UNIVERSITY OF WUPPERTAL
BERGISCHE UNIVERSITÄT WUPPERTAL

EUROPÄISCHE WIRTSCHAFT
UND
INTERNATIONALE MAKROÖKONOMIK

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A Spatial Knowledge Production Function Approach for the Regions of the Russian Federation

Diskussionsbeitrag 217
Discussion Paper 217

Europäische Wirtschaft und Internationale Wirtschaftsbeziehungen
European Economy and International Economic Relations
ISSN 1430-5445

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August 2016

Herausgeber/Editor: Prof. Dr. Paul J.J. Welfens, Jean Monnet Chair in European Economic Integration

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JEL classification: O31, R11, R15, P25
Key words: Knowledge Production Function; Russian Federation; National Innovation System; Panel Econometrics; Regional Economics; Patent Data

Summary: At the core of every national innovation system two concepts are of central importance: The generation and the diffusion of innovations and ergo knowledge; on the one hand inside the system itself and on the other across the system's borders. The present study picks up on the aspect of knowledge generation in the context of the Russian Federation. An extended knowledge production function is estimated on the basis of Russian regional data and it is shown that the Russian NIS, nationally as well as internationally, is functional, however, not all channels of knowledge transfer work as efficiently as those in comparable Western European countries.

Zusammenfassung: Im Zentrum eines jeden nationalen Innovationssystems (NIS) stehen zwei essentielle Konzepte: Die Erzeugung und die Diffusion von Innovationen bzw. Wissen; einerseits innerhalb des Wissens, andererseits die Grenzen des Systems übergreifend. Die vorliegende Studie greift den Aspekt der Wissengenerierung im Kontext der Russischen Föderation auf. Eine erweiterte Wissensproduktionsfunktion wird unter Nutzung russischer Regionaldaten geschätzt. Es wird gezeigt, dass das russische NIS national als auch international effizient funktioniert, allerdings funktionieren nicht alle Kanäle des Wissenstransfer so effektiv wie in vergleichbaren westeuropäischen Staaten.

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1. Introduction

In 1992 Lundvall introduced the concept of the national innovation system (NIS) into economic literature providing a comprehensive frame of reference to analyze the innovation dynamics in economies. Following the OECD's 1999 report on national innovation systems, regional innovation systems are the essential building blocks of any NIS. The analysis of an NIS is therefore inherently of a regional nature.

At the core of every NIS two concepts are of central importance: The generation and the diffusion of innovations and ergo knowledge; on the one hand inside the system itself and on the other across the system's borders.

The present study picks up on the aspect of knowledge generation in the context of the Russian Federation (RF)[1]. Over the last two decades the RF experienced a transition from a Soviet centrally planned economy to a market economy, however it is still not considered to be a fully developed knowledge society comparable to Western European economies where the terms of knowledge society or knowledge economy can be interchanged with the term NIS.

In this context the Russian Federation is a very interesting subject not only because it has a much different history and recent development path than most established knowledge societies but also because it is politically and economically in a phase which many developed nations have long since left behind. An analysis of the RF therefore allows us to take a look at how an innovation system - or at least the knowledge generation mechanism - in such a developing economy under such specific restrictions looks and works. It can thus be taken as an analytical template for other BRICS countries or countries at a similar level of development and comparable economic characteristics like Indonesia.

This study furthermore aims at uncovering in how far the RF reports patterns of an NIS comparable to Western European patterns by estimating a knowledge production function across the regions of the RF.

Fritsch and Slavtchev (2006) argue that estimating a knowledge production function allows to test the efficiency of an NIS. The link between knowledge inputs and knowledge output basically coincides with the knowledge generation process in an NIS and an estimation of the quality of this link thus reflects on the efficiency of the knowledge generation process and thereby on the efficiency of the NIS itself.

While studies like Fritsch and Franke (2004), Lee and Park (2005) or Wang and Huang (2007) operate on a firm basis this study tackles the question from a regional perspective and with a focus on the RF. To test the validity of the knowledge production function approach a number of knowledge transmission channels as well as other control variables are accounted for.

The study is structured in four sections. In the following second section the implemented methodology of knowledge production functions is introduced.

1 A comprehensive analysis of the knowledge generation and transmission process can be found in Perret (2013) while Perret (2014) takes a more detailed look into the transmission process.

The third section estimates the knowledge production function and discusses results, advantages and shortcomings.

The study concludes in the fourth section with a conclusion picking up as well on policy implications.

2. Methodology - Knowledge Production Functions

In analogy to traditional production functions that describe the relation between economic input and output factors, a KPF describes the relation between knowledge inputs on the one hand and knowledge output on the other. Therefore, with K^I as knowledge inputs and K^O as knowledge output, a knowledge production function is a function $K^O(K^I)$.

A KPF can take different forms[2]. As knowledge inputs can be subsidized to a certain degree - e.g., researchers can be subsidized by additional expenditures on R&D as in the purchase of external knowledge - a KPF can be seen as a substitutional production function.

Additionally, a KPF does not have a theoretical maximum as the generation of knowledge is bounded only by the quantity of input factors.

It is thus reasonable to assume the form of a Cobb-Douglas-type production function when modeling a KPF:

$K^O = a \cdot (K^I_1)^\alpha \cdot (K^I_2)^\beta ...$

This line of argumentation leads to the basic form of a KPF as discussed and used in a similar fashion by Griliches (1979) when introducing the KPF concept into economics.

In a traditional production function input factors include the labor force and the capital stock; any extended model just adds to this stock of base variables. In this study only labor, as in researchers, is considered as an input factor, as the capital stock can only partially be approximated by the stock of patents or the cumulated expenditures on R&D.

The discussion about the most suitable way to approximate knowledge output is as old as the idea of the KPF itself. Griliches himself argued that the idea of using patent grants or applications is flawed, as patents only represent part of the codified knowledge. If patents are considered, the following aspects of knowledge are omitted:

Tacit knowledge

Knowledge that is codified but has not been patented yet or has been deemed unfit to be patented

Knowledge that can be codified, but is not supposed to be codified

However, in the absence of a more suitable indicator, this study uses the number of patent grants as an approximation of the stock of knowledge.

