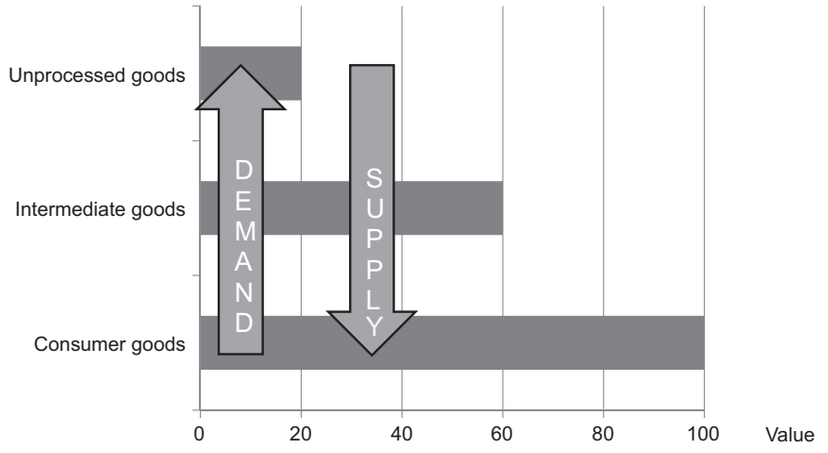

Fig. 1. Exemplary structure of production

Source: Own elaboration.

[2] Term introduced by Mises in 1949 describing the methodology of modern Austrian School.

[3] It has to be mentioned, that proposed macroeconomic structure of production was mostly inspired by Skousen's "Aggregate Production Structure" [2011], which was designed with empirical research in mind.

Contrary to the neoclassical model, macroeconomic structure of production views the production side of the economy as a series of stages of production on which entrepreneurs produce goods differing in maturity. While neoclassical model depicts production side of the economy as a *horizontal*, single-dimensional entity in which goods and services are being produced (and through which money flows in and out), Austrians propose a structure in which some of the goods are "further away" from the final demand represented by consumers and some are "closer" to completion, while money is being paid for goods and services exchanged between the stages. This results in different price levels on each stage [Cochran 2011].

According to Austrians, production side of the economy should be depicted *vertically* [Skousen 2011]. Money flows into the structure at the bottom of Figure 1 where consumers pay for final goods and services in the economy. This remarks one of the key elements of the model – the ultimate goal of all entrepreneurial activity in the structure is the production of consumer goods. However, as Hayek [2008] mentions production takes time. Before the final output reaches the consumer, intermediate goods and raw materials need to be produced and exchanged between stages. The demand of consumers induces an intermediate demand which causes entrepreneurial activity of producers which are "further away" from consumer goods stage, eventually allowing money to reach stages of production at the bottom of the structure[4].

Though the final demand results in all activity within the structure, the production itself starts with raw materials stage ("unprocessed goods" in Figure 1). From this point on, a supply chain between stages is established allowing the flow of goods differing in maturity, while value is added at each stage before they reach consumer goods stage. One should notice, that goods at the bottom of the structure do not represent much of a value. They will mature in time as they are being transformed into consumer goods [Menger 2007].

One can examine a more practical example, namely a production process of a car. Cars are made, at least partially, out of steel. Before steel can be used to produce parts of the car, an ore has to be extracted and produced. Only then producers of particular car parts are able to start their production. In the end all the parts are brought together by the producer who outputs the car itself[5].

In this particular structure of production there are three stages, which is mostly due to availability of empirical data that could have been assigned to a particular stage. In the literature however, one can find examples of structures consisting of even ten stages, where the analysis focuses mainly on theoretical framework [Lachamnn 1978]. What becomes clear however, is the difference in level of aggregation between neoclassical and Austrian macroeconomic model. While neoclassical approach favours pure aggregation of all production in the economy, Austrian model resembles microeconomics, where particular goods produced are placed within a framework of supply chain[6].

