Artur Gorzałczyński

Michał Przybyliński

University of Lodz, Poland

Corresponding author: michal.przybylinski@uni.lodz.pl

An attempt to assess the interdependence between prices and the structure of inputs on the basis of input-output tables expressed in constant and current prices

Draft

Inflation is a constant phenomenon in the world economy, but it becomes the center of attention quite rarely. In conditions of stable economic growth, it is usually low and predictable. Recent years, however, have brought a series of unforeseen events that have disrupted the previously smooth-running gears of the world economy, leading to an increase in inflation.

Input-output tables make it possible to trace with high accuracy, on the one hand, changes in technological processes expressed in changes in the structure of real intermediate inputs, and on the other hand, the impact of price changes on these structures. Changes in the prices of intermediate products resulting from broadly understood changes on the supply side are transferred to production costs and, consequently, to the prices of final goods, according to the cost formula. Both producers and final consumers try to adapt to these changes by changing the structure of their purchases. Substitution mechanisms cause a decrease in the share of these intermediate inputs which prices relatively increase. The structure of consumption changes in a similar way.

From the point of view of price formation, the strength of the imbalance between demand and supply is decisive. A price shock may therefore have its source on both the demand and supply side. Input-output tables and models could be used to assess the strength of the adjustment mechanisms and, consequently, the transfer of price impulses. The condition is that the data should be expressed both in current and constant prices. Such possibilities have been shown in our previous paper (Przybylinski, Gorzalczynski 2022).

Here we focus on one of the components of the complex price formation and transmission mechanism - substitution in the production process. We want to answer the question of whether producers are flexible enough to offset the increase in production costs by changing the structure of inputs.

Research has shown that firms tend to respond to changes in production costs by either substituting inputs or changing their production technology. According to a study by Acemoglu and Restrepo (2017), firms in the manufacturing sector are more likely to substitute inputs when faced with an increase in the cost of a particular input. This is because substitution is often a quicker and more cost-effective solution than changing the entire production process. On the other hand, firms in the service sector are more likely to change their production technology when faced with cost increases. This is because services are often more complex and require a higher level of customization, making substitution less feasible. A study by Brynjolfsson and McAfee (2014) found that firms that invest in new technologies are more likely to be successful in adapting to changes in production costs. This is

because new technologies can increase efficiency and reduce costs in the long run. Overall, the choice between substitution and changing production technology depends on the specific industry and the nature of the input or service being produced.

Several studies have utilized the input-output model to investigate the relationship between production structure and prices. These studies show the problem from a different perspective. For example, Chen and Chen (2017) used the model to analyze the impact of changes in the energy sector on the overall economy and prices. Similarly, Zhang et al. (2019) examined the effect of changes in agricultural production on food prices using the input-output model.

The method we used consisted in calculating price indices for individual products based on the structure of the production costs of these products. All necessary information is given in input-output tables.

Let's assume the following notations:

Subscript $i = 1,\ldots,n$ denotes the product (branch or product group depending on the classification used).

Subscript $j = 1,\ldots,n,n+1,\ldots,2n,2n+1,\ldots,m$ denotes the type of inputs, which are the products of domestic branches (*1* to *n*), imported products (*n+1* to *2n*), and other costs, mostly value added (*2n+1* to *m*).

Superscripts *t* and *t-1* denote current and previous year, respectively.

q_{ij} - is the quantity (volume) of inputs *j* used to produce a unit of product *i*.

p_{ij} - is the price of inputs *j* used for product *i*.

Thus, the Laspeyres formula for price index based on inputs is:

$$P_i^L = \frac{\sum_{j=1}^{m} q_{ij}^{t-1} p_{ij}^{t}}{\sum_{j=1}^{m} q_{ij}^{t-1} p_{ij}^{t-1}}$$

and the Paasche formula is:

$$P_i^P = \frac{\sum_{j=1}^{m} q_{ij}^{t} p_{ij}^{t}}{\sum_{j=1}^{m} q_{ij}^{t} p_{ij}^{t-1}}$$

The first index (Laspeyres) shows the hypothetical price of product *i* in the period *t*, with unchanged unit inputs from the year t-1. This would be the price, if the producers didn't react at all, just passed on the price impulse in its entirety.

The second index (Paasche) is based on the quantities from the year *t*, the unit inputs which have been already changed in response for (among others) the price impulse.