The basic KPF therefore has the following form[3]:

[2] For example Bitzer (2003) suggests a different approach to modeling a KPF from the basic one used herein.

3 Fritsch (2002) and Fritsch and Franke (2004) advocate the use of either researchers or R&D expenditures as knowledge inputs, though not both at the same time. The basic idea is that a large share of the R&D expenditures is used to pay for the researchers and therefore including both would lead to biases in the

$\text{Patents Granted}_t = a \cdot \text{Res.}^{\alpha}_t$

Admittedly, patents are not granted instantaneously. First, the input factors need to be used before patentable knowledge is created. Here we assume a time frame of one year for knowledge to be produced that can be patented accordingly[4].

If, finally, new knowledge is generated, this knowledge needs to be submitted to the corresponding patent office, where it will be appraised whether the application describes newly discovered knowledge that also fulfills additional regulations.

This study assumes this process to take approximately one to two years. Even though the patenting process in the Russian Federation might realistically take much longer, officially it should take between six months and two years[5]. For patent applications at the European Patent Office (EPO) one to two years can be seen as a reasonable assumption[6].

All told, a time lag of two years is considered, which can be modeled as follows[7]:

$\text{Patents Granted}_t = a \cdot \text{Researcher}^{\alpha}_{t-2}$

To make the estimation of the equation easier its logarithmized version is used in the ongoing study:

$\log(\text{Patents Granted}_t) = \log(a) + \alpha \cdot \log(\text{Researcher}_{t-2})$

While this is not the first study to estimate a knowledge production function, among studies that have tested the KPF for specific regions or sectors there are the only two studies with a view on the Russian Federation; Roud (2007) and Savin and Winker (2012). Other studies can be roughly categorized into one of four categories.

In the first category, studies take a look at a specific group of countries: Madsen (2008) (OECD) or Buesca; Heijs and Baumert (2010) (Europe / EU).

A second category consists of those studies that consider only individual countries. Besides Roud (2007) and Savin and Winker (2012) for Russia, there are, for example, studies by Ponds; van Oort and Frenken (2010) (Netherlands), Andersson and Ejermo (2003) (Sweden), Ranga; Debackere and von Tunzelmann (2004) (Belgium), Conte and Vivarelli (2005) (Italy), Fritsch and Franke (2004) (Germany), Wagner (2006) (Germany), Fischer and Varga (2003) (Austria), Masso and Vahter (2008) (Estonia), Wu (2009) (China) and for the US Varga (2000), Audretsch and Stephan (1999), Ò huallachain and Leslie (2007) and Branstetter (2001) (US and Japan).

The third category is comprised of studies on specific sectors: Zucker; Darby and Ma (2007) (Nanotechnology), Stephan; Audretsch and Hawkins (2000) (Biotechnology), Ramani; El-Aroui and Carrère (2008) (Biotechnology and Food) and Pardey (1989) (Agriculture).

Finally, the fourth group consists of those studies that have a more general focus unrelated to any sector or region. This category includes: Abdih and Joutz (2005) (Total Factor

regression results.

[4] In some sectors, like pharmaceuticals, the time frame might be much longer, while in other sectors, like food products, it can be much shorter.

[5] See WIPO (2012).

[6] Officially, an application should be processed after 18 months.

[7] Fritsch and Slavtchev (2006) suggest that a three year lag offers the best alternative. However, preliminary tests showed that results for a two year lag are superior to those for a three year lag.

Productivity), Masso and Vahter (2008) (Total Factor Productivity) and Anselin; Varga and Acs (1997) (State-level vs. Metropolitan-level) as well as, from a more theoretical perspective, Griliches and Mairesse (1998) and Acs; Braunerhjelm and Carlsson (2009).

3. Estimation of the KPF

3.1 Variable Design

The basic KPF only includes researchers, therefore the problem of omitted variables is therefore almost endemic, as shown by the results of a link-test as well as a Ramsey test on omitted variables.

Considering that a significant part of the knowledge generation process is omitted, if only basic inputs are observed, the classical KPF needs to be extended through the introduction of additional variables.

Some aspects considered herein have already been implemented in other studies on the KPF approach. Following a broader perspective, as with the study by Asheim and Gertler (2005) or the seminal work on innovation systems by Lundvall (2010), where the KPF is described as a statistical representation of the national innovation system, underlines that a national innovation system cannot be described in its entirety by only one variable and region specific effects.

While patents as indicators of knowledge output were available since 1987 from the EPO, Rospatent freely publishes patents on a regional level since 1995. Additionally, using the Patstat database from Spring 2008 allows to only account for patents up to 2006. To ensure comparability of both patent sources, and accounting for the two year time lag, the considered time therefore spans the years from 1997 to 2006 for the patent data and from 1995 to 2004 for the dependent variables.

EPO data might limit the results of the analysis to those firms that have a general interest in the European market. However, considering that the correlation between the patents from the EPO and the patents from Rospatent across all regions for the ten years from 1997 to 2006 amounts to 0.9245 it can be assumed that the distribution of international EPO patents across regions mirrors that of domestic Rospatent patents which should be less biased towards the European market. Nevertheless, a suitable way to complement this study would be to use triad patents or at least Japanese or Chinese patent data; thereby covering for possible patenting in the Far Eastern regions which might be more oriented towards Asian markets than towards the European market.

Patents used herein represent patent grants and are assigned to specific years via their priority dates. As data from Rospatent is only available on a regional basis EPO patents have been aggregated to the regional level using the official Russian classification of regions[8].

[8] The Nenetsia Autonomous Okrug is considered part of the Arkhangelsk Oblast and the Yamalia and Khantia-Mansia Autonomous Okrugs are considered parts of the Tyumen Oblast.

The analysis is focussed on the Russian perspective therefore only patents from inventors of Russian origin are considered and the assignment of patents to regions is performed on the basis of the inventors' addresses.

Due to the small amount of patents in general a dissemination of the data into different technology groups is not prudent. Considering the time horizon two sub-periods are observed, the transition years spanning the years 1995 to 1998 and the later years spanning the years 1999 to 2006.