The application of microeconomic disaggregation within macroeconomic theory proves to be more efficient in explaining events happening in the economy as a whole [Skousen 2011]. The most important theoretical tenets used as a basis of this research were the ones concerning prices. On each production stage not only are different prices being determined (which is truism – concerning the addition of value and different goods traded), but the movement and volatility of prices differs as well [Jędruchniewicz 2013]. This is why one cannot simply aggregate all the producing activity and speak about "general price level" in the economy. Austrians argue that, especially throughout economic cycles, prices do not change uniformly. Higher volatility of prices should be ob-

[4] Which rests at the top of Figure 1.

[5] Skousen's [2011] "Aggregate Production Structure" consists of four stages. Skousen's structure also includes "wholesale" stage. Due to unavailability of the data it was not possible to include it in the analysis and so the author decided to propose his own idea of the structure.

[6] One can notice an explicable simillarity of the proposed model to some of the microeconomic "supply chain" models. Indeed, as explained by Skousen [2015] structure of production is an adaptation of microeconomic methods on the field of macroeconomics.

served on "further" production stages, compared to consumer goods stage. The main objective of this paper was to investigate this dependency on the basis of Polish economy in 2010–2016 period. In this article author does not go into detail on why such occurrence takes place. Extensive explanations can be found in Rothbard [2008], Mises [1953] and other positions mentioned above, especially in Huerta de Soto [2006].

DATA AND RESEARCH METHODS

For the purpose of this research author proposed an exemplary structure of production fitting the available empirical data. As a basis of measuring price volatility, price indices corresponding to the particular stage of production were used. The indices, as measured by Central Statistical Office of Poland, represent a change in price level of particular production stage compared to the corresponding period of a previous year. The data comes from 2010–2016 period and was measured on a monthly basis. 84 observations were noted per each stage of production giving 252 observations in total. Data used to represent particular stages of production was as follows:

- Unprocessed goods – *Capital goods price indices*;
- Intermediate goods – *Intermediate goods price indices*;
- Consumer goods – *Consumer goods and services indices of prices* (CPIs)[7].

It has to be mentioned that no empirically based structure of production will ever truly represent complexity of entrepreneurial activity throughout the economy. Such task would require an enormous effort of data gathering, which would not only be difficult and expensive, but might not bear much fruit either. Author realises that compromises made in this paper might be controversial. Nonetheless, one has to remember that this is one of the first attempts at proving the discussed theory using given methods.

In this research a number of statistical tests was carried out. Most of them revolve around analyses of variance of the samples described above. All of the computations were done in *R* statistical computing software. Throughout the research 0.05 statistical significance was adopted. Figure 2 represents density plots for examined data.

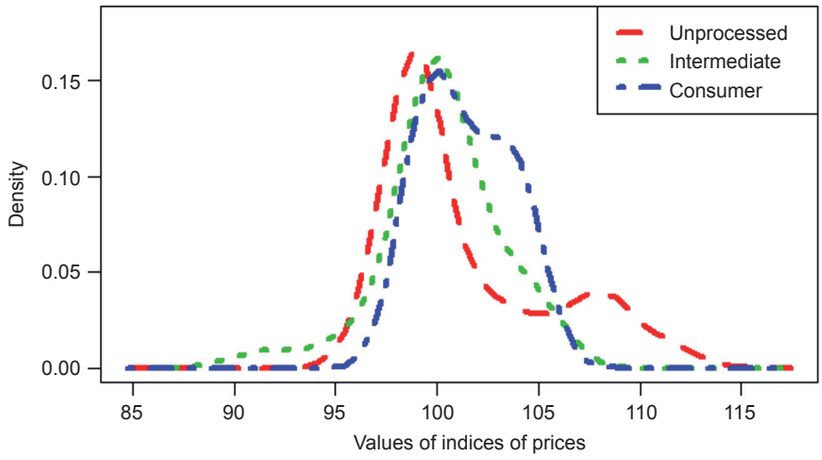

Fig. 2. Density plots for examined data

Source: Own elaboration based on Central Statistical Office of Poland.

