The Impact of Financial Crises on Patenting Activity

Seminar monograph

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Abstract

The study is dedicated to the influence of financial crisis conditions on patenting activity. The latter was limited to filing of patent applications related to Patent Office and applicant's origin. It was shown that the crisis environment constraints on country level result in short-term reduction of patent applications filing abroad by country residents, however long-term tendency of applications number growth remains. The study was limited to eight countries, belonging to OECD group (USA, Germany, Japan and Israel) and to emerging economies (China, India, Brazil and Russian Federation). For Brazil and India Granger causality between economic development indicator and filing patent applications abroad has been found.

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Introduction

What happens to patenting activity in financial crisis conditions when the economic process is seriously disturbed and financial resources necessary to feed this activity are suddenly and significantly diluted?

Patents are thought to "play a crucial role in the economy" [1]:

> "To start with, it is important to recognize the primary problem that the patent system solves. This problem-often called the appropriability problem-is that if a firm could not recover the costs of invention because the resulting information were available to all, then we could expect a much lower and indeed suboptimal level of innovation".[1]

Innovation, in turn, is widely believed to drive the modern economy [2]:

> "Today's advanced economies live or die by their ability to get smarter. Growth comes not from competing on labor costs, raw materials or access to capital: our competitive edge depends on our capacity to innovate."[2]

Not arguing concerning competitive edge and growth, we are now witnessing how today's advanced economies are struggling for survival by cutting labor costs and securing access to capital. The latter seems yet to be crucial for capacity to innovate. The circle is full now: financial resources deficiency causes underinvestment, leading to lower level of innovation, causing slow-down in economic development, etc. Is this a real "magic circle", or long-term growth trends prevail, bringing economy to the departure point? Not pretending to exhaustive analysis, this study focuses on the issue of patenting activity changes under conditions of financial crisis, and tries to show that for countries belonging to developed or emerging economies a certain kind of patenting activity, namely filing patent applications by residents abroad, is particularly sensitive to short-term economic disturbances. However, long-term trends prevail in both economic development and patenting activity. For certain emerging economies (India and Brazil) the study determines Granger causality between economic development and patenting activity.

After Schmookler [3] the belief exists that financial crisis situation creates demand pull conditions for innovation. On the other side, there are theories, connecting economic developments to positive or negative technology shocks. Economic developments and

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[1] *K. W. Dam "The Economic Underpinnings of Patent Law"* ***The Journal of Legal Studies*** *23 (1) (1994) 247.*

[2] *I. Hargreaves "Digital Opportunity. A Review of Intellectual Property and Growth"* ***An Independent Report*** *(2011) 2 , http://www.ipo.gov.uk/ipreview-finalreport.pdf*

innovations interrelationship is very complicated, and following certain aspects of their multiple and complex mutual dependences requires thorough choice of targets, variables, data types and sources, and methodology. The current study aims a very limited target of testing the influence of economic disturbances, such as financial crises, on the specific kinds of patenting activity (and not on innovation in wider sense), taking into account the interference and the balance between long-term trends and short-term constraints, using the quantitative methodology based on statistical analysis of data available in the time series format. The first part of this paper is dedicated to literature survey, focusing on the typical features of the financial crisis, the role of innovation in crisis environment, patenting activities and patent statistics from the viewpoint of economic analysis. The second part deals with choice of data and methodology, including countries, variables, and sources of available data. The third part is dedicated to the discussion of obtained data analysis results, the last part – to conclusions. The paper is ended with the list of references, and accompanied with appendixes, containing charts and tables visualizing the data and summarizing the statistical analysis results.

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1. Literature survey

1.1. Financial crisis and its features

Financial crisis is a complex phenomenon that can be defined in very general terms as sudden and unexpected lose of value of some major financial assets. Financial crises occurred relatively frequently in previous two centuries and not always resulted in changes in real economy. When such changes took place the term “economic crisis” could better describe the situation. More than 140 events recognized as banking crises have been identified over the period 1970-2011 [4]. The crisis may come in different shapes and demonstrate various features, such as banking runs and panics, speculative bubbles, stock markets failures, currency instabilities, as well as more severe phenomena - sovereign defaults, recessions and depressions. This study takes into account mainly short-term banking and stock market failures, rather then long-term phenomena such as recession or depression. That is because the former two features directly and immediately affect credit and equity markets [5].

> "Credit markets are just as important as equity markets to financial development. And in most countries far more finance is generated in credit markets than in public equity markets. Even in the United States, which is usually thought the country with the most pronounced equity culture, far more money is raised in credit markets than in equity markets."[3]

Nevertheless, the importance of equity markets should not be underestimated. The blood cycle of modern economy is closed: credits are used to increase equity, and equity – to secure credits.

> "The size and growth of credit, which is the lifeblood of business, will be inadequate. An adequate law on secured credit helps to deter procrastination by allowing creditors to foreclose on property provided by debtors to secure their repayment."[4]

Securing credits is of the highest importance for stability of financial system, since it serves to prevent positive feedbacks in this system. On the other side, tight connection and interdependence of credit and stock markets make them extremely sensitive to mutual fluctuations. Therefore relatively small size events may trigger significant failures in the system, especially when credits are not properly secured.

The causes of financial crises were widely discussed, however there is yet no consensus regarding this issue. Among possible reasons have been mentioned a coordinated, or, even, herd behavior of investors on financial markets (Keynes, [6]), mismatch in the term of banks' assets (long-term loans) and their liabilities (short-term deposits) [7], regulatory failures [8] in the financial sector (e.g. irresponsible behavior of hedge funds), systemic risk features, such as non-reasonable financial leverage and spread of small bank failures also known as financial contagion [9]. Theories of financial crises have been developed, including business cycles [10, 11], Minsky's financial fragility [12] and later positive feedback and herding behavior models [13-15].

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[3] *K. W. Dam "Credit Markets, Creditors' Rights and Economic Development" (2006) 1.* *http://www.law.uchicago.edu/Lawecon/index.html*,

[4] *Ibid.*, 5

> “The appearance of periodically recurring economic crises is the necessary consequence of repeatedly renewed attempts to reduce the “natural” rates of interest on the market by means of banking policy. The crises will never disappear so long as men have not learned to avoid such pump-priming, because an artificially stimulated boom must inevitably lead to crisis and depression.”[5]

We will not go deeply here into the roots of crises, but rather consider financial crisis as a given environment for study of developments in patent activity. Financial crisis of 2007-2008 (which is thought lasting until now) is considered the worst crisis after the Great Depression, demonstrating a variety of features, including housing bubble in the US, bankruptcy and even collapse threat of financial institutions, bailouts of banks by governments, liquidity crisis, failure of major businesses, European sovereign-debt default. These features, presenting in different combinations worldwide allow economists stating systemic and global character of the present crisis. The question is whether the peak of the crisis is already behind us and whether stabilization and recovery began, making it possible to study the crisis short-term effect on patenting activity.

1.2. The role of innovation in the crisis environment

Innovation is an extremely important factor of modern economy, a way of its existence and development. Innovations have been