Intersectoral diffusion of innovations. The case of Poland

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Plan of the presentation

- Innovations – definition, classifications
- Transfer of innovations
- Methodology employed
    - Process innovations
    - Product innovations
- Empirical results
- Conclusions

Definition of innovations (according to the Oslo methodology):

- Technological innovations take place when a new or improved product is introduced to the market or a new or improved process is applied, and both product and process are new for the enterprise introducing them.

Types of innovations:

- The above definition distinguishes two main types of innovations:
  - product innovations
  - process innovations

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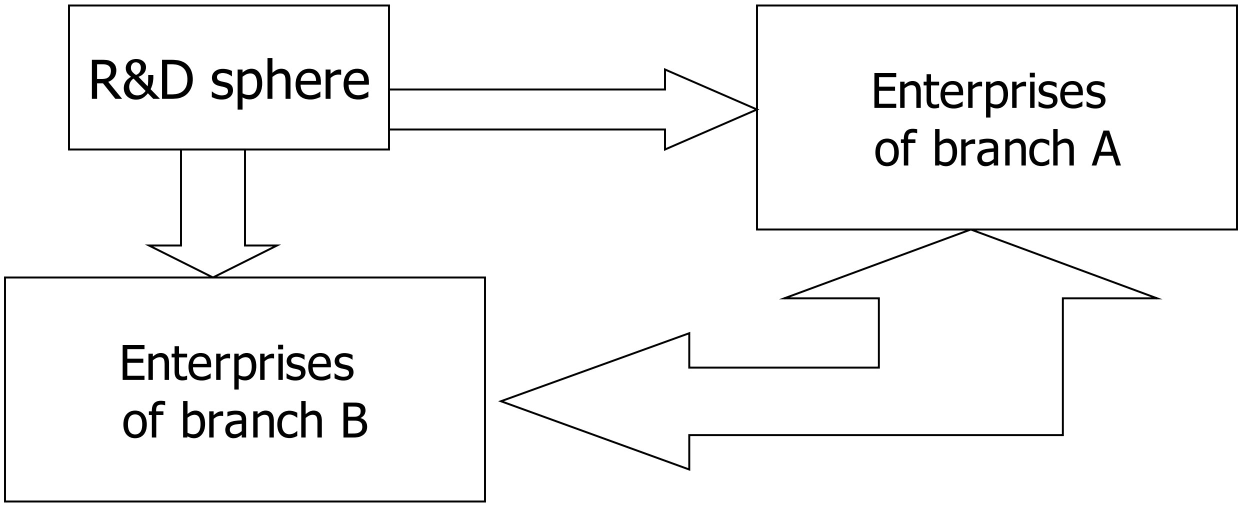
Transfer of innovations

- The significant feature of innovations is their ability to spread among other subjects which have not yet included the similar changes – in the framework of a given country and/or on an international scale.

- The diffusion process of innovation can be observed at several level (vertical transfer, horizontal transfer, social transfer).

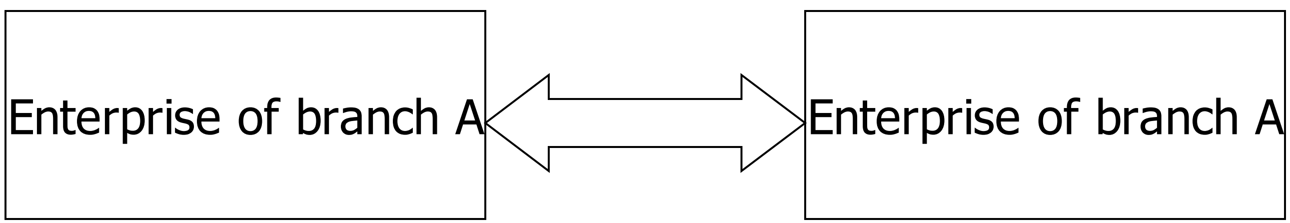
Vertical transfer of innovations

- **Vertical transfer of innovations (product and process) is the transfer between R&D sphere (being innovation supplier) and enterprises (receivers). R&D sphere can be treated as a distinct branch of the economy „producing” innovations, from which they flow straightforward to enterprises of a given sector or sectors (Pack H., Saggi K., 2001)**