These two sub-periods have been chosen because the first period - transition years - describes a phase of economic decline ending with the ruble crisis in 1998 while from 1999[9] the Russian Federation entered a period of economic growth. Additionally, in the second period, due to rising prices for oil and gas, the importance of the natural resources sector became more distinct than it has been in the first period. Third, from a political point of view the first period can be seen as a rather chaotic period of declining socialism, economic transition, privatization and de-govermentalization[10], while the second period, with the beginning of the presidency of Vladimir Putin, has been a phase of overall stabilization and rising state influence[11].

In all cases the base variable is the number of researchers[12]. It is complemented by control variables to account for the relative economical size of the regions; the regional real GRP with base year 1995[13].

An approximation for the shadow economy's share of the GRP is included in addition to the official GRP to measure income and wealth effects not covered by the GRP[14].

In different studies[15] four channels of direct and indirect knowledge transfers are introduced - tacit knowledge spillovers via inventor or researcher movements, codified knowledge spillovers via patent citations and spillovers via trade and FDI - and since they provide to the generation of knowledge, they are considered as suitable controls. With tacit knowledge already accounted for by the researcher variable, the number of students per region adds to this aspects while accounting in some part for the institutional framework as well, as student numbers in Russia are highly correlated with universities. The regional

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[9] Following official statistics the economic revival had already started in 1997.

[10] Privatization and de-govermentalization by themselves are not economically harmful, however their implementation can be considered to have taken place in a rather chaotic way.

[11] In this context it is helpful that the data is only available up to the beginning of 2008 or else a third period starting in 2008 motivated by the recession due to the world financial crisis would have become necessary.

[12] All variables implemented in this section enter the regression in logarithmized terms, except for shares or dummy-variables. It can be argued that scaling the researcher variable by using per capita values would be more suitable for the overall validity of the estimation, to ensure comparability with other studies of KPF however absolute numbers are considered.

[13] Integrating the GRP also allows one to control for business cycle effects.

[14] In an economy with an overall share of the shadow economy of between 20% and 50% quite a large portion of effects is not covered by official GRP. Note that the share of the shadow economy is calculated with 1995 as a base year, as the results of a study by Afontsev (1998) have been used as base values and results are extrapolated forward using the electricity method discussed in more detail in Kaufmann and Kaliberda (1996) or Johnson; Kaufmann and Shleifer (1997). As no energy consumption statistics were available on a consistent basis for all years of the study, energy production data has been used instead - under the assumption that energy production patterns in Russian regions roughly match energy consumption patterns. The use of the electricity method is strongly criticized by authors like Eilat and Zinnes (2002) and Alexeev and Pyle (2003).

[15] See for example Kim (2010).

imports[16] and the foreign direct investment inflows are added to the regression accounting for spillovers via trade and FDI[17]. As patent data has only been available for a restricted time horizon the consistent calculation of a stock of patents as proxy for the availability of codified knowledge has not been possible.

Furthermore, the market structure is included in the model[18] via the shares of small and medium enterprises - an indicator in order to argue in line with Schumpeter (2011) that small and medium enterprises are more innovative than large enterprises and thereby generate more new knowledge. Additionally, following the ideas presented in Ayyagari; Beck, Demirgüc (2003), SME are correlated to the institutional framework of the region and the business environment; a higher share of SME indicates a more open and free business environment, while a lower share might be an indicator for a large share of the informal economy.

The number of government personnel is included to approximate the amount of corruption taking place - but also to account for government presence in general. As a proxy for corruption the size of the government accounts indirectly for institutional efficiency. The choice of government personnel as an approximation for corruption has been made as a number of surveys taken in Russia[19] show that the highest amount of corruption is perceived in contexts with government officials like the police or members of the judicial and the education system. A higher number of government employees thus indicates a larger potential for corruption, which by itself would be harmful for knowledge generation as capital flows could be used more efficiently elsewhere. Secondly, state-owned businesses are considered to be less efficient than private businesses and therefore less innovative as well[20]. On a region-wide level a higher amount of government personnel might be an indicator for more state-owned businesses as well and therefore for more inefficiency and fewer innovations[21].

The amount of oil and gas exploited in each region[22], as well as a dummy variable for the region being an oil and gas producer at all, are included, since studies show on the one hand that the level of corruption is much higher in this sector than in others[23]. Furthermore, the sector itself is less innovative than other sectors[24]. The size of the sector is included as

[16] Lichtenberg (1998) stresses that it is not so much the intensity of imports, but the distribution of the countries of the origin of imports that matters, however these effects are not accounted for in this study.

[17] It is noted that a feedback relation between the generation of knowledge via patents and FDI flows seems highly likely even though respective tests do not yields corresponding results in this context.

[18] The link between the market structure and the innovative output, the innovativeness of a region, is argued in detail already by Mansfield (1981), Cohen and Levin (1987), Rothwell (1989) and Levin; Klevorick and Bozeman (1991).

[19] See respective reports by Yuri Levada Analytical Center (2012) or Russian Public Opinion Research Center (2012).

[20] See Netter and Megginson (2001).

[21] Again it can be noted that a feedback relation could exist between expenditures on R&D and government personnel numbers. The implemented scenarios however proved stable. As with the researchers it can argued that it might be more prudent to use per capita values, however to ensure comparability with the researchers both variables are calculated in absolute values.

[22] As not all regions are oil and gas producers and therefore report zero oil and gas output, in contrast to the other variables the absolute output is used as a variable, measured in billions of tons.

[23] Leite and Weidmann (1999) argues that corruption depends on natural resources, while Tompson (2006), a little less drastically, links corruption to large state-owned firms, which in Russia persist in the oil and gas industry.

[24] Note, in this context, also the proclaimed negative relation between resource endowments and economic

a large oil and gas sector coincides with other less developed sectors, especially with a lower share of science-intensive sectors.