The difference in the obtained results indicates the direction in which the change in the real cost structure contributed to the change in the prices of individual products. If the index calculated on the basis of the Laspeyres formula is higher, it proves that the change in the unit inputs contributed to the slowdown of inflation impulses - a rational substitution or technological progress took place.

A higher Paasche index means that changes on the real side amplified the inflationary impulses. This may also suggest, that the inflationary impulse came from the demand side.

The availability of symmetrical tables expressed in fixed prices (prices from the previous year) is still very limited. That is why the study was conducted on the basis of data describing the Danish economy, published on the website of Statistics Denmark. The Danish tables are symmetrical input-output tables presented according to the Danish Industry Classification (DB07), which is a version of the international nomenclatures NACE, Rev. 2, ISIC, Rev., at the level of 117 branches. In an EU-perspective there is a high degree of comparability with national accounts and input-output tables made by other countries. The choice of Denmark as the subject of the study results also from the limitations of the availability of the latest statistical data, i.e. tables for the analyzed period reaching 2019.
Soon, it will be possible to analyze the reaction of producers to the dramatic events that have significantly changed the rules of the global economy in recent years, primarily the COVID-19 pandemic, as well as the war in Ukraine. As announced, the set of tables for 2020 will be released in June this year. A more in-depth analysis of the causes of inflation that we are dealing with now will be possible in two years' time.

Statistics Denmark also publish input-output tables in 69-branch aggregation covering the next two years (currently until 2021), but they are compiled in a simplified way, based on past coefficients. The use of these tables would not bring much in the case of extending our analyzes to 2020-2021, because it is the changes in the coefficients that make it possible to assess the type and strength of the price adjustments.

Our calculations, based on the method described above cover the period 1967-2019. The values of q_{ij}^{t-1} were calculated as input-output coefficients on the basis of the tables expressed in current prices for the period t-1 and the values q_{ij}^{t} were calculated from the tables expressed in previous year's prices for the year t. The prices p_{ij} were calculated by dividing the values in current prices by the values in previous year's prices. The results are quite extensive.
The results presented in table 1 refer to the differences between indices based on Paasche and Laspeyres formulas. In the 3rd column we put the mean of these differences for each sector. As it can be seen, almost all means are positive, which means, that the Paasche indices are higher than Laspeyres indices. There are only two exceptions: Extraction of gas and oil and Own-account repair and maintenance of buildings. The next three columns show that not only means are positive, but generally all the observations as well. Plus signs in columns 5 and 6 mean, that for this sector mean minus standard deviation and mean minus 3 standard deviations are still positive. It is very unlikely to find a negative value in such time series. Last two columns show if there is a long term trend in these differences.

Table 1. The results

Code	**Sector**	mean	standard deviation	mean - stdv	mean - 3 stdv	**trend coeficient**	**Significance**
010000	Agriculture and horticulture	0,0484	0,0337	+	-	-0,0011	***
020000	Forestry	0,3008	0,0837	+	+	-0,0028	***
030000	Fishing	0,1799	0,0436	+	+	0,0007	*
060000	Extraction of oil and gas	-0,2849	3,9537	-	-	0,0343	
080090	Extraction of gravel and stone	0,2725	0,0587	+	+	-0,0026	***
090000	Mining support service activities	0,4142	0,2942	+	-	-0,0005	