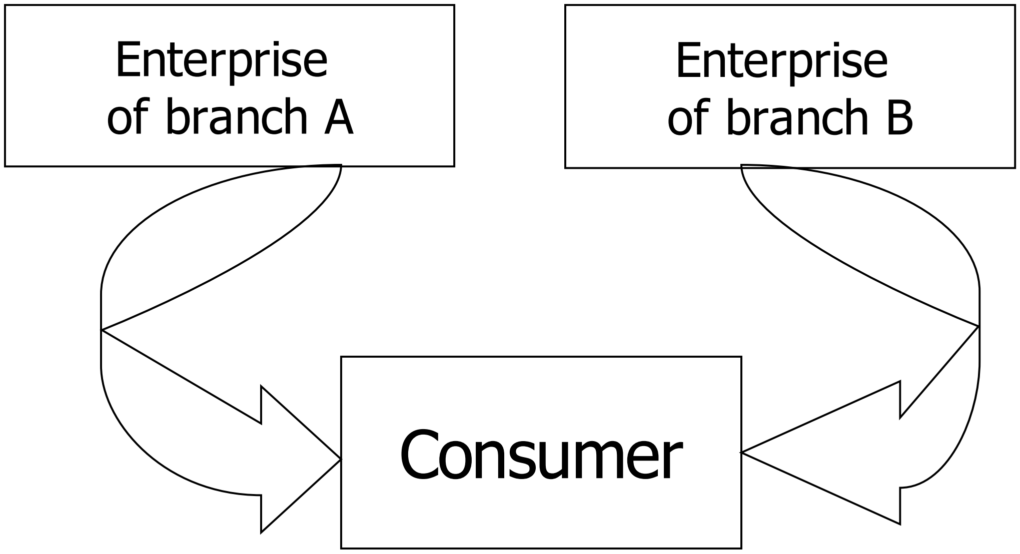
Horizontal transfer of innovations

- Horizontal diffusion (product and process) involves innovation transfers between enterprises of a given sector, within a one country or on an international scale (Kogut B., Zander U., 1992)



Social transfer of innovations

- Social transfer (mainly for product) – the key role is played by a consumer making decisions based upon the acceptation of a given innovation (Bauman et al., 1991)



Methodology employed

- The methodology is based on the idea presented by Dietzenbacher (2000).
- We analysed, through the raw materials flows between sectors, how the innovation are spreading through the economy and how they affecting the gross output in sectors.
- This methodology is based on Leontief inverse multipliers matrix, characterizing the strength of raw materials links between sectors, direct and, what is important for our analysis, indirect ones.

Methodology employed

Applying the standard Leontief model:

$$\mathbf{X} = \mathbf{AX} + \mathbf{y},$$

x

where **X** is the $n \times 1$vector of sectoral gross outputs (it is assumed that each of the n sectors produces exactly one good), **y** is the $n \times 1$ vector of final demands and **A**- is the $n \times n$ matrix of input coefficients. The elements of $a_{ij} = \frac{x_{ij}}{X_j}$ denote the amount of product i required, as an input in process j, for production of one unit of output of good j.

Methodology employed (2)

The fundamental assumptions of input-output model are the following:

- the flows of products from sector *i* to sector *j* depend only on gross output of sector *j* in the proportion of a_{ij}, i.e. $x_{ij} = a_{ij} X_j$,
- there is no substitution between inputs into *j* sector, meaning that the proportion between inputs in *j* sector is constant, $\left(a_{ij} / a_{kj} \right) = const.$,
- the model (1) is a static model,
- in the analyses carried out on the model the constant prices of gross output by sectors are usually assumed,
- each of the sectors produces homogenous product.

Methodolgy employed (3)

- The model (1) solved according to gross output by sectors has a form:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{y}$$

- Matrix $(\mathbf{I} - \mathbf{A})^{-1} = \mathbf{S} = \left[s_{ij}\right]$ is the Leontief inverse, or multiplier matrix.

- Its element denotes the additional output of product *i* as required (directly or indirectly) per additional of final demand for product *j*.

Methodolgy employed (4)

- The structure of links between sectors described by input coefficients are changed under process and product innovations.