Finally, the base model includes the amount of exports and an indicator for economic openness[25]. The influence of exports can be motivated as export oriented firms are usually more successful, since they are more accustomed to competition. They need to be more modernized and more innovative to compete internationally and therefore are more likely to generate new patents. This argument can be backed up with studies by Podmetina; Vaatanen and Smirnova (2011) who show that export oriented firms are generally more innovative than firms oriented only towards their home market. Furthermore, Silva; Afonso and Africano (2010) as well as the literature cited in Wagner (2002) argue along the lines of learning-by-exporting and therefore the growth of knowledge through exporting.

A similar line of argumentation holds for the openness indicator as regions that are more open to the world economy are confronted more with international competitive pressure and are therefore forced to innovate more[26].

In addition, Torkkeli; Podmetina and Väätänen (2009) stresses the importance of FDI and trade flows on knowledge absorption and therefore the absorptive capacity in the Russian Federation. Including these trade variables into the model thereby automatically accounts in part for the absorptive capacity[27].

3.2 Econometric Results

Preceding the estimation itself, a few preliminary tests on the structure of the regression model were run.

A Hausmann-test revealed that only a fixed-effect model is applicable to the estimation. As the model suffers from heteroskedasticity in the error terms, only robust standard errors were used. Testing for serial and spatial autocorrelation shows that while serial autocorrelation does not pose a problem, a Lagrange-multiplier test indicated that a spatial error model should be used. The model implements a dynamic spatial lag and a dynamic Durbin structure however, as the Han-Philips model used is not designed for spatial error effects[28].

Even though no serial autocorrelation is detected, a dynamic setup is considered here to test for possible path-dependency of the knowledge generation process.

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growth which, in the literature, is referred to as the *resource curse*. See for a discussion of this phenomenon for example Auty (1993).

[25] The indicator is calculated as the relation of the sum of exports and imports against the GDP. Even though the exports are as well part of the openness indicator, multicolinearity is no problem in this context.

[26] The inclusion of the openness indicator might, however, not generate significant additional information as it basically replicates the effects of exports, imports and GDP in a composite form.

[27] All monetary variables including the GRP, the exports and imports as well as the FDI enter the model in real terms with the base year 1995.

[28] Perret (2013) shows that results for the spatial lag and the spatial error model do not differ significantly.

Table 1: Regression Results for Patent Grants from Rospatent

	Lag-Model			Durbin-Model		
	I	II	III	I	II	III
LAGT-1	0.3013*	1.0023***	0.2574	0.3094*	1.0111***	0.2463
	(1.72)	(42.74)	(1.39)	(1.75)	(7.39)	(1.29)
RES	1.0471***	0.6737***	-0.0293	1.0392***	2.1060***	0.6576***
	(2.68)	(9.04)	(-0.31)	(2.60)	(17.14)	(3.47)
SME	0.1360	0.3958	-0.1749	-0.0185	0.5348*	-0.0626
	(0.35)	(1.29)	(-0.65)	(-0.04)	(1.86)	(-0.23)
SHADOW	-0.2329	-2.0086***	0.1004	0.1270	0.3797	0.4695
	(-0.44)	(-5.43)	(0.26)	(0.22)	(0.95)	(1.17)
EX	0.1436**	0.4476***	0.3459***	0.1395**	0.4091***	0.3511***
	(2.18)	(7.00)	(4.85)	(2.05)	(6.98)	(4.88)
IM	0.5244***	-0.5082***	0.4134***	0.5205***	-0.6327***	0.4083***
	(5.33)	(-5.50)	(5.13)	(5.10)	(-6.91)	(4.92)
OPEN	-0.0039*	-0.0008	-0.1093***	-0.0031	-0.0011	-0.1054**
	(-1.77)	(-0.86)	(-2.65)	(-1.32)	(-1.36)	(-2.17)
FDI	-0.0120	0.0513***	0.0713***	-0.0164	0.0030	0.0442
	(-0.43)	(3.49)	(2.64)	(-0.58)	(0.21)	(1.50)
STUD	-0.5203***	0.0703	0.8063***	-0.5465***	0.1314***	0.7351***
	(-5.22)	(1.42)	(8.65)	(-5.30)	(2.75)	(7.47)
OILGAS	-0.1420	0.3880	-0.2160	-0.1150	-0.1700	-0.201
	(-0.13)	(0.90)	(-0.61)	(-0.10)	(-0.41)	(-0.55)
OGDUMMY	-0.0571	-0.0416	-0.1739	-0.0956	0.8753***	-0.3404
	(-0.09)	(-0.23)	(-0.75)	(-0.15)	(4.45)	(-1.17)
TRDUM	-0.9905***			-1.4850**		
	(-5.19)			(-2.11)		
λ	-0.1800	-1.8828***	-0.4275***			
	(-1.15)	(-8.68)	(-3.47)			
λRES				-1.7785	-6.8001***	-1.2119
				(-0.29)	(-6.60)	(-0.91)
λSME				-0.1948	-1.2739	0.8971
				(-0.11)	(-0.81)	(0.56)
λSHADOW				0.6619	10.6931***	6.5489
				(0.13)	(3.11)	(1.44)
λEX				-0.9105	-1.0220*	0.101
				(-1.15)	(-1.89)	(0.13)
λIM				0.6805	0.7781	0.5438
				(0.93)	(0.60)	(0.81)
λOPEN				-0.0211	0.0303**	-0.159
				(-1.02)	(2.19)	(-0.75)
λFDI				-0.0663	-0.9838***	-0.0366
				(-0.26)	(-2.61)	(-0.18)
λSTUD				-1.8158	3.2809***	0.2785
				(-0.79)	(2.61)	(0.18)
λOILGAS				0.0002	-0.0002	0
				(0.73)	(-1.16)	(0.26)
λOGDUMMY				-1.5679	14.6873***	-7.5784
				(-0.11)	(4.01)	(-1.29)
CONST	-1.1162	-0.0269	-0.0711	3.8408	0.0017	0.003
	(-1.27)	(-1.04)	(-0.99)	(0.29)	(0.06)	(0.04)
R^2	0.064	0.678	0.299	0.067	0.841	0.321
F-Test	5.812	194.309	39.357	3.587	277.076	24.727

Table 1[29] summarizes the results for patent grants from Rospatent by reporting results for the whole time frame (model I) and for splitting the time frame in the transition years of

[29] In all tables one asterisk (*) marks the 10% significance level, two asterisks (**) mark the 5% level and

1995 to 1998 (model II) and the later years from 1999 to 2006 (model III). Serial and autocorrelation effects played a role mostly in the transition years or if the full time horizon is considered. The R^2- and F-statistics however imply that the models for the subperiods are superior to the models for the full time frame. While the results for the R^2-statistic might be biased by the additional number of variables in the Durbin model, calculating an adjusted R^2 reveals that the results change only marginally and the Durbin model remains superior to the spatial lag model.