[7] For more detailed information about branches and sectors aggregated in particular stages see: Commission Regulation (EC) No 656/2007 of 14 June 2007 amending Regulation (EC) No 586/2001 on implementing Council Regulation (EC) No 1165/98 concerning short-term statistics as regards the definition of main industrial groupings (MIGS).

Firstly, it had to be determined whether data samples follow normal distribution. This was crucial to the research, as the methods available for measuring data dispersion sometimes largely depend on the normality of distribution assumption. For that purpose Shapiro-Wilk normality test was used because of its good power properties [Razali and Wah 2011]. Shapiro-Wilk statistic is given as:

$$W = \frac{\left(\sum_{i=1}^{n} a_i y_i\right)^2}{\sum_{i=1}^{n}\left(y_i - \bar{y}\right)^2} \tag{1}$$

where: y_i – the i^{th} order statistic;
$\bar{y}$ – the sample mean.

$$a_i = \left(a_1, \ldots, a_n\right) = \frac{m^T V^{-1}}{\left(m^T V^{-1} V^{-1} m\right)^{1/2}} \tag{2}$$

and $m = (m_1, \ldots, m_n)^T$ are the expected values of the order statistics of independent and identically distributed random variables sampled from the standard normal distribution. Where V is the covariance matrix of those order statistics and the *P-value* below statistical significance points out to rejection of normality assumption in particular sample. It has to be mentioned, that in this research a modified algorithm (AS R94) for the test was used as provided by Royston [1995] which makes the test usable for samples of up to 5,000 observations.

Results of Shapiro-Wilk test led to rejection of normality assumption in all of three samples. Therefore, proper non-parametric statistical tests had to be considered for measurement of volatility. The volatility differences were measured using Brown-Forsythe test of homogeneity of variances, which proves very efficient while considering large, multiple samples of non-normally distributed data [Denekowska et al. 2009]. The statistic is given as:

$$F = \frac{(N - g)}{(g - 1)} \frac{\sum_{i=1}^{g} n_i \left(Z_i - \bar{Z}\right)^2}{\left[\sum_{i=1}^{g}\sum_{j=1}^{n_i}\left(Z_{ij} - \bar{Z}_i\right)^2\right]}$$

where: $Z_{ij} = \left|Y_{ij} - \tilde{Y}_i\right|$; (4)

$$\bar{Z}_i = \frac{1}{n_i}\sum_{j=1}^{n_i} Z_{ij}; \tag{5}$$

$$\bar{Z} = \frac{1}{N}\sum_{i=1}^{g}\sum_{j=1}^{n_i} Z_{ij}; \tag{6}$$

$$\tilde{Y}_i = median\left(Y_{i1}, Y_{i2}, Y_{i3}, \ldots, Y_{in_i}\right). \tag{7}$$

Hypotheses tested are given as:

$$H_0: \sigma_1^2 = \sigma_2^2 = \sigma_3^2 = \ldots = \sigma_g^2 \tag{8}$$

$$H_1: \sigma_1^2 \neq \sigma_2^2 \neq \sigma_3^2 \neq \ldots = \sigma_g^2 \tag{9}$$

Brown-Forsythe test is in fact a slight modification of statistic proposed by Leven [Brown and Forsythe 1974]. Originally, the test used mean instead of median, which made it appropriate for testing normally distributed data-samples. The reason behind modification was to make the test more robust to non-normal distributions. In this research, *p-value* below given statistical significance pointed out to non-homogeneity of at least one population's variance compared to others, indicating differences in dispersion between data samples, which also proves the assumption of non-uniform price movements within the economy (in between stages of production).

Lastly, it needed to be tested if the volatility was higher the "further" a given stage of production was situated compared to consumer goods stage. In this part of the research, Ansari-Bradley's test was used which is a rank sum type of test used for measuring differences in dispersion [Ansari and Bradley 1960]. In general, the test is used to investigate whether the difference in scale of two cumulative distribution functions is different than 1. For that purpose Ansari and Bradley introduce a scale parameter (θ) given as:

$$G(\theta u) \equiv F(u) \tag{10}$$

where $G(u)$ and $F(u)$ are cumulative distribution functions derived from independent samples. In that case H_0 assumes the value of θ to be no different than 1. An alternative hypothesis stating that scale parameter is less than 1 was used for the purpose of this research. H_1 indicated higher dispersion of $G(\theta u)$ distribution[8].

