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Innovation subsidies, competition, and labor productivity

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Abstract

This paper has tried to answer the following research question: *What is the relation between providing innovation subsidies and labor productivity through innovation and competition?* An answer was found by using an OLS regression with the control variables general expenditure on education per GDP and the age dependence rate. No causal effects could be established since the results are not significant and multiple biases are present. A positive relation between innovation and labor productivity, and competition and labor productivity is found. Also, the relation between innovation subsidies and innovation, and innovation subsidies and competition turned out positive. This makes the results suggest that the overall relation between innovation subsidies and labor productivity through innovation and competition is positive, due to the sum of only positive effects. The literature-based idea that innovation subsidies and innovation output could lead to a reduction in the level of competition was not found in this research.

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I. Introduction

For 2022 the United States has reserved more than 170 billion dollars for federal research and development (R&D) funding, increasing the budget by 8.5 percent compared to 2021. The motivation: "strengthening U.S. innovation and competitiveness in the global economy" (Sargent et al., 2022, p.1). Just as the European Commission budgeted close to a 100 billion euros for the research and innovation funding program 'Horizon Europe', running from 2021 to 2027. Here as well, one of the goals of the programme is to further strengthen the competitive advantage (European Commission, 2021). Clearly, these world leaders value innovation highly. But what are the effects of such innovation subsidies on labor productivity, a driver of economic growth? One might think it increases because of the innovations following from it. On the other hand, when market powers increase their market share and thus competition gets lowered, by either the subsidy itself or the innovation following from it, labor productivity might eventually decrease.

This leads to the following research question: *What is the relation between providing innovation subsidies and labor productivity through innovation and competition?*

Relevance

Since several years two major economic trends can be experienced, which make the research question highly relevant. Firstly, there is a decrease in productivity growth (Bergeaud, Cette, & Lecat, 2016). Secondly, the labor force is declining (Karabarbounis & Neiman, 2014). Therefore, an increase in labor productivity is desired to make the economy grow. Even more, when considering that another factor that can increase economic growth, more input, might not be desirable. This will damage the climate, which in the long run will have a negative impact on economic growth (Tol, 2018). As innovation is generally seen as labor productivity increasing and thus a lot of subsidies are provided, it is important to check whether the effects of innovation actually exceed the possible negative effects of competition. The outcome will be of value to policy makers, firms and individuals.

The analysis in this paper is done using an OLS regression. The data consists of the gross domestic spending on R&D per GDP as proxy for innovation subsidies and the GDP per hours worked as proxy for labor productivity. For the data on innovation output, the global innovation index is used. Competition is measured with the Herfindahl–Hirschman index. This all, led to the finding that both innovation and competition have a positive relation with labor productivity. Also, innovation subsidies have a positive relation with both innovation and competition. Therefore, the overall relation between innovation subsidies and labor productivity was found to be positive.

The structure of the paper is as follows. Chapter II provides a literature review on previous research about the effect of providing innovation subsidies on labor productivity through innovation and competition. From the literature review, hypotheses will follow. A timeline of events is shown in chapter III. Chapter IV gives an empirical analysis to answer the research question. Finally, a discussion and conclusion will follow in chapter V and VI.

II. Literature review

To get a good view on what has already been researched, the existing literature will be reviewed. Before that, the definitions of the key terms maintained in this paper will be explained. Then, the effects of innovation and competition on labor productivity will be discussed separately. Next, the mutual effects between innovation and competition will be analyzed. After that, it will be addressed how innovation subsidies effect innovation and competition. The explained literature will then lead to several hypotheses.

Definitions

The following terms will be defined: innovation subsidy, innovation, competition and labor productivity. Innovation subsidy is defined as a government intervention aimed at supporting the research, development and creations of innovations (Rua, 2022).

The literature separates two types of innovation: product and process innovation. Product innovation can be defined as a product that is significantly different from previous ones (OECD & Eurostat, 2018). Process innovation can be defined as a production method that is significantly different from previous ones (OECD & Eurostat, 2018).

Competition can be seen as “the ability of a firm to influence price” (Stigler, 1972, p. 92). In this paper the use of the term competition will be interchangeable with the term market concentration, which is a proxy for competition. It measures the degree of concentration of market shares under a number of firms or countries (OECD, 2018).

Productivity can be measured in multiple ways. In this paper we focus on labor productivity, but in the literature review total factor productivity is also included. Labor productivity is output per input of labor, where total factor productivity is the output per total input (Eurostat, 2013). Both are useful as measures for economic growth (Sargent & Rodriguez, 2000).

Innovation and labor productivity

Creating an improved product with product innovation attracts a wider range of consumers, such that demand will increase. This can increase labor productivity due to scale economies. If these new products require less materials to manufacture, labor productivity is also improved in this way (Mohnen and Hall, 2013).

In the case of an improved process, productivity can increase because higher output can be achieved with fewer input, for example the amount of labor. A decrease in production costs follows because of this productivity improvement, which can lower the price for consumers as well. This in turn will give raise to demand. With economies of scale, the resulting increase in sales gives way to higher productivity (Mohnen and Hall, 2013).

Now that the theoretical effects are clear, some empirical research on the effects of innovation on labor productivity will be reviewed. Studying French manufacturing firms, Crépon et al. (1998) construct a new technique to look at the way research affects innovation and the way innovation and research affect productivity. Their CDM-model is based on four equations which show the effect of research on its determinants, the effect of research on innovation output and the effect of innovation output on productivity. The latter one is the most relevant for this paper. To research this effect, they set up an augmented Cobb-Doulas production function. The input variables are physical capital, employment, skill composition and innovation output, which is measured by expected patents per employee or by the share of innovative sales. The data they use consist of 4164 firms that filled in an innovation survey. A positive correlation between innovation output and productivity is found using this method.

Looking at small and medium-sized enterprises in Italy, Hall et al. (2009) find a positive impact of innovation on labor productivity. They use data from three surveys on manufacturing firms covering nine years. To find the relation between innovation and labor productivity, a Cobb-Douglas production function, as imposed by the CDM-model, is used. The output variable is labor productivity, and the input variables are physical capital and the predicted probability of product and process innovation, which they found by looking at the input of R&D. As a result, process innovation is found to lead to a 2.62 times higher labor productivity. It must be said that this is mostly due by investment in capital. Product innovation shows a smaller result (0.96), but with more robustness to investment.

Harrison et al. (2014) find a varying effect of innovation on productivity when looking at the channels through which innovation affects employment. They use random samples from manufacturing and service firms from France, Germany, Spain and the United Kingdom. The dataset contains in total 20,000 firms who report data about their sales and introduction of process and product innovation from 1998 to 2000 in the Community Innovation Survey of Eurostat. When looking at manufacturing, three of the countries show a higher productivity growth for innovating firms. In Spain no difference in the productivity growth for innovating and non-innovating firms is shown. In services, half the countries show a higher productivity growth of innovators and half show a higher productivity growth of non-innovators.