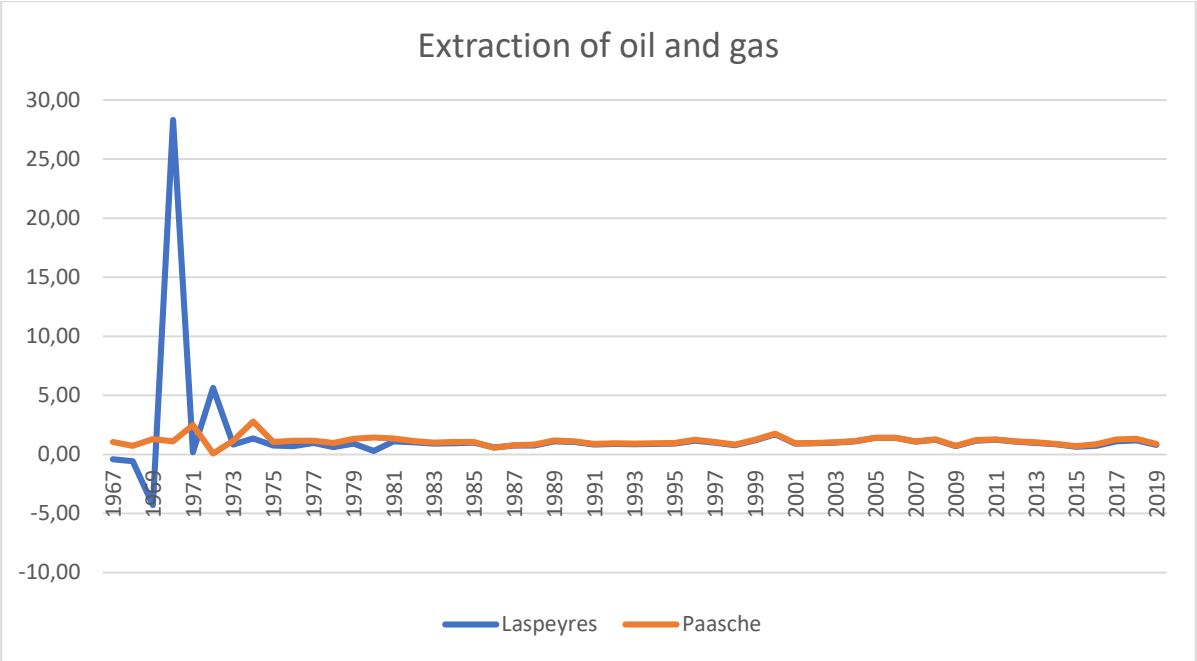
100010	Production of meat and meat products	0,1331	0,0385	+	+	0,0014	***
100020	Processing and preserving of fish	0,1062	0,0318	+	+	0,0005	*
100030	Manufacture of dairy products	0,0971	0,0268	+	+	0,0006	**
100040	Manufacture of grain mill and bakery products	0,2829	0,0248	+	+	-0,0010	***
100050	Other manufacture of food products	0,1304	0,0235	+	+	0,0003	
110000	Manufacture of beverages	0,2957	0,1056	+	-	-0,0058	***
120000	Manufacture of tobacco products	0,2153	0,0927	+	-	-0,0045	***
130000	Manufacture of textiles	0,2607	0,0264	+	+	-0,0008	***
140000	Manufacture of wearing apparel	0,1588	0,6287	-	-	-0,0129	*
150000	Manufacture of leather and footwear	0,0443	1,6419	-	-	-0,0302	*
160000	Manufacture of wood and wood products	0,2612	0,0278	+	+	0,0007	***
170000	Manufacture of paper and paper products	0,2634	0,0283	+	+	-0,0011	***
180000	Printing etc.	0,3910	0,0710	+	+	-0,0041	***
190000	Oil refinery etc.	0,0162	0,0743	-	-	-0,0005	
200010	Manufacture of basic chemicals	0,1956	0,0318	+	+	-0,0009	***
200020	Manufacture of paints and soap etc.	0,1900	0,0263	+	+	-0,0013	***
210000	Pharmaceuticals	0,2215	0,0566	+	+	-0,0030	***
220000	Manufacture of rubber and plastic products	0,2766	0,0352	+	+	-0,0003	
230010	Manufacture of glass and ceramic products	0,4063	0,1001	+	+	-0,0053	***
230020	Manufacture of concrete and bricks	0,2944	0,0333	+	+	-0,0015	***
240000	Manufacture of basic metals	0,2236	0,0337	+	+	0,0000	
250000	Manufacture of fabricated metal products	0,3362	0,0213	+	+	-0,0006	***
260010	Manufacture of computers and communication equipment etc.	0,2382	0,0495	+	+	-0,0021	***
260020	Manufacture of other electronic products	0,3496	0,0840	+	+	-0,0047	***
270010	Manufacture of electric motors, etc.	0,3182	0,0693	+	+	-0,0039	***
270020	Manufacture of wires and cables	0,3153	0,0872	+	+	-0,0041	***
270030	Manufacture of household appliances, lamps, etc.	0,2727	0,0297	+	+	-0,0007	***
280010	Manufacture of engines, windmills and pumps	0,3359	0,1183	+	-	-0,0070	***
280020	Manufacture of other machinery	0,3179	0,0236	+	+	-0,0010	***
290000	Manufacture of motor vehicles and related parts	0,2730	0,0491	+	+	-0,0016	***
300000	Manufacture of ships and other transport equipment	0,2788	0,0899	+	+	-0,0040	***
310000	Manufacture of furniture	0,2680	0,0222	+	+	-0,0006	***
320010	Manufacture of medical instruments, etc.	0,3596	0,0737	+	+	-0,0042	***
320020	Manufacture of toys and other manufacturing	0,2666	0,0800	+	+	-0,0039	***
330000	Repair and installation of machinery and equipment	0,3955	0,0849	+	+	-0,0048	***
350010	Production and distribution of electricity	0,1576	0,0402	+	+	-0,0013	***
350020	Manufacture and distribution of gas	0,0806	0,0635	+	-	-0,0019	***
350030	Steam and hot water supply	0,0522	0,0178	+	-	0,0000	
360000	Water collection, purification and supply	0,1502	0,0455	+	+	-0,0019	***
370000	Sewerage	0,2097	0,1232	+	-	-0,0039	***
383900	Waste management and materials recovery	0,3085	0,1170	+	-	-0,0066	***
410009	Construction of new buildings	0,3330	0,0474	+	+	-0,0022	***
420000	Civil engeneering	0,2654	0,0394	+	+	-0,0013	***
430003	Professionel repair and maintenance of buildings	0,3944	0,0266	+	+	-0,0011	***