To carry out Ansari-Bradley's procedure, both of the tested samples are ranked in a combined array represented by:

$$Z_1, \ldots, Z_{m+n} \tag{11}$$

where ranks are being assigned from both ends, starting with 1 and working towards the center (middle ranks are given as $(m + n)/2$ in this case[9]). Then Ansari-Bradley's statistic is given as:

$$W = \sum_X R(Z) \tag{12}$$

P-value for the test was calculated by the software. If below statistical significance, alternative hypothesis was adopted. One can notice, that the test was designed to be used for two samples. Therefore, the test had to be run twice for two pairs of indices samples; once for *unprocessed goods* and *intermediate goods* and once for *intermediate goods* and *consumer goods*, which allowed the author to check if dispersions in price changes were higher at the bottom of the structure of production.

Before moving on to Ansari-Bradley's test however, its assumptions needed to be considered. Firstly, observations in tested samples had to be independent – this condition was certainly met all across the data. Secondly, both of the tested samples had to come from the same type of distribution function differing only in scale. To test this assumption, another rank type test was used, namely Wilcoxon rank sum test [Fahoome 2002]. This let the author check whether H_0 stating that two independent samples used in particular Ansari-Bradley's procedure were selected from the same distributions without statistically significant differences in location parameters.

[8] One can also use "greater than 1" or two-sided hypotheses.

[9] Formula is slightly different when odd number of overall observations is considered.

Wilcoxon procedure involves combining samples in ordered manner, keeping track of sample membership. The ranks of the sample with the smaller sum are added, giving the S_n statistic, formally represented as:

$$S_n = \sum_{j=1}^{n} R_j \tag{13}$$

where R_j are the ranks of sample n expected to have the smaller sum. *P-value* below the statistical significance led to rejection of H_0, thus making the use of Ansari-Bradley's test inadequate for the given pair of samples.

RESULTS

The first step of the research was to find out if analysed samples follow normal distribution. Table 1 represents *p-values* of Shapiro-Wilk's normality test for each sample.

Table 1. Results of Shapiro-Wilk's test

Stage of production	Unprocessed goods	Intermediate goods	Consumer goods
P-value for S-W's test	0.00000002	0.001308	0.00002

Source: Own elaboration.

As mentioned before, based on the results and adopted statistical significance, it had to be concluded that none of the samples follows normal distribution. This assumption necessitated the usage of robust tests in further proceedings.

The next test was Brown-Forsythe's test. This test had to be run only once, as it measured if homogeneity of variances was present between all of the samples. Result for this test was *p-value* at the level of 0.005031. Based on adopted statistical significance, given H_0 does not apply anymore and it had to be concluded that price movements between stages of production were not uniform.

For the last stage of the research (Ansari-Bradley's test) it needed to be determined whether the data came from the same type of distribution. For that purpose, Wilcoxon's rank sum test was run for two pairs of the samples for which Ansari-Bradley's test was to be run as well. Table 2 represents *p-values* as measured for both tests. Based on the results of Wilcoxon's test and adopted statistical significance, it can be noticed that when it comes to measuring differences in spread of indices between *unprocessed goods* stage and *intermediate goods* stage H_0, stating that both of the samples come from the same distribution type with statistically negligible location differences could be adopted. However, when it comes to *intermediate goods* and *consumer goods* pair of samples, the results were not so favourable. In this case H_0 for Wilcoxon's test could be adopted only if statistical significance is to be lowered (to 0.001 for example).

Table 2. Results of Wilcoxon's and Ansari-Bradley's test

Pair of indices of prices	*Unprocessed goods* and *intermediate goods*	*Intermediate goods* and *consumer goods*
P-values for Wilcoxon's test	0.938	0.007266
P-values for A-B's test	0.01872	0.2616

Source: Own elaboration.