Considering only the results for the subperiods where they are in line with economic theory, with the exception of the later years in the spatial lag model, the coefficient for researchers is always significantly positive. In the single case that it becomes negative it is highly insignificant.

In can therefore been stated that the Russian NIS seems to be working efficiently on a domestic scale as Rospatent patents only represent a domestic perspective.

Other channels of external knowledge transfer, like trade and FDI, report significant impacts as well. While FDI have a significant positive impact in both periods - but only in the spatial lag model - the effects for the imports are positive only in the later years. In the transition years the import hinders the formation of new Russian knowledge.

This effect is however not generated by additional competition via imports as the openness index has a significant impact only in the later years. Additionally, the exports are highly significant and positive also strengthening the hypothesis that the most innovative firms can be found among exporters.

It surprises that the impact of oil and gas remains mostly insignificant as the theory behind the Dutch disease debate and the resource curse hypothesis would motivate a significant negative relation.

With consistently insignificant coefficients, the share of the shadow economy as a characteristic of a failed institutional system does not play any important role in the context of the domestic knowledge generation process. Either the system works despite the failed institutions or aspects thereof have become part of the NIS itself.

The positive impact of students indicates that additional education in Russia has a beneficial effect on the Russian NIS. This sheds new light on the brain drain discussion in Russia, as students, and therefore the Russian human capital, are an essential building block of the Russian NIS.

Finally, the lagged dependent variable is significantly positive for the transition years, showing that while in the transition years the Russian NIS has still been path dependent this changes in the later years when the variable becomes insignificant.

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three asterisks (***) mark the 1% level. λ marks the spatial effects and the variable TRDUM is a dummy for the transition years; including it in the model for the whole period controls for a structural break in levels between both sub periods.

Table 2: Regression Results for Patent Grants from the EPO

	Lag-Model			Durbin-Model		
	I	II	III	I	II	III
LAGT-1	0.1055*	0.2286***	0.0725	0.0565	0.5039***	-0.0553
	(1.89)	(3.13)	(0.88)	(1.00)	(6.25)	(-0.69)
RES	0.4824	3.3141***	2.8944***	0.3266	3.3723***	4.1458***
	(0.34)	(7.93)	(6.90)	(0.23)	(6.15)	(10.99)
SME	-0.7761	-1.6910*	1.8570*	-0.7266	-1.7684	2.5552***
	(-0.43)	(-1.81)	(1.87)	(-0.39)	(-1.35)	(2.91)
SHADOW	-0.8522	-2.0756	-2.9839***	0.5607	0.1495	-0.998
	(-0.46)	(-1.49)	(-2.83)	(0.30)	(0.08)	(-1.08)
EX	-0.0874	0.1756	-0.0981	-0.0555	0.0017	-0.2192
	(-0.53)	(0.80)	(-0.51)	(-0.33)	(0.01)	(-1.20)
IM	-0.0156	0.0554	-0.0036	-0.0233	0.3625	-0.0649
	(-0.04)	(0.19)	(-0.02)	(-0.06)	(0.85)	(-0.34)
OPEN	0.0001	0.0019	0.2394**	-0.0003	-0.0054	0.4966***
	(0.03)	(0.48)	(2.20)	(-0.09)	(-0.72)	(4.48)
FDI	0.0274	0.1151*	0.1048	0.0012	0.1020	-0.0467
	(0.34)	(1.62)	(1.41)	(0.01)	(1.38)	(-0.64)
STUD	0.1930	-0.1454	0.0209	0.2186	-0.1375	-0.3139*
	(0.80)	(-0.54)	(0.10)	(0.88)	(-0.44)	(-1.68)
OILGAS	0.8900	-2.6800**	-0.7560	1.1900	-3.7600**	-1.1
	(0.27)	(-2.30)	(-0.91)	(0.35)	(-2.21)	(-1.49)
OGDUMMY	-1.2912	-0.3153	0.1985	-1.2488	-0.1024	0.6302
	(-0.90)	(-0.60)	(0.40)	(-0.89)	(-0.12)	(1.13)
TRDUM	-0.2924			0.0451		
	(-0.71)			(0.02)		
λ	-1.3688***	2.1603***	2.1243***			
	(-2.80)	(10.18)	(11.02)			
λRES				-6.5607	-10.1689*	-2.4172
				(-0.22)	(-1.76)	(-0.64)
λSME				6.0884	33.3546*	-36.776
				(0.76)	(1.75)	(-1.22)
λSHADOW				20.4352	-35.8672	-17.8518
				(0.94)	(-1.05)	(-1.28)
λEX				2.0678	1.1804	-1.6254
				(0.74)	(0.21)	(-0.69)
λIM				3.5853	13.0867	6.0395
				(0.63)	(1.16)	(0.99)
λOPEN				-0.1067	-0.0980	0.321
				(-1.05)	(-0.70)	(0.33)
λFDI				-1.5561	-2.4464	-0.5444
				(-1.15)	(-1.02)	(-0.57)
λSTUD				5.4418	1.6095	-5.1547
				(0.82)	(0.21)	(-1.39)
λOILGAS				0.0014	-0.0009	-0.0005*
				(0.99)	(-1.51)	(-1.83)
λOGDUMMY				-69.2637	10.7807	21.4815
				(-1.35)	(0.59)	(1.36)
CONST	-14.0878***	-0.0334	-0.1041	7.6420	0.0807	0.0013
	(-2.90)	(-0.26)	(-0.63)	(0.09)	(0.57)	(0.01)
R^2	0.020	0.505	0.515	0.009	0.384	0.635
F-Test	1.079	60.151	62.725	0.288	20.712	57.797

Switching from a national perspective, as inherent when using Rospatent patent grants, to an international perspective, Table 2 reports the results for patent grants from the European Patent Office.