430004	Own-account repair and maintenance of buildings	-0,0007	0,0048	-	-	0,0000	
450010	Sale of motor vehicles	0,4794	0,0583	+	+	-0,0005	
450020	Repair and maintenance of motor vehicles etc.	0,2309	0,0578	+	+	-0,0004	
460000	Wholesale	0,3287	0,0269	+	+	0,0003	
470000	Retail sale	0,4375	0,0351	+	+	0,0013	***
490010	Passenger rail transport, interurban	0,5025	0,1326	+	+	-0,0062	***
490020	Transport by suburban trains, buses and taxi operation, etc.	0,2597	0,0343	+	+	0,0001	
490030	Freight transport by road and via pipeline	0,2746	0,0272	+	+	0,0006	**
500000	Water transport	0,1206	0,0842	+	-	-0,0048	***
510000	Air transport	0,2482	0,1079	+	-	-0,0034	***
520000	Support activities for transportation	0,3218	0,0522	+	+	-0,0024	***
530000	Postal and courier activities	0,6060	0,1416	+	+	-0,0069	***
550000	Hotels and similar accommodation	0,3021	0,0259	+	+	0,0008	***
560000	Restaurants	0,2887	0,0253	+	+	0,0012	***
580010	Publishing	0,3459	0,0407	+	+	0,0007	*
580020	Publishing of computer games and other software	0,2332	0,0784	+	-	0,0038	***
590000	Motion picture and television programme production, and sound recording activities	0,2793	0,0886	+	+	-0,0051	***
600000	Radio and television broadcasting	0,3176	0,0486	+	+	-0,0017	***
610000	Telecommunications	0,2507	0,0853	+	-	-0,0045	***
620000	Information technology service activities	0,3981	0,0594	+	+	-0,0023	***
630000	Information service activities	0,3279	0,0581	+	+	-0,0014	***
640010	Monetary intermediation	0,3826	0,0567	+	+	0,0029	***
640020	Mortgage credit institutes, etc.	0,1956	0,0329	+	+	-0,0009	***
650000	Insurance and pension funding	0,4574	0,0571	+	+	0,0000	
660000	Other financial activities	0,2481	0,1012	+	-	0,0055	***
680010	Buying and selling of real estate	0,4774	0,0966	+	+	0,0009	
680030	Renting of non-residential buildings	0,0635	0,0122	+	+	-0,0001	
680023	Renting of residential buildings	0,1105	0,0531	+	-	-0,0017	***
680024	Owner-occupied dwellings	0,1065	0,0331	+	+	-0,0012	***
690010	Legal activities	0,4082	0,0337	+	+	-0,0012	***
690020	Accounting and bookkeeping activities	0,5240	0,0395	+	+	0,0009	**
700000	Business consultancy activities	0,3328	0,1086	+	+	0,0064	***
710000	Architectural and engineering activities	0,4079	0,0400	+	+	-0,0016	***
720001	Scientific research and development (market)	0,4292	0,2037	+	-	0,0022	
720002	Scientific research and development (non-market)	0,4280	0,1363	+	+	-0,0085	***
730000	Advertising and market research	0,1836	0,0436	+	+	0,0022	***
740000	Other technical business services	0,3086	0,0312	+	+	0,0001	
750000	Veterinary activities	0,1381	0,2686	-	-	0,0101	***
770000	Rental and leasing activities	0,1240	0,0603	+	-	0,0013	**
780000	Employment activities	0,8312	0,1297	+	+	-0,0060	***
790000	Travel agent activities	0,2697	0,1164	+	-	-0,0063	***
800000	Security and investigation activities	0,4345	0,1072	+	+	0,0051	***
810000	Services to buildings, cleaning and landscape activities	0,4869	0,0551	+	+	0,0029	***
820000	Other business service activities	0,2875	0,0730	+	+	0,0034	***