- In Dietzenbacher (2000), it is assumed that the introduction of innovation into production process in the sector *k* increases the efficiency of this process, what diminishes the costs of raw materials and services used in sector *k* in the same portion α ($0<\alpha<1$). It means that the same amount of output engages less inputs, decreased by α times

- Product innovation in Dietzenbacher (2000) is understood as the increase of the efficiency of a given input use, resulting from the increase of the quality parameters of this input. Thus, it can be assumed that in each sector using this input, the same amount of gross output will be obtain with the less (β times) costs.

Methodolody employed (5) – Process innovation

Process innovation taking place in sector k is identified as a proportional decrease of each input with α*100% in sector k. It will be reflected by the decrease of coefficients of column k in the **A** matrix:

$$\overline{a_{ik}} = (1-\alpha)\cdot a_{ik}, \qquad \text{for} \qquad i = 1,2,\ldots n \qquad (3)$$

where $0<\alpha<1$.

Under the same final demand the standard Leontief model has a form:

$$\overline{\mathbf{X}} = \overline{\mathbf{A}}\cdot\overline{\mathbf{X}} + \mathbf{y}, \qquad (4)$$

where matrix $\overline{\mathbf{A}} = \left[\overline{a_{ij}}\right]$ differs from the **A** matrix only for column k, which elements are defined by formula (3).

The model (4) is solved as:

$$\overline{\mathbf{X}} = (\mathbf{I}-\overline{\mathbf{A}})^{-1}\mathbf{y} = \overline{\mathbf{S}}\cdot\mathbf{y}. \qquad (5)$$

Methodolody employed (6) – Process innovation

The process innovation causes:

- the increase of the efficiency of inputs used in sector *k* which means a decrease of production costs in this sector or - the same amount of gross output is produced with the smaller costs. The gross output value of this sector decreases under constant prices.
- in turn, it diminishes the demand for inputs in sectors being suppliers to sector *k*, thus, under constant prices the gross output of those sectors decreases (indirect effect in other sectors than *k*)
- through the feedbacks the use of sector *k* product in other sectors (indirect effect in sector *k*) also decreases.

Methodolody employed (7) – Process innovation

- The difference between k column of multiplires matrices can be written as:

$$(\overline{\mathbf{S}_k \cdot} - \mathbf{S}_k) = -\alpha \cdot \mathbf{A}\mathbf{e}_{\mathrm{k}} + \sum_{t=2}^{\infty} (\overline{\mathbf{A}}^{t} - \mathbf{A}^{t}) \cdot \mathbf{e}_k$$

The particular components of above sum express direct and indirect effects of sectoral gross output changes resulting from the unit increase of final demands for products of sector k, in which process innovation is applied.

Methodology employed (8) – Process innovation

- The difference between j column of multiplier matrices can be written as:

$$(\overline{\mathbf{S}}_j \cdot - \mathbf{S}_j) = \sum_{t=2}^{\infty} (\overline{\mathbf{A}}^t - \mathbf{A}^t) \cdot \mathbf{e}_j$$

It is seen that the effects of process innovations took place in sector *k* change the amount of gross output of all sectors needed in fulfilling the unit final demand for *j* sector product

Methodology employed (9) – Process innovation

As the measure of effects of propagation observed in sector *j* resulting from the innovations undertaken in sector *k*, Dietzenbacher (2000) proposes the following indicator:

$$dyf_i = \frac{\bar{s}_{ij} - s_{ij}}{\bar{s}_{kj} - s_{kj}} \qquad (6)$$

where $\bar{s}_{ij}$ is an amount of gross output of sector *i* being the effect of additional unit of final demand in sector *j.*

The above equation after some transformation can be performed as (Ditzenbacher, 2000)

$$dyf_i = \frac{s_{ik}}{s_{kk} - 1} \qquad (7)$$

It shows only the amount of propagation of innovations if process innovation is taking place in sector *k* for which product the unit final demand occurred.