Considering the R^2 and F-statistic, or rather the respective adjusted R^2, it can be seen that in this case the spatial lag model is superior to the Durbin model. In particular the spatial parameter is highly positive and significant in the subperiods, showing that inventions made in other nearby regions are essential for the generation of new internationally relevant knowledge.

Again the impact of the researchers is consistently significant and positive. However, in this case the impact of the traditional channels of knowledge transmission is severely diminished. Only the FDI and only in the transition years report any significant impact.

However, the share of SME exhibits a significantly negative impact in the transition years and a positive impact in the later years. This development reveals that while previously large firms have been primarily important for the generation of new knowledge the focus shifted in the later years to small and medium firms. Additionally, in the 1990s new firms formed mainly with a view of market exploration and due to the overall supply-lack. In this situation innovations were essential neither for the formation of an SME nor for its survival in the market. In the later years however the Russian market became increasingly more sated and SME needed to compete; thus innovations and the generation of new knowledge became increasingly more important. Furthermore, the later years were accompanied with a general rise in the standard of living and therefore the demand for newer more innovative and more differentiated goods rose as well.

Additionally, the share of the shadow economy reports a consistently negative sign - however insignificant in the transition years - which is an indicator that shortcomings of Russian institutions or practices like corruption might not have an impact when considering domestic / national patents as the applicants might have adapted to the environment while for international / European patents they pose a problem as applicants in many of these cases are not native Russians.

While oil and gas production did not impact the generation of Rospatent patents it has a negative impact on international patenting - however the impact becomes less pronounced in the later years. In the international context the dynamics behind the resource curse theory thus hold.

Similar to the Rospatent case is the path dependency reported via the positively significant coefficients for the lagged dependent variable in the transition years.

While the results appear rather stable they still lack from two problems which have not been accounted for yet. Both cases above are inherently based on patent data. As such both approaches are based on count data - even though it has been logarithmized. Additionally, patent grants from the EPO are rather sparsely distributed across the regions of the RF, therefore there are a lot of observations with no patent grants. Inherently the knowledge production function therefore is a zero-inflated count model. As it has the form of a Cobb-Douglas-type production function the patent data however needs to be logarithmized for the model to be soluble. To check the stability of above results two additional models are estimated for Rospatent as well as for EPO data.

For Rospatent patents, almost all observations are larger than zero, allowing to estimate on the one hand a panel negative binomial model[30] which has been estimated assuming a linear production function and using discreet patent data. This model accounts for the count nature of the patent data. On the other hand a truncated OLS has been estimated with a truncation of all negative values. Here logarithmized variables are implemented. This model accounts for the fact that even the logarithmized variables can never be smaller than zero.

For EPO patents, on the one hand a zero-inflated negative binomial model has been estimated and on the other hand a truncated OLS. In both cases the zero generating process or the truncation takes care of the zero-inflation of the data[31].

Table 3: Regression Results for Rospatent Patents

	Panel Negative Binomial			Truncated OLS		
	I	II	III	I	II	III
RES	0.0077*	-0.0342	0.0207	0.7252***	0.7769***	0.3920***
	(1.64)	(-0.33)	(1.15)	(18.35)	(21.17)	(8.64)
SME	0.0243	0.4170	-0.6504	0.2251***	0.1602***	0.2344***
	(0.06)	(1.02)	(-1.43)	(5.76)	(4.09)	(4.57)
SHADOW	-0.0222	-0.0484	0.0653	0.0325	0.0055	0.0315
	(-0.18)	(-0.14)	(0.33)	(0.54)	(0.06)	(0.45)
EX	0.0041	0.0308	-0.0048	0.0606***	0.0692***	0.0574
	(0.28)	(0.15)	(-0.31)	(3.05)	(3.69)	(1.56)
IM	-0.0006	0.0135	-0.0591	-0.0035	-0.0198	0.0542*
	(-0.05)	(0.12)	(-1.29)	(-0.09)	(-0.64)	(1.93)
OPEN	0.0016	0.0124**	-0.0016	-0.0016***	-0.0015***	-0.0227
	(1.41)	(1.99)	(-0.09)	(-2.65)	(-2.63)	(-1.51)
FDI	0.0051	-0.0477	0.0160	0.0043	-0.0041	0.0035
	(0.33)	(-0.29)	(0.54)	(0.87)	(-0.58)	(0.52)
STUD	0.0005	0.0253	0.0023***	0.0739	0.0314	0.6932***
	(1.42)	(1.25)	(2.86)	(1.10)	(0.86)	(8.65)
OILGAS	-0.5130	103.1000	-4.7700	0.0020	0.0156	-0.0093
	(-0.06)	(0.61)	(-0.68)	(0.17)	(1.12)	(-0.58)
OGDUMMY	0.0048	5.5262	0.2613	0.0083	-0.0464	0.0024
	(0.04)	(1.24)	(0.99)	(0.21)	(-0.95)	(0.04)
TRDUM	-0.1855***			-0.0747**		
	(-4.43)			(-2.17)		
CONST	2.8578***	-10.2378	3.7539***	-0.6022***	-0.7313***	-0.6021***
	(22.79)	(-1.08)	(14.49)	(-6.10)	(-4.98)	(-5.19)
χ2	81.10	29.80	32.29	2k	1k	2k

Even though only χ^2 statistics are reported, Table 3 indicates that the non-linear version - the truncated OLS - is by far the superior model in regards to the model fit. This is strengthened by the results, as for this model the researcher variable is significantly positive in both subperiods as well as in the full period.

The results from Table 1 are partially mirrored by this table. Of the classical transmission channels only the imports are significant and that only in the later years; there they have a positive impact on the generation of new knowledge. The exports in contrast are only significant in the transition years; in the later years however they are slightly insignificant. Additionally, the FDI is significant in no period. The results for the Durbin models in Table 1 are thus validated by these results of the truncated OLS regression.