840010	Public administration	0,5440	0,0415	+	+	-0,0023	***
840022	Defence, public order, security and justice activities (non-market)	0,6263	0,1276	+	+	-0,0079	***
840021	Rescue service ect. (market)	0,5710	0,1598	+	+	0,0018	
850010	Primary education	0,7835	0,0570	+	+	-0,0030	***
850020	Secondary education	0,6944	0,0567	+	+	-0,0028	***
850030	Higher education	0,5874	0,1057	+	+	-0,0061	***
850042	Adult and other education (non-market)	0,6249	0,0856	+	+	-0,0043	***
850041	Adult and other education (market)	0,2450	0,1375	+	-	0,0074	***
860010	Hospital activities	0,7207	0,1239	+	+	-0,0067	***
860020	Medical and dental practice activities	0,3818	0,0968	+	+	0,0055	***
870000	Residential care activities	0,6976	0,0805	+	+	-0,0047	***
880000	Social work activities without accommodation	0,7729	0,0430	+	+	0,0006	
900000	Theatres, concerts, and arts activities	0,1732	0,0350	+	+	-0,0009	***
910001	Libraries, museums and other cultural activities (market)	0,4664	0,1257	+	+	0,0019	*
910002	Libraries, museums and other cultural activities (non-market)	0,5136	0,0752	+	+	-0,0039	***
920000	Gambling and betting activities	0,1524	0,0394	+	+	-0,0018	***
930011	Sports activities (market)	0,5322	0,1466	+	+	0,0040	***
930012	Sports activities (non-market)	0,4377	0,2323	+	-	0,0026	
930020	Amusement and recreation activities	0,3147	0,0582	+	+	-0,0012	*
940000	Activities of membership organizations	0,4987	0,0878	+	+	0,0051	***
950000	Repair of personal goods	0,3897	0,1160	+	+	-0,0066	***
960000	Other personal service activities	0,2897	0,0297	+	+	-0,0007	***
970000	Activities of households as employers of domestic personnel	1,0661	0,0613	+	+	-0,0032	***

Significance levels:* 0,1 ** 0,05 ***0,01

The obtained results do not confirm the hypothesis about the substitution effect of expenditures towards the reduction of production costs. On the contrary, the results suggest that the causal relation is the opposite: an increase in demand for intermediate products (or reduction of supply) causes their prices to rise. In the context of further considerations, a detailed analysis of individual cost items should be undertaken, which would allow indicating those that played the crucial role in shaping the overall indices. Below we present the exceptional case, which is the extraction of oil and gas sector. The negative mean for the whole period results from the fuel crisis in the early 1970s.



Thanks to a unified methodology for creating IO tables, the described procedure can be applied universally. Necessary time series of IO tables expressed in previous year's prices will certainly become widely available, and the level of detail will almost certainly increase.

Pointing to the potential of input-output tables expressed in fixed prices was one of the motivations for writing this article. The authors hope that in this way they will encourage statistical offices to pay more attention to the construction of such tables.

References:

Acemoglu, D., Restrepo, P. (2017). Robots and jobs: Evidence from US labor markets. National Bureau of Economic Research.

Brynjolfsson, E., McAfee, A. (2014). The second machine age: Work, progress, and prosperity in a time of brilliant technologies. WW Norton & Company.

Chen, Y., Chen, Y. (2017). The impact of changes in the energy sector on the economy and prices: An input-output analysis. Energy Economics, 68, 24-31.

Przybyliński, M., Gorzałczyński, A. (2022) Applying the input–output price model to identify inflation processes. Economic Structures 11, 5 https://doi.org/10.1186/s40008-022-00264-w

Zhang, Y., Wang, Y., Li, Y. (2019). The impact of agricultural production structure on food prices: An input-output analysis. Journal of Cleaner Production, 220, 104-112.