Methodology employed (10) – Process innovation

Total effects of process innovation spillovers can be measured by the relationship of gross output changes in all sectors, except for sector *k*, to the changes of gross output in the whole economy. Therefore, the total spillover effect can be measured by formula:

$$spill_k = \frac{\sum_{i \neq k} (\bar{X}_i - X_i)}{\sum_{i} (\bar{X}_i - X_i)} \cdot 100\% \qquad (8)$$

This formula is equal to the indicator

$$spill_k = \frac{S_k - s_{kk}}{S_k - 1} \cdot 100\% \qquad (9)$$

where S_k -- is the gross output multiplier being the sum of elements of the column *k* of Leontief inverse matrix.

Methodology employed (11) – product innovation

The product innovations taking place in sector *k* change the row *k* of input coefficients by $\beta * 100$ %. This means that:

$$\overline{a_{kj}} = (1-\beta)\cdot a_{kj} \qquad (10)$$

where $\beta \in (0,1)$.

Parameter β characterizes the scale of the increase of the efficiency of input *k* use, resulting from the innovation, and therefore directly the use of product *k* in all sectors diminishes. Thus sector *k* requires less products as inputs from other sectors, in turn each of these products requires less inputs from sector *k*, what indirectly decreases the use of product *k*.

Methodology employed (12) – product innovation

In Dietzenbacher (2000) is shown that the amount of propagation effects of product innovation taking place in sector *k* can be described, similarly to the process innovation, by the changes of gross output in sector *i*, relatively to the changes of gross output in sector *k.* This ratio is equal to:

$$dyf_i = \frac{s_{ik}}{s_{kk}} \qquad (11)$$

Therefore it does not depend either on parameter β or final demand **y**.

Methodology employed (1) – product innovation

The total effects of spillovers of product innovation taking place in sector *k* is equal to:

$$\overline{spill}_k = \frac{S_k - s_{kk}}{S_k} \cdot 100\% \qquad (12)$$

It is easy to see that the effects of product innovation spillover ($\overline{spill}_k$) are evidently less than process innovation.

Empirical results

- Results presented in a paper are based on the input-output table for the Polish economy, including 54 sectors for the year 2000.
- The results give some empirical material for comparison with the results obtained by Dietzenbacher, in which the EU input-output table, including 25 sectors for 1991, was used.
- The Polish input output table was aggregated to 25 sectors, specified in EU table. Although these are tables for different years, it seems that the rough comparison is possible taking into account that the Polish economy is „delayed" in getting the EU input-output structure.

Table 1. The spillover effects of process innovation for Poland and EU

Sectors	$spill_k$ POLAND %	$spill_k$ EU %
Agriculture, forestry and fishing	64.8	76.8
Fuel and power products	50.7	46.7
Metals	73.1	59.8
Nonmetallic mineral products	87.9	83.2
Chemical products	74.6	67.7
Metal products (except machinery and transport equipment)	89.9	89.5
Machinery (agricultural and industrial)	92.4	85.4
Office equipment	76.1	91.7
Electrical goods	90.9	85.1
Transport equipment	81.9	84.5
Food, beverages and tobacco products	79.9	81.8
Textiles and clothing, leather and footwear	70.2	68.6
Paper and printing products	65.7	60.6
Rubber and plastic products	86.1	91.6
Other manufacturing products	77.6	82.6
Building and construction	82.7	92.4
Trade	85.4	93.3
Lodging and catering services	99.2	99.2
Inland transport services	91.3	96.5
Maritime and air transport services	90.4	92.4
Auxiliary transport services	86.9	85.6
Communication services	82.7	92.4
Credit and insurance	52.1	42.4
Other market services	74.4	69.6
Nonmarket services	95.5	92.9
Average	80.2	80.5
Spearman Rank correlation coefficient	0.80	

Source: For Poland – authors' calculation;
For EU – Dietzenbacher, 2000, p.35;

Table 2. The ranking of ten branches with the highest of percentage changes of gross output

Poland		EU	
Sectors	$spill_k$ %	Sectors	$spill_k$ %
Lodging and catering services	99.2	Lodging and catering services	99.2
Nonmarket services	95.0	Inland transport	96.5
Machinery&equipment	92.4	Trade	93.3
Inland transport	91.3	Nonmarket services	92.9
Electrical goods	90.9	Martimate&air transport	92.4
Martimate&air transport	90.4	Communication services	92.4
Metal products	89.9	Building and construction	92.4
Nonmetalic mineral products	87.9	Office equipment	91.7
Auxiliary transport services	86.9	Plastic and rubber products	91.6
Plastic and rubber products	86.1	Metal products	89.5