Results of Ansari-Bradley's test could be examined only while taking Wilcoxon's test results into consideration. When it comes to *unprocessed goods* stage and *intermediate goods* stage, based on the tests' *p-values* and adopted statistical significance, it had to be concluded that *unprocessed goods* indices of prices distribution scale parameter is less than 1. This result indicates higher dispersion of price indices on *unprocessed goods* stage. Ansari-Bradley's test's function coded in *R* estimated θ parameter at the level of 0.9093484, indicating that price volatility is expected to be around 9.9689% higher on *unprocessed goods* stage, compared to *intermediate goods* stage.

When it comes to *intermediate goods* and *consumer goods* however, it was already indicated that Wilcoxon's test H_0 can be adopted only for much lower statistical significance. That would also apply for the Ansari-Bradley's test run for this set of data. Based on this test's *p-value*, it had to be concluded that the difference in scale parameter of both distributions was not statistically significant. Therefore, one cannot conclude if the price volatility was higher on *intermediate goods* stage, compared to *consumer goods* stage.

Moreover, Brown-Forsythe's test run for *intermediate goods* and *consumer goods* set of data scored *p-value* of 0.2834 indicating no statistical difference in populations' variances, thus pointing out to no difference in price volatility between those stages.

CONCLUSIONS

The theory discussed in the beginning section of this paper was partially proven. While *unprocessed goods* in Polish economy are characterised by higher price volatility than *intermediate goods* one cannot say if the same follows for *intermediate goods* as compared to *consumer goods*. Furthermore, it cannot be concluded if there was any difference in price volatility between those stages at all. Nonetheless, price volatility on *unprocessed goods* stage differs from the rest of the stages and it is enough to conclude that prices in Polish economy did not change uniformly. Therefore, aggregating whole economic activity and speaking of an uniform price level in the economy can be misleading.

As for the limited provability of the theory, a few factors might have had an impact on the research. Firstly, the discussed theory is mostly applicable for *developed* market economies, while Poland is still considered a *developing* country. Secondly, as the Austrian School deals only with pure market phenomena (of which regulations and state activity are not a part) the validity of the theory largely depends on the level of economic freedom. Polish economy, according to Heritage Foundation report is only moderately free[10]. Various state interventions and regulation could impact entrepreneurial activity in examined sectors and branches, distorting the results. Thirdly, one of the limitations of Austrian model is the lack of foreign trade impact examination. Structure of production theory is in fact limited only to 'supply chain' of national economy, mostly lacking any serious consideration of globalisation phenomena, which could influence the findings. Fourthly, the problem may lay in the data and its examination itself. Possible limitations of the model were already mentioned and it might very well be that proposed level of disaggregation and number of stages of production were not sufficient or that the statistical data was somewhat flawed. Nonetheless, one has to keep in mind that methods used in this article are merely a proposition, as the theory did not see many empirical verifications as of yet, and there is still much place for improvement.

[10]See The Heritage Foundation [2016]. Index of Economic Freedom: Promoting Economic Opportunity and Prosperity report, were Poland scores 39th place out of 186 economies examined.

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ZMIENNOŚĆ CEN W MAKROEKONOMICZNEJ STRUKTURZE PRODUKCJI W POLSCE

STRESZCZENIE

W artykule zawarto wyniki badań empirycznych w ramach teorii struktury produkcji szkoły austriackiej w ekonomii, dotyczące zmienności cenowej w polskiej gospodarce w latach 2010–2016. W badaniach wykorzystano dane o indeksach cenowych dla różnych etapów struktury, które zostały poddane obróbce statystycznej. Badania częściowo potwierdziły założenia teoretyczne w zakresie różnic w zmienności cenowej w gospodarce, w której największą zmienność odnotowano w zakresie dóbr nieprzetworzonych. Nie stwierdzono istotnych statystycznie różnic w zakresie zmienności cenowej między etapem dóbr pośrednich i konsumpcyjnych.

Słowa kluczowe: struktura produkcji, zmienność cenowa, szkoła austriacka, statystyka matematyczna, makroekonomia