In conclusion from the above, a positive impact of innovation on (labor) productivity is found in several cases when looking at manufacturing firms, both for process and product innovation. A less clear result was found for services, so that little can be said about the effects in that industry.

Competition and labor productivity

Competition influences the productivity of companies through three different processes: innovation, efficiency gains and diffusion (Pilat, 1996). First, competition puts pressure on companies to innovate, which, as shown above, mostly has a positive effect on productivity. More on the relationship between competition and innovation will be discussed in the next paragraph. Inefficient firms will also be forced to restructure and reallocate to avoid an exit from the competitive market. To survive, there is no place for organizational slack. Technological diffusion plays a role in the productivity level as well. Firms will take over products and processes developed by others to increase their productivity. This is mostly encouraged by international competition.

In the literature the most is said about efficiency gains, where the focus is on organizational slack by managers. In general, the goal of managers and owners is not aligned. Managers strive for effort minimization, while owners want profit maximization. Since managers have the control in the firm, they have the opportunity to implement their inefficient policy (Hart, 1983). In a market with a homogenous good, where firms are separated by the fact that they are run in the interest of the owner (entrepreneurial firm) or in the interest of the manager (managerial firm), Hart (1983) finds that the average amount of managerial slack will be reduced in case of correlated firms' environments. No reduction is seen if the firms' environments are independent. The correlation is suggested to be caused by competition. The reduction in managerial slack in case of correlated firms' environment is a result of the fact that entrepreneurial firms will expand in times of low cost. Then product prices decrease, and managerial firms do not have the opportunity anymore to be that inefficient as they would have been if only their costs were low and no change in product prices would appear. The entrepreneurial firms make it easy to evaluate managers of managerial firms when the environments are correlated. So, the correlation caused by competition makes the managerial slack decrease, though not disappear.

However, this model is criticized by Scharfstein (1988) and Schmidt (1997) because of the specific manager's utility function: beyond a certain threshold the manager does not give value to income anymore. Scharfstein (1988) even shows that managerial slack increases because of competition when the manager derives strictly positive utility from income and concludes that too little is known to make hard statements about the effect of competition on manager incentives. Schmidt (1997) himself creates a model where he focusses on the idea that competition reduces profits to a point where the firm is threatened with liquidation and then looks at the effects on managerial incentives of it. Assumed is that the manager has a negative utility when he loses his job due to a liquidation. The combination of this disutility and the fact that it becomes cheaper for the owner to incentivize the manager, makes that an increase in competition increases the managers productivity. Another effect only occurs when the manager gets paid a rent on top of his reservation wage. Because of competition and thus a lower profit margin, the value of cost reductions can decrease. Then the effort of the manager is of lower value to the owner and the rent is reduced. As said, this only plays a role when the participation constraint of the manager is not binding. Otherwise, the liquidation-effect makes that competition leads to an increase in the managers productivity.

An empirical analysis on the differences in impact of competition on productivity for entrepreneurial and managerial firms is done by Griffith (2001). To measure the level of competition, the European Union Single Market Programme is used as an instrumental variable. This program was established to generate free movement of goods, services, capital and labor in the EU. To express the correctness of the program as instrument, Griffith (2001) shows a correlation with the Lerner Index. Using data on UK manufacturing firms from 1980 to 1996, four groups are established based on if the program was ex ante expected to increase competition or not and if they are an entrepreneurial or a managerial firm. The study results in a positive relation of competition on productivity for managerial firms, but this was not found for entrepreneurial firms. Griffith (2001) states that the raise in productivity through competition could be due to a decrease in agency costs.

Now we will take a further look at the empirical literature on an increase in international competition. For example, this study that looked at the effect of the Canada-US Free Trade Agreement (FTA) (Trefler, 2004). This agreement, where tariff reductions were granted from Canada to the US, gives rise to an increase of competition in Canada. The data contains the pre-FTA period, 1980 to 1986, as well as the years 1989 to 1996 in which the tariffs had to be reduced each year. It includes the 213 industries that stem from the Canadian Standard Industrial Classification data. Labor productivity is defined as value added in production activities per hour worked by production workers. Using OLS, Trefler (2004) finds an increase in labor productivity of almost six percent in the manufacturing industry. As explanation for this increase scale effects and reorganization of Canadian plants are mentioned, but not confirmed.

Another study is done in the manufacturing industry in Australia. Bloch and McDonald (2001) use a database that contains information on Australian firms over the period 1983-1994, after the border protection has decreased significantly due to lower tariffs and import quotas. The labor productivity is measured as the ratio of real revenue to the number of employees and competition is based on the share of the domestic market and the share of exported output. The regression results show that labor productivity increases through import competition from a minimum level of market concentration, after which the positive effect grows with higher market concentration.

So, although the theory is somewhat ambiguous about the relationship between competition and productivity, the empirical literature finds it to be positive.

Innovation and competition

Innovation can affect competition due to firms gaining market share after successfully innovating. Competition can affect innovation because in a highly competitive market firms are forced to be as efficient as possible. These are examples which show the reversed causality in the relationship between innovation and competition. For this paper the effect of innovation of competition is the most important, since we do assume innovations to change competitions levels, but we do not assume competition to be a driver of innovation. Nevertheless, the relationship will be discussed both ways because crucial insights are given by the literature.

Aghion et al. (2005) did breakthrough research on the effect of competition on innovation. The used data contains 311 firms in 17 industries in the United Kingdom from 1973 to 1994. Innovation is measured as the average number of citation-weighted patents of firms and the Lerner index is used to measure competition. Using a Poisson regression, they find an inverted-U shape relationship between innovation and competition, which can be interpreted in the following way: if there is initially low competition and competition rises, higher innovation is expected; if there is initially high competition and competition rises, lower innovation is expected. Next, they use multiple policies as instrumental variable for changes in competition. The results still show the inverted-U shape. To explain the outcome Aghion et al. (2005) constructed a model where there are two possible effects of competition. In the case of high competition in a neck-and-neck situation, laggards will have lower incentives to innovate, because the profit benefits of catching up are small. This is called the Schumpeterian effect. On the other hand, the firms in that high competition neck-and-neck situation will have higher incentives to innovate because of the higher value to get ahead. This is called the escape-competition effect, thought of by Arrow (1962). In conclusion is the effect of competition on innovation ambiguous.

Aghion et al. (2018) further investigated the relationship with two laboratory experiments where they pair people and let one person per period choose R&D investments. Each pair represents a sector and after a period they receive rents for their relative technological location in the sector. Both the escape-competition and Schumpeterian effect are confirmed with the experiment. The latter one shows to be stronger with a shorter time horizon. A positive effect of competition on aggregate innovation is found.

Less is said about the effect of innovation on competition, but that does not make it less present. An understanding of the literature will be discussed here. Innovation can influence competition in various ways: changing the market structure, driving out competitors or blocking market entrants (OECD Secretariat, 2023).

The idea that innovation influences competition can be derived from Schumpeter's (1942) theory of creative destruction. The idea that new innovations keep destroying old ones and their dominancy, is based on the fact that innovation leads to market power and a temporarily decrease in competition.

Furthermore, Van Heerde et al. (2004) look at the effect of innovation on market structure. Research was done by studying the introduction of an innovative product in the frozen pizza industry. A new brand introduced the innovative rising-crust pizza, which was found to change the market structure. By uncovering an increase in cross-price elasticities for existing brands, which measure the change in demand for one good in response to the change in price of the other good, Van Heerde et al. (2004) conclude that the introduction of the innovative product by the new brand has led to the existing brands being seen as more similar by consumers and therefore closer substitutes. Also, the price elasticity of the existing brands increased, which indicates reduced revenue. A change in competitive position because of innovation is found.

Other research shows a sometimes positive relationship between innovation and market concentration, in a way that there is a decrease of competition. Alfranca et al. (2014) uses the Herfindahl index to measure the degree of concentration in the European wood industry from 1996-2007. R&D spending and R&D personnel are used to define innovation. With the seemingly unrelated regression method, the outcome that innovation strengthens market concentration is found, but only when initial market concentrations is sufficiently high. Alfranca et al. (2014) indicate that this could be because firms in low competitive markets innovate with the purpose to reinforce their leading position.

From all the above it can be understood that the effect of competition on innovation is, if it is there, one with a more permanent result since innovation will not be reversed. On the other hand, the effect of innovation on competition is more circular due to the ever-changing market structure as a result of these innovations. Also, there seems to be a positive relationship from competition to innovation, but a negative relationship from innovation to competition. Although, the latter is suggested to depend on an initially high competition level.

Innovation subsidies

We will now take a look at innovation subsidies and their effects. It is relevant when researching the effect on labor productivity to take innovation subsidies as the first link in the process, because these are an essential element for some firms to be able to carry out an innovation at all (González & Pazó, 2008). Also, by providing innovation subsidies to only a few sectors or companies, an effect on competition can arise, which in turn can affect labor productivity, as discussed before.

The OECD (2022) explains a subsidy is generally seen as good when it tackles market failures (like monopolies) and thus increases efficiency. A bad subsidy distorts a market and thus decreases efficiency. A legitimate reason for the use of subsidies is underinvestment in R&D. Also, the effect of subsidies on competition is clearly explained. By subsidizing, non-subsidized competitors can experience trouble entering the market or even have to exit because of a loss of market share.

The effect of policies on competition and productivity when allocated to certain sectors is studied by Aghion et al. (2015). As industrial policies are taken subsidies, tax holiday, loans and tariffs. The data contains medium and large firms in China from 1998 to 2007. Competition is measured with the Lerner Index at both county and sector level. Productivity is defined as the cost reduction following from process innovation. The main outcome states that productivity increases if policies are granted in competitive sectors. They argument that industry policies in competitive sectors help firms to innovate and improve productivity instead of differentiating horizontally and escape the competition. Using OLS with firm-level fixed effects and the Olley-Pakes method, the result is found that subsidies have a positive relationship with productivity if granted in sectors with initial high competition. Also, this relationship turns out to be even more positive when policies are not concentrated on just a few firms within the sector.

González et al. (2005) find that most of the subsidies are granted to firms who would have innovated anyway in the Spanish manufacturing industry in the 1990s. Which is thus not in line with the justifications for the use of subsidies given by the OECD (2022). While this same research shows also that other firms only perform innovatively if they receive a subsidy. Although private R&D expenditures are not founded to be crowded out by the subsidy, this again shows that the correct allocation of innovation subsidies is crucial to get the most out of it.

Those financial constraints of mostly small firms are researched by Bronzini & Piselli (2016). They look at the effect of innovation subsidies on innovation output for small and medium sized firms in Italy when a business R&D program is implemented in the 2000s. As measure for innovation output, they use patent applications. With a regression discontinuity design, it is found that the program leads to a higher amount of patent applications, especially for small firms.

The finding that small firms might depend on innovation subsidies to innovate effectively will not further be researched in this paper, but facilitates as idea for a follow-up study. The above has also contributed to a new insight that for research of the effect of innovation subsidies on labor productivity through innovation and competition it matters if the subsidies are provided in initially highly competitive markets or not. However, also to this finding it applies that no further discussion of it will take place in this paper. What will be of direct use to the research in this paper are the ideas that innovation subsidies lead to higher innovative output, at least in terms of patent applications. As well as that (bad) subsidies can lead to a lower level competition leading to lower efficiency.

Hypotheses

The following hypotheses are created based on the literature review above:

Hypothesis 1: Innovation will lead to higher labor productivity.

Hypothesis 2: Competition will lead to higher labor productivity.

Hypothesis 3: Innovation subsidies will lead to higher innovation.

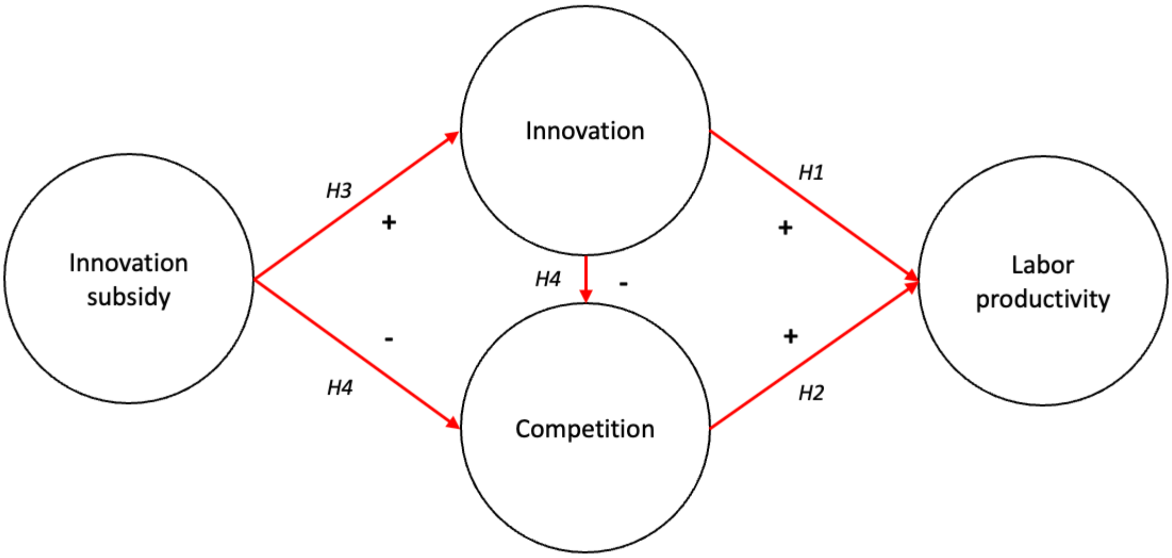
Hypothesis 4: Innovation subsidies and innovation will lead to lower competition.

III. Timeline

The idea of this research is the following. Innovation subsidies are provided which causes innovation to occur. As a result of the innovation subsidy and subsequent innovation, a decrease in competition occurs. The higher innovation has a positive effect on labor productivity, while the lower competition has a negative effect on labor productivity. The overall effect on labor productivity depends on the sum of the impact of the variables between innovation subsidy and labor productivity, namely innovation and competition. The timeline is shown below in the form of a directed acyclic graph, which visualizes relationships between events.

Figure 1

Directed acyclic graph, including hypotheses



IV. Empirical

Data

The dataset for this paper contains data from the Organisation for Economic Co-operation and Development (OECD), the World Integrated Trade Solution (WITS), the World Intellectual Property Organization (WIPO) and the World bank's World Development Indicators (WDI).

The OECD is an international organization mainly concerned with setting standards for economic and social policies for its 38 member states (OECD, n.d.). WITS is a software that provides data on trade and tariffs. It is maintained by the World Bank in collaboration with United Nations Conference on Trade and Development (WITS, n.d.). The WIPO is a self-funding agency of the United Nations, who brings out the global innovation index each year. To do so, they look at 80 indicators of 132 countries (WIPO, n.d.). The WDI is the main databank of the World Bank and provides cross-country comparable data on development. Their data includes the following themes: poverty and inequality, environment, markets, people, economy and global links (World Bank, n.d.).

As a measure for labor productivity, the gross domestic product (GDP) per hour worked in US dollars current PPP from the OECD is used. It operates with the total hours worked of all persons engaged in production. The data contains information from 40 countries over the period of 1990 to 2021 but does have missing observations.

To look at innovation subsidies per country, the gross domestic spending on R&D in US dollars current PPP from the OECD is used. As source of funding, the government sector is selected, since we do not want to include expenditure by the business or education sector when looking at innovation subsidies. Then the GDP in US dollars current PPP from OECD is used to get the gross domestic spending on R&D per GDP. The data contains information from 34 countries over the period of 1990 to 2020 but does have a lot of missing observations.

As measure of innovation, we will only look at innovation output. A database from the WIPO provides innovation output as sub-index from the global innovation index. The scores received from the innovation output sub-index reach from 0 to 100 and are based on the following criteria: knowledge creation, knowledge impact, knowledge diffusion, intangible assets, creative goods and services, and online creativity. The data contains information from 40 countries over the period of 2013 to 2021 but does have missing observations.

For competition the Herfindahl–Hirschman index is used, which is a measure for market concentration. It is calculated by the sum of all squared market shares in an industry. The outcome of 0 means there is perfect competition and the outcome of 1 means there is only one monopolistic producer (Eurostat, 2021). WITS provides the HH market concentration index over the period of 1990 to 2020 for 38 countries but does have missing observations. It is defined as the concentration of a countries trade. Trade to a few markets has an index around 1 and a diversified trade portfolio leads to an index around 0.

Since it is not a randomized experiment where randomly selected countries undergo innovation subsidies leading to innovative output and competition consequences and others do not, selection bias is most likely to enter. This implies that the outcome without innovation subsidies will not be similar for countries; there is initial difference. To try and isolate the effect of innovation subsidies from the selection bias, control variables will be added. However, we cannot include all variables relevant for the model, such that also the omitted variable bias will appear. Especially, since we can only control for observable variables.

The control variables need to affect the dependent variable and the independent variable. For hypotheses 1 and 2 this means that it needs to have an influence on the labor productivity of a country and on innovative output and competition. For hypothesis 3 the control variable needs to have an influence on innovation and on innovation subsidies and for hypothesis 4 on competition and on innovation subsidies and innovation. In this paper the following control variables will be used: the government expenditure on education per GDP and the age dependency ratio. The data for these control variables is taken from WDI for 32 countries and the years between 2013 and 2020. A small number of observations is missing.

Government expenditure on education is measured as percentage of GDP. Spending on education can affect the labor productivity of a country, since higher educated people might work very efficient. It can affect innovation subsidies in a way that higher educated people might innovate more and therefore request more innovation subsidies. Another way of thinking is that higher educated people are better informed about the possibility of an innovation subsidy and therefore request more innovation subsidies. Competition is also influenced by the government expenditure on education, at least through innovation and innovation subsidies.

The age dependency ratio measures the number of dependents as percentage of the working age population. Dependents are younger than 15 and older than 64. The working age population is between 15 and 64 years old. The age dependency ratio can influence labor productivity since it affects the labor force. A bigger labor force can for example give rise to economies of scale. Also, innovation and innovation subsidies might be influenced by it. For example, in a country with a high age dependency ratio the focus of innovation and innovation subsidies might lie on the health care sector. This focus on spending on the domestic health care sector by the government is a way in which competition can be influenced by the age dependency ratio.

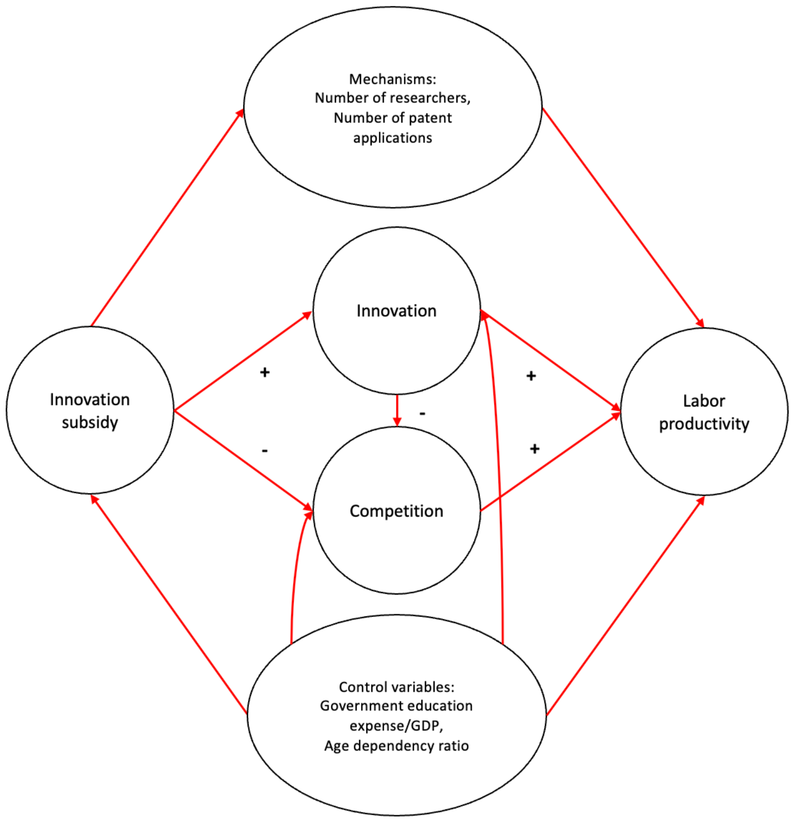
The number of researchers in R&D is specifically not included as control variable since these can be an outcome of the dependent variable innovation subsidies, which makes it a mechanism. The same holds for the number of patent applications. Assumed in this paper is that the number of researchers in R&D and the number of patent applications in a country is an outcome of innovation subsidies and that innovation subsidies are not an outcome of the number of researchers in R&D or the number of patent applications. In the last situation the variables should be included as control variable, in the first they should not. Otherwise, the variable takes away part of the impact of innovation subsidies on labor productivity. For that reason, they are not included as control variable here.

The above leads to a balanced dataset with 6 variables for 32 countries from the years 2013 to 2020. The included countries are the following: Austria, Belgium, Canada, Chile, Colombia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Israel, Italy, Japan, Latvia, Lithuania, Luxembourg, Mexico, Norway, the Netherlands, New Zealand, Poland, Portugal, Slovenia, Spain, Sweden, Switzerland, the United Kingdom, and the United States.

To give a clear view on the relationships between the variables, a directed acyclic graph is shown again.

Figure 2

Directed acyclic graph, including control variables and mechanisms



To give insight in the data, the descriptive statistics are included in the table below.

Table 1

Descriptive statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
Labor productivity	1,062	38.178	20.256	5.763	128.373
Innovation subsidies	776	0.232	0.459	0.001	2.787
Innovation output	296	42.219	10.074	18	68.6
HH index	1,062	0.121	0.127	0.032	0.708
Educational expenditure	216	5.092	1.079	3.078	8.494
Age dependency ratio	220	53.264	5.571	41.881	70.934

Note: Descriptive statistics of the labor productivity, the gross domestic spending on R&D per GDP, the innovation output, the HH market concentration index, the government expenditure per GDP, and the age dependency ratio. Per variable the number of observations, the mean, the standard deviation and the minimum and maximum are given.

Methodology

To answer the hypotheses a cross-country regression in the form of OLS will be used. With OLS the difference between the observed data and the predicted linear approximation of the function of the independent variable is minimized. In the OLS-regressions, the control variables government expenditure on education per GDP and age dependency ratio are included to minimize the omitted variable bias.

Logically, labor productivity is not affected overnight. Therefore, a delay in the independent and control variables should be included. The literature states that the effect of innovation subsidies on innovation output has a delay of two years (Liu et al., 2019; Wang & Sawur, 2022). Furthermore, the benefits from firm improvements take some time to materialize. Bloom et al. (2013) found that a change in management does not need more than one year to affect productivity significantly. However, for this paper, we cannot be sure about the delay in effect. Therefore, the average of a delay from one to seven years is taken, which is the full range of the balanced dataset (2013-2020). For both the independent variables and the control variables, the average of a delay from one to seven years is taken to test it on the dependent variable in the year 2020.

To get a first look at the relationship between labor productivity and innovation, and labor productivity and competition, the scatterplots below have been added. Since a lower market concentration index means higher competition, the x-axis in the scatterplot of the HH market concentration index and labor productivity is reversed, to make the sign of the correlation more visual.

Both the scatterplots show a positive correlation with labor productivity. This is in line with the hypotheses 1 and 2. A strong correlation between innovation and labor productivity is shown in Figure 3, such that a general trend can be observed clearly. In the scatterplot of the relation between HH market concentration index and labor productivity (Figure 4), it can be seen that the distribution is skewed to the left. Two outliers are shown: Canada and Mexico. This might be due to the fact that their trade is very concentrated on the United States (Government of Canada, 2022). A high HH market concentration index will follow from it, because their trade portfolio is little diverse. When Canada and Mexico are deleted from the dataset, a better distribution appears with still a positive relation. Since these are explainable outliers and no measurement error, elimination from the data for the regression analyses is not necessary.

Figure 3

Scatterplot of the relation between innovation output and labor productivity

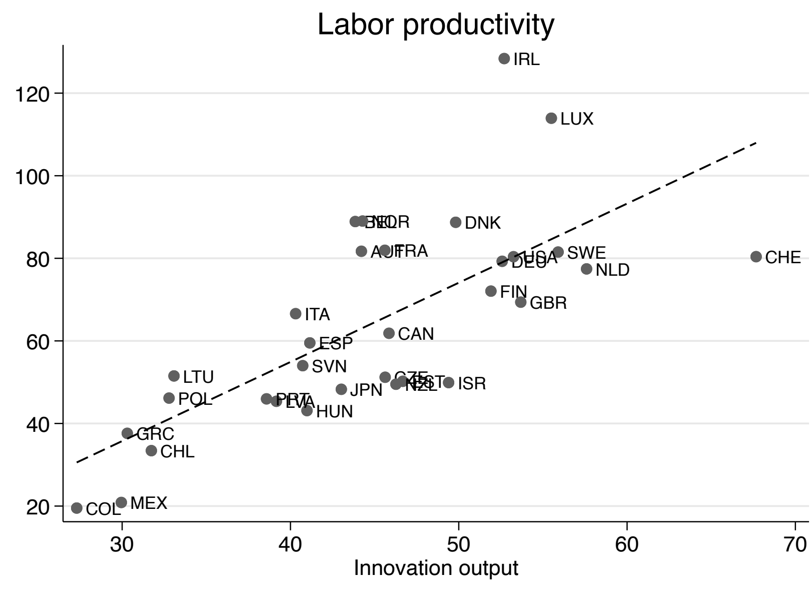
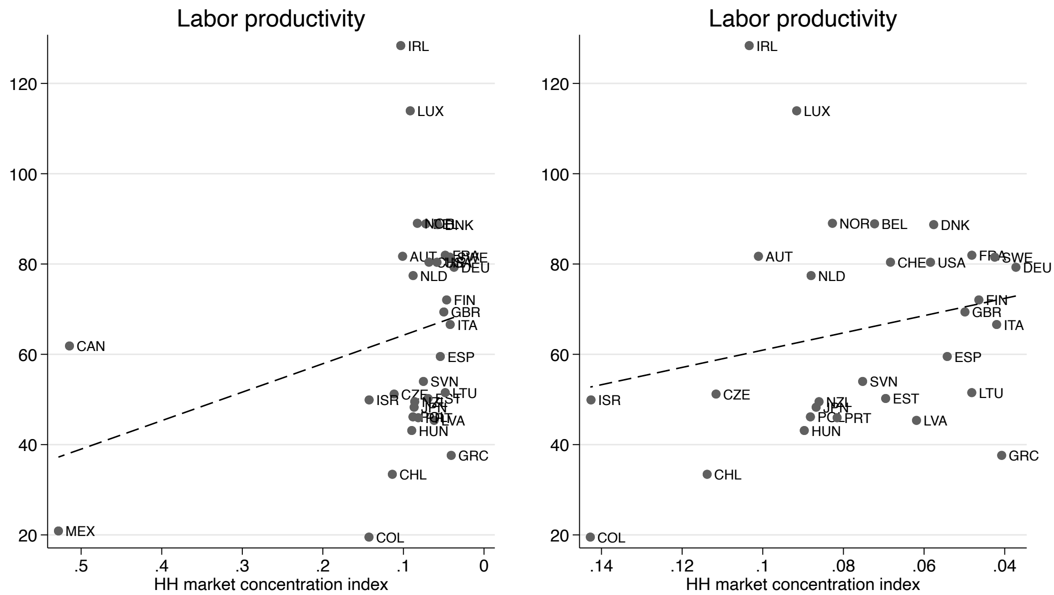


Figure 4

Scatterplot of the relation between HH market concentration index and labor productivity



Note: The left scatterplot includes Canada and Mexico. The right scatterplot excludes Canada and Mexico.

To answer the first two hypotheses, we will take a look at the correlations between innovation and labor productivity, and competition and labor productivity.

The regression will take the following form:

$$(1)\ labor\ productivity_{2020} = \alpha + \beta_1 innovation\ ouptut_{\bar{t}1-7} + \beta_2 HH\ index_{\bar{t}1-7} + \beta_3 educational\ expenditure_{\bar{t}1-7} + \beta_4 age\ dependency\ ratio_{\bar{t}1-7} + \varepsilon$$

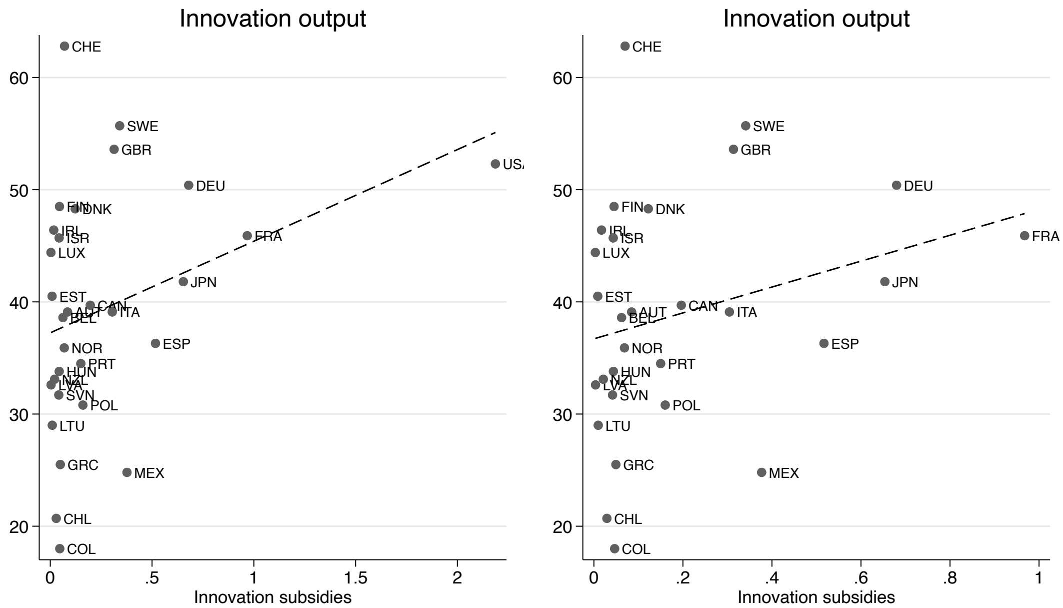
Coefficients are shown with β's. The constant is α and ε is the error term. The subscript of $\bar{t}1-7$ indicates that those variables are delayed in time with the average of a delay from one to seven years.

To get a first look at the relationship between innovation subsidies and innovation, innovation subsidies and competition, and innovation and competition, the scatterplots below have been added. Since a lower market concentration index means higher competition, the y-axis in the scatterplots of innovation subsidies and innovation output with the HH market concentration index are reversed, to make the sign of the correlation more visual.

All the scatterplots show a positive correlation. For the scatterplots of innovation subsidies and innovation output with the HH market concentration index (Figure 6 & Figure 7), this finding is not in line with the hypothesis (hypothesis 4), which assumes a negative correlation between those variables. In Figure 5 and Figure 6 the scatterplots are skewed to the right, even after elimination of the outliers. The United States is also shown to be an outlier, but it is assumed to be reasonable that the United States has a very big spending on R&D and that it is not a measurement error. Therefore, elimination from the data for the regression analyses is not necessary. The scatterplot in Figure 7 shows a normal distribution after elimination of the outliers.

Figure 5

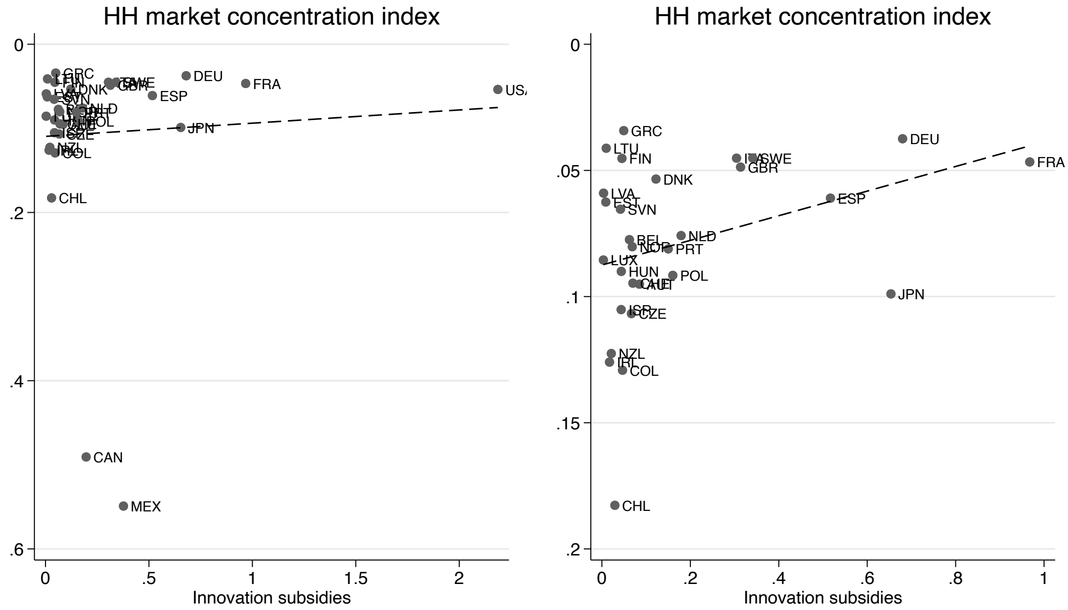
Scatterplot of the relation between innovation subsidies and innovation output



Note: The left scatterplot includes the United States The right scatterplot excludes the United States.