[30] Estimating the distributions has shown that using a negative binomial model is superior to a Poisson model.
[31] A Vuong test shows that the model is indeed suffering from significant zero-inflation.

The similarity also holds for the consistently positive impact of students - the coefficient however is only significant for the later years - and the insignificance of both oil and gas related variables.

Interestingly enough the share of SME reports a positive impact in both subperiods, again underlining the development of a SME oriented industrial policy approach by Russian policy makers.

Domestically the Russian knowledge generation process is therefore mostly driven by researchers or more precisely agglomerations of researchers which, due to the observed path dependency in the transition, are supposedly former Soviet research centers. In the transition years knowledge generation was furthermore driven by exporting firms which needed to be more innovative per se to compete internationally and are therefore especially innovative on a national scale.

Results that are not unambiguous are the impact of students, imports and oil and gas, whereas for the first two variables at least the signs coincide. As such it can be assumed that a less strong impact in favor of knowledge came from the amount of students or indirectly, due to their strong correlation with universities, from the number of universities. Imports, in contrast, had a minor impact on reducing the amount of newly generated knowledge - supposedly through a general disinterest in growth by imitation in Russia.

Table 4: Regression Results for EPO Patents

	Zero-Inflated NB			Truncated OLS		
	I	II	III	I	II	III
	Negative Binomial					
RES	0.0753***	0.0805***	0.0815***	0.6195***	0.1093*	-0.0314
	(5.92)	(4.55)	(3.30)	(11.31)	(1.77)	(-0.43)
SME	-0.2985*	-0.5295**	-0.3792	-0.1276***	-0.3022***	-0.4230***
	(-1.73)	(-2.00)	(-1.22)	(-2.82)	(-3.21)	(-3.94)
SHADOW	-0.0218	-0.9905	0.3819	-0.0838	-0.4716**	-0.2601*
	(-0.06)	(-1.62)	(0.96)	(-0.74)	(-2.05)	(-1.74)
EX	-0.0700***	-0.0518**	-0.1752**	-0.0818**	-0.2117***	-0.4146***
	(2.77)	(-1.97)	(-2.13)	(-2.10)	(-3.10)	(-5.29)
IM	-0.0520	-0.0269	-0.1937	0.1355**	0.4046***	0.4673***
	(-0.19)	(-0.74)	(-1.20)	(2.33)	(3.48)	(5.90)
OPEN	0.0058*	0.0051	0.2359***	0.0035***	0.0017	0.0297
	(1.74)	(1.31)	(3.79)	(3.55)	(0.90)	(1.31)
FDI	0.0013	-0.0113	-0.2800	-0.0214	0.0746**	0.0136
	(0.02)	(-0.16)	(-0.72)	(-1.62)	(2.40)	(0.64)
STUD	-0.0017	-0.0010	0.0056**	0.0396	0.0235	0.5375***
	(-1.38)	(-0.50)	(2.20)	(1.25)	(0.97)	(3.53)
OILGAS	2.5800	-12.9000*	14.1000***	0.0274	-0.0343	0.1280***
	(1.05)	(1.77)	(3.04)	(1.18)	(-0.92)	(3.82)
OGDUMMY	-0.0032	0.0655	-0.2438	-0.2595***	-0.1014	-0.5902***
	(-0.02)	(0.30)	(-0.88)	(-3.08)	(-0.81)	(-4.76)
TRDUM	-0.4008***			-0.2083***		
	(-2.89)			(-4.48)		
CONST	0.8199***	0.9411**	-0.1718	-1.6721***	-0.0094***	-0.0131***
	(3.44)	(2.36)	(-0.57)	(-10.15)	(-5.34)	(-5.98)
	Logit					
RES	-0.8256***	-0.6305***	-1.4746			
	(-3.71)	(-2.82)	(-1.57)			
SME	-2.3755*	-2.4342	-3.0685			
	(-1.84)	(-1.24)	(-0.35)			
SHADOW	1.9509	1.1178	3.0248			
	(1.58)	(0.68)	(-)			
EX	-0.5012***	-0.2979***	-1.1273			
	(-3.26)	(-2.79)	(-0.54)			
IM	-0.3859	-0.1527	-1.5140			
	(-1.22)	(-0.74)	(-0.46)			
OPEN	0.0273	0.0107	0.1495			
	(1.42)	(1.01)	(0.94)			
FDI	1.0228**	0.5384	2.0160			
	(2.29)	(0.61)	(0.44)			
STUD	-0.0412***	-0.0532***	-0.0273			
	(-2.65)	(-2.92)	(-1.18)			
OILGAS	-112.1000	-189.6000	-2,224.6000			
	(-1.16)	(-1.45)	(-0.28)			
OGDUMMY	0.2366	0.3382	-0.1641			
	(0.46)	(0.48)	(-0.13)			
TRDUM	-0.5176					
	(-1.21)					
CONST	3.1157***	3.0665***	2.8885***			
	(5.01)	(3.30)	(2.81)			
χ^2	456.04	739.47	128.82	465.78	231.82	326.16
Vuong	6.55	4.71	6.39			

In contrast to the previous case, the results for EPO patents summarized in Table 4 do not allow to name one model as superior. Comparing, therefore, the results for the linear and the non-linear KPF design it can be seen that the researcher variable is positive and significant in all setups except for the later years in the truncated regression.

Concerning the impact of the share of the shadow economy, the FDI inflows and the students, all results coincide with the results from the previous model. SME shares in the later years are, in contrast, significantly negative in both models, while before their impact has been positive. Similarly, the results for the imports are different in all approaches, while the coefficients for oil and gas exploitation in Table 4 have opposite signs as in Table 2.

The results for exports potentially coincide since in Table 2 their impact has been insignificant and here it is negative in both sub-periods.

Summarizing, the results for internationally important patents at the EPO are not as clear-cut as the results for domestic patenting at Rospatent. It can, however, be shown that in the transition years it has been primarily the presence of larger and foreign owned firms - via FDI - that has been important for the EPO patents. These effects diminish in the later years where new knowledge, even internationally, was related to the presence of students and therefore the presence of universities. Knowledge generation has been negatively impacted in the later years by the spread of illegal activities as measured via the share of the shadow economy.