Source: For Poland – authors' calculation;
For EU – Dietzenbacher, 2000, p.35;

Table 3. The ranking of branches with the most similar and with the most different effects in the process innovation

Branches with most similarities	Branches with most differences
1. Lodging and catering services	1. Office equipment
2. Metal products	2. Metals
3. Auxiliary transport services	3. Building and construction
4. Textiles	4. Credit & insurance
5. Food, beverages, tobacco	5. Communication services

Source: For Poland – authors' calculation;
For EU – Dietzenbacher, 2000, p.35;

Table 4. The spillover effects of product innovation for Poland and EU

Sectors	$\overline{spill}_k$ POLAND %	$\overline{spill}_k$ EU %
Agriculture, forestry and fishing	36.6	39.8
Fuel and power products	24.2	17.6
Metals	38.1	35.9
Nonmetallic mineral products	43.5	40.6
Chemical products	28.3	36.9
Metal products (except machinery and transport equipment)	42.9	45.6
Machinery (agricultural and industrial)	34.4	43.3
Office equipment	10.5	44.8
Electrical goods	39.2	40.4
Transport equipment	37.8	45.3
Food, beverages and tobacco products	47.7	45.9
Textiles and clothing, leather and footwear	28.9	35.8
Paper and printing products	32.1	30.2
Rubber and plastic products	37.4	47.0
Other manufacturing products	35.4	41.7
Building and construction	44.3	44.1
Trade	34.8	31.8
Lodging and catering services	47.2	45.4
Inland transport services	39.6	40.2
Maritime and air transport services	40.1	41.7
Auxiliary transport services	41.9	29.7
Communication services	30.0	19.4
Credit and insurance	27.0	29.9
Other market services	32.9	17.7
Nonmarket services	26.6	33.3
Average	35.6	36.9
Spearman Rank correlation coefficient	0.46	

Source: For Poland – authors' calculation;
For EU – Dietzenbacher, 2000, p.35;

Table 5. The ranking of ten branches with the highest of percentage changes of gross output (product innovation)

Poland		EU	
Sectors	$spill_k$ %	Sectors	$spill_k$ %
Food, beverages and tobacco	47.7	Plastic and rubber products	47.0
Lodging and catering services	47.2	Food, beverages and tobacco	45.9
Building and construction	44.3	Metal products	45.6
Minerals	43.5	Lodging and catering services	45.4
Metals products	42.9	Transport equipment	45.3
Auxiliary transport services	41.9	Office equipment	44.8
Martimate&air transport	40.1	Building and construction	44.1
Communication services	40.0	Machinery and equipment	43.3
Inland transport	39.6	Martimate&air transport	41.7
Electrical goods	39.2	Other manufacturing products	41.7

Source: For Poland – authors' calculation;
For EU – Dietzenbacher, 2000, p.35;

Table 6. The ranking of branches with the most similar and with the most different effects in the product innovation

Branches with most similarities	Branches with most differences
1. Building and construction	1. Office equipment
2. Inland transport	2. Communication services
3. Electrical goods	3. Other market services
4. Maritime & air transport	4. Auxiliary transport services
5. Food, beverages, tobacco	5. Plastic and rubber products

Source: For Poland – authors' calculation;
For EU – Dietzenbacher, 2000, p.35;

Conclusions

- This methodology was applied for the Polish *i-o* table for 2000, and a certain comparison with the results obtained by Dietzenbacher for EU was presented.
- In the case of process innovations, the results for Poland are more similar to the results obtained by Dietzenbacher for EU. Typically, sectors that depend predominantly on themselves, as reflected by large diagonal elements of input coefficients matrices, exhibit low spillovers. From this reason, the larger spillovers of process innovation effects were reported for the service sectors – these sectors are characterized by a large dependence upon other sectors.
- For product innovation, the spillovers effects were found to be two to three times smaller than those of process innovations. The larger spillovers effects were obtained for manufacturing sectors, rather than for service or raw materials sectors in the case of EU. For Poland this statement is not so obvious.