Figure 6

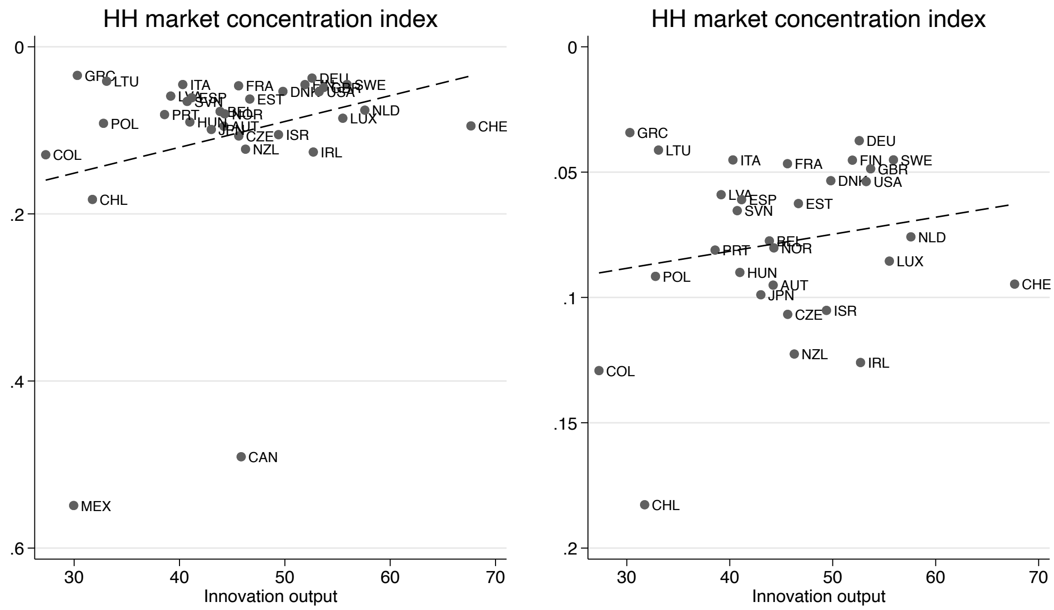
Scatterplot of the relation between innovation subsidies and HH market concentration index



Note: The left scatterplot includes Canada, Mexico and the United States. The right scatterplot excludes Canada, Mexico and the United States.

Figure 7

Scatterplot of the relation between innovation output and HH market concentration index



Note: The left scatterplot includes Canada and Mexico. The right scatterplot excludes Canada and Mexico.

To answer hypothesis 3, we will take a look at the correlation between innovation subsidies and innovation.

The regression will take the following form:

$$(2)\ innovation\ output_{2020} = \alpha + \beta_1 innovation\ subsidies_{\bar{t}1-7} + \beta_2 educational\ expenditure_{\bar{t}1-7} + \beta_3 age\ dependency\ ratio_{\bar{t}1-7} + \varepsilon$$

Coefficients are shown with β's. The constant is α and ε is the error term. The subscript of $\bar{t}1-7$ indicates that those variables are delayed in time with the average of a delay from one to seven years.

To answer hypothesis 4, we will take a look at the correlation between innovation subsidies and competition, and innovation and competition.

The regression will take the following form:

$$(3)\ HH\ market\ concentration\ index_{2020} = \alpha + \beta_1 innovation\ subsidies_{\bar{t}1-7} + \beta_2 innovation\ ouput_{\bar{t}1-7} + \beta_3 educational\ expenditure_{\bar{t}1-7} + \beta_4 age\ dependency\ ratio_{\bar{t}1-7} + \varepsilon$$

Coefficients are shown with β's. The constant is α and ε is the error term. The subscript of $\bar{t}1-7$ indicates that those variables are delayed in time with the average of a delay from one to seven years.

Results

In Table 2 the results of the first OLS-regressions are shown. Here, the correlations of innovation and labor productivity, and competition and labor productivity from hypotheses 1 and 2 are tested. In Column 1 only innovation is taken as independent variable. In Column 2 only competition is taken as independent variable. In Column 3 innovation and competition are both taken as independent variable. In Column 4 the control variables general expenditure on education per GDP and age dependency ratio are included.

Table 2

OLS-regressions of labor productivity on innovation and competition

Labor productivity	1	2	3	4
Innovation output	1.917***		1.837***	1.835***
	(0.338)		(0.348)	(0.369)
HH index		-63.059	-27.508	-30.129
		(37.974)	(28.389)	(29.083)
Educational expenditure				1.772
				(3.010)
Age dependency ratio				-0.632
				(0.657)
Constant	-21.781	70.538***	-15.346	8.898
	(15.414)	(5.778)	(16.799)	(36.362)
Observations	32	32	32	32
R^2	0.518	0.084	0.533	0.551

Note: Table shows the results of OLS-regressions with labor productivity as dependent variable and innovation output and HH market concentration index as independent variable. Standard error in parenthesis. Significance: *p < 0.1, **p < 0.05, ***p < 0.01.

After controlling for general expenditure on education per GDP and age dependency ratio, the coefficient shows that on average, a one-unit increase in innovation output is estimated to increase the GDP per hours worked by 1.835, ceteris paribus. Also, a one-unit increase in the HH market concentration index is estimated to decrease the GDP per hours worked by 30.129, ceteris paribus. For innovation output this result has a significance level of 1%, which means the null hypothesis that the coefficient is equal to zero can be rejected and that it is unlikely that the coefficient is only found by chance. For competition the result is not significant.

Since innovation output is measured on a scale from 0 to 100 and the HH market concentration index on a scale from 0 to 1, the coefficients found cannot be compared with each other. To make the variables more comparable, we need to look at the standardized coefficient, which corrects for the scale. For innovation output in Column 4 the standardized coefficient is 0.688. For the HH market concentration index in Column 4 the standardized coefficient is -0.139. These indicates that innovation output has a stronger positive correlation than competition has with labor productivity.

The control variables general expenditure on education per GDP and age dependency ratio show both unsignificant results. Also, they only seem to take away a bit of the omitted variable bias for the relation between competition and labor productivity as the coefficient of the HH index shows a small decrease after controlling. The coefficient of innovation output does not show a serious change. This indicates that other unobservable variables are influencing the outcome.

There is no sense in interpretating the constant since there is no independent variable which takes the value 0 in the data.

From the above it follows that hypotheses 1 and 2 do not need to be rejected. However, it must be kept in mind that only innovation output gives significant results and also the omitted variable bias is most likely present.

In Table 3 the results of the OLS-regression are shown, where the correlation of innovation subsidies and innovation from hypothesis 3 is tested. In Column 1 only innovation subsidies is taken as independent variable. In Column 2 the control variables general expenditure on education per GDP and age dependency ratio are included. The countries Czech Republic and the Netherlands are not included, since no data is available for the innovation output of these countries in 2020.

Table 3

OLS-regressions of innovation output on innovation subsidies

Innovation output	1	2
Innovation subsidies	8.166*	7.777*
	(4.313)	(4.203)
Educational expenditure		2.390
		(1.609)
Age dependency ratio		0.497
		(0.362)
Constant	37.243***	-1.321
	(2.151)	(18.710)
Observations	30	30
R^2	0.114	0.2677

Note: Table shows the results of OLS-regressions with innovation output as dependent variable and innovation subsidies as independent variable. Standard error in parenthesis. Significance: *p < 0.1, **p < 0.05, ***p < 0.01.

After controlling for general expenditure on education per GDP and age dependency ratio the coefficient shows that on average, a one-unit increase in innovation subsidies is estimated to increase the innovation output by 7.777 units, ceteris paribus. This result has a significance level of 10%, which means the null hypothesis that the coefficient is equal to zero can be rejected.

The control variables general expenditure on education per GDP and age dependency ratio show both unsignificant results. Though, they seem to take away a small bit of the omitted variable bias as the coefficient of innovation subsidies shows a small decrease after controlling. However, it is unlikely that no other unobservable variables are influencing the outcome, such that there is still omitted variable bias.

There is no sense in interpretating the constant since there is no independent variable which takes the value 0 in the data.

From the above it follows that hypothesis 3 do not need be rejected. However, it must be kept in mind that the omitted variable bias is most likely present.

In Table 4 the results of the last OLS-regression are shown. Here, the correlations of innovation subsidies and competition, and innovation output and competition from hypothesis 4 are tested. In Column 1 only innovation subsidies is taken as independent variable. In Column 2 only innovation output is taken as independent variable. In Column 3 innovation subsidies and innovation output are both taken as independent variable. In Column 4 the control variables general expenditure on education per GDP and the age dependency ratio are included.

Table 4

OLS-regressions of HH market concentration index on innovation subsidies and innovation output

HH index	1	2	3	4
Innovation subsidies	-0.016		-0.004	0.002
	(0.049)		(0.049)	(0.052)
Innovation output		-0.003	-0.003	-0.003
		(0.002)	(0.002)	(0.002)
Educational expenditure				-0.003
				(3.065)
Age dependency ratio				-0.003
				(0.004)
Constant	0.110***	0.244**	0.244**	0.416*
	(0.024)	(0.100)	(0.101)	(0.232)
Observations	32	32	32	32
R^2	0.003	0.063	0.063	0.086

Note: Table shows the results of OLS-regressions with HH market concentration index as dependent variable and innovation subsidies and innovation output as independent variable. Standard error in parenthesis. Significance: *p < 0.1, **p < 0.05, ***p < 0.01.

After controlling for general expenditure on education per GDP and age dependency ratio the coefficient shows that on average, a one-unit increase in innovation subsidies is estimated to increase the HH market concentration index by 0.002 units, ceteris paribus. Also, a one-unit increase in innovation output is estimated to decrease the HH market concentration index by 0.003, ceteris paribus. Both the results are not significant, which means that it is not unlikely that the coefficient is only found by chance. Therefore, not much can be said about these results.

However, it is notably that the sign of the correlation between innovation subsidies and the market concentration switches when the control variables are added. The correlation between innovation output and market concentration stays exactly the same. The control variables are not significant as well. Therefore, it is unlikely that no other unobservable variables are influencing the outcome, such that there is omitted variable bias.

Here as well, there is a difference in the scales of innovation subsidies and innovation output. Therefore, we look at the standardized coefficients again. For innovation subsidies in Column 5 the standardized coefficient is 0.07. For innovation output in Column 5 the standardized coefficient is -0.215. These indicates that, would the results have been significant, the positive correlation between innovation subsidies and market concentration would never outweigh the negative correlation of innovation output and market concentration.

There is no sense in interpretating the constant since there is no independent variable which takes the value 0 in the data.

From the above it follows that hypothesis 4 can be rejected. Although the sign of the correlation between innovation subsidies and market concentration eventually turns positive, which means there is a negative correlation between innovation subsidies and competition, none of the results are significant. Also, it must be kept in mind that the omitted variable bias is most likely present.

V. Discussion

The above interpretations only hold when the effects are causal. However, the results based on these datasets and made with this methodology are no causal effects. This follows from the results not being significant and the presence of multiple biases. The control variables added in this paper do not eliminate initial differences between the countries, as a result of which the selection bias does not disappear. Apart from that, it is also not possible to add all observable variables that influence the independent and dependent variable, which means the omitted variable bias is present.

Multiple variables in the data can be questioned. Such as innovation output, which is based on rather subjective elements. These subjective elements may also be related to labor productivity, obstructing the research into the relationship between them. Also, the HH market concentration index from the World bank, which is based on the concentration of a countries trade, is probably not the best proxy for competition since the most competition is experienced between firms and not between countries. Therefore, data on the competition in multiple sectors would be better. In addition to these problems, the range of the years in the balanced dataset should be higher to increase the number of observations. Then also the exact delay in effect can be found.

This in turn gives way to different regression methods like a fixed effects regression. In a fixed effects regression, there is already a control for unobservable and observable time-invariant differences across countries. That way, the omitted variable bias would have been at least a whole lot smaller.

VI. Conclusion

This paper has tried to answer the following research question: *What is the relation between providing innovation subsidies and labor productivity through innovation and competition?*

The literature search led to four hypotheses that were used to answer the research question. The first two hypotheses assumed a positive relationship between innovation and labor productivity, and competition and labor productivity. The third hypothesis proposes that innovation subsidies lead to higher innovation. The fourth hypothesis states that innovation subsidies and innovation lead to lower competition, in other words, a negative correlation. An answer to the hypotheses has been reached by using an OLS regression with the control variables general expenditure on education per GDP and the age dependence rate.

All that is mentioned here is under the assumption that causal effects have been found, which is not the case in this study. The connections between innovation and labor productivity, and competition and labor productivity are indeed found to be positive. It should be noted, however, that the result for the latter relationship is not significant. When the relationships are weighed up by means of a standardized coefficient, those of innovation appear to be stronger. The third hypothesis also does not need to be rejected, because a positive relationship between innovation subsidy and innovation has been found. Finally, the fourth hypothesis needs to be rejected, since the results show an insignificant and positive relationship between at least innovation and competition. The relationship between innovation subsidies and competition is found to be negative after adding the control variable but does not outweigh the positive relationship between innovation output and competition.

Looking at the overall relation between innovation subsidies and labor productivity through innovation and competition, it must be concluded that it is found to be positive due to the sum of only positive effects. The literature-based idea that innovation subsidies and innovation output could lead to a reduction in the level of competition was not found in this research. To refer back to the introduction, based on this research, no reduction in providing innovation subsidies is necessary.

Follow-up research

Some findings in the literature review give room for follow-up research. First, one can look at the dependence of small firms on innovation subsidies. This is especially important when looking at the effect of innovation subsidies on innovation output, since for these small firms their innovation output will be fully depending on whether or not innovation subsidies are provided. Where some literature suggests that it is mainly the large companies, who would innovate anyways, that now receive a subsidy, this is not in line with the justification of providing subsidies from the OECD. From providing such poor subsidies market distortion can occur.

Another interesting finding from the literature review is the idea that for research of the effect of innovation subsidies on labor productivity through innovation and competition it matters if the subsidies are provided in initially highly competitive markets or not. To test if it is true that productivity only increases from innovation subsidies if they are granted in competitive sectors, one can split up sectors or countries in to a high and low competitive group and look at the difference in outcomes of a regression. In combination with the idea above that small firms depend on innovation subsidies to innovate, these studies can give more insight in where to provide subsidies and where not, to make them the most efficient.

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