Impacts of the foreign trade structure cannot be deduced. These results were partially predictable as imitation of goods can only generate a positive effect on the international stock of knowledge when imitation turns to innovation. To measure this type of effects the time horizon of this study, however, is too short.

4. Conclusions

The knowledge generation process is an essential building block of every NIS. The KPF that models this process, and thereby a major part of the NIS, allows for an empirical assessment of the efficiency of an NIS. The present study estimated an KPF on the basis of the Russian regions to analyze the Russian NIS.

The study has been conducted from a domestic point of view by using Rospatent data and from an international point of view by using EPO data. The results revealed that modelling the domestic knowledge generation process is simpler in so far as results are more pronounced. Nevertheless, it has been possible to not alone assert that the Russian NIS is working efficiently - although the domestic system (based on national, Rospatent data) more efficiently than the international one (based on European, EPO data) - but that different aspects between the traditional channels of knowledge transfers play an important role in the knowledge generation process as well. However, the knowledge generation effects of the traditional channels of imports and FDI are not as pronounced as might have been guessed from theory.

By using a dynamic approach it has been possible to analyze whether the Russian knowledge generation process is path-dependent as would be suspected if Russia were still stuck with only its Soviet-inherited research infrastructure. This study however has shown that the dependence on previously established innovative centers ceased in the later years.

Two additional important insights gained from this study are that SME do play a relevant role in the Russian NIS as well as students and thereby the official education system. Both aspects should be an incentive to Russian policy makers to actively foster related policies and programs, especially if their goal is to generate a Russia that is based not only on oil and gas but on industry and innovations as now Prime Minister Dmitry Medvedev announced in one of his early speeches as Russian President in 2008. Aside from official initiatives like the FASIE program to foster the formation of SME or the reform of the education system, especially the system of tertiary education, in 2012 - all in all relevant steps - it is even more important to ensure that they are efficiently and consequently executed.

The main disadvantage of this study has been that the patent basis has been limited on the one hand for natural reasons as the Russian patenting system only became fully functional in the early 1990s. On the other hand due to data availability only patent data up to 2006 could be implemented. This excludes two important events in the Russian development of the last decade. With Dmitry Medvedev Russia had a president from 2008 to 2012 who, at least officially, endorsed an innovation oriented development path for the RF. While Medvedev openly endorsed the modernization of the Russian economy it can be argued that the political reality has been not very different from the situation under the Putin administration. On the one hand if, under Medvedev, the state really increased its modernization efforts or simply its outward presentation thereof. On the other hand it can be said that the Putin administration already has been active in a number of modernization attempts such as the introduction of university grant programs.

If it were thus possible to extend the study to include Medvedev's as well as Putin's third presidential term it might generate new insights if the Russian NIS actually changed during these times. Additionally, it might reveal whether an approach, as taken by Putin, to influence the system as a whole is more or less effective than an approach as by Medvedev to influence particular aspects of the whole system.

Secondly, with the economic and financial crisis that reached Russia in 2008 - 2009 it seems an important aspect in how far the crisis and government actions to prevent it impacted the Russian NIS. An enlargement of the data source might generate new insights here as well.

An additional extension of the study could be to test not for the existence of patents per se but for their actual use as measured by patent citations or licensing of patent rights.

Summarizing, the study has already shown that in the Russian Federation an NIS comparable to the NIS of Western countries exists and functions in similar ways. Aiming at a modernization oriented development path - independent of its design - these results offer the security that Russia already possesses the necessary institutional prerequisites.

Acknowledgements

The author would like to thank Evgeniya Yushkova for research input and David Hanrahan for editorial assistance.

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Appendix

Table 5: Conditional Fixed-Effects Poisson Regression

	Rospatent Data			EPO Data		
	I	II	III	I	II	II
RES	0.0265	1.2788***	1.3279***	-0.0634	1.1670***	1.1670***
	(1.02)	(9.26)	(5.41)	(-0.21)	(3.31)	(3.31)
SME	0.0204	-0.1345	0.0629	-0.2166	-0.6665	-0.6665
	(0.45)	(-0.71)	(0.33)	(-0.41)	(-0.59)	(-0.59)
SHADOW	0.1094	1.3200***	0.4761**	0.1861	1.4833	1.4833
	(1.43)	(4.30)	(2.33)	(0.38)	(1.54)	(1.54)
EX	0.0095	0.0116	0.0754***	-0.0290	0.3291	0.3291
	(0.86)	(0.84)	(6.76)	(-0.25)	(0.63)	(0.63)
IM	0.0277*	0.1267*	0.0711***	-0.0022	-0.0571	-0.0571
	(1.81)	(1.94)	(3.88)	(-0.02)	(-0.16)	(-0.16)
OPEN	-0.0008	-0.0023***	0.0554**	-0.0012	-0.0049**	-0.0049**
	(-1.47)	(-2.62)	(2.28)	(-0.85)	(-1.96)	(-1.96)
FDI	-0.0104*	-0.0009	-0.0170*	0.0098	0.0969**	0.0969**
	(-1.78)	(-0.11)	(-1.95)	(0.25)	(2.45)	(2.45)
STUD	-0.0241***	0.0115	1.2490***	0.0253	-0.0162	-0.0162
	(-3.51)	(0.71)	(4.15)	(0.38)	(-0.49)	(-0.49)
OILGAS	-0.3910	38.3000	-2.4900***	5.6700***	59.1000	59.1000
	(1.23)	(1.34)	(-3.36)	(3.10)	(0.58)	(0.58)
OGDUMMY	-0.0186	0.4798***	0.0537	-0.0595	0.8078**	0.8078**
	(-1.04)	(2.87)	(0.38)	(-0.26)	(2.33)	(2.33)
TRDUM	-0.0708***			-0.0928		
	(-2.57)			(-0.73)		
χ^2	25.15	934.84	1k	38.01	237.59	237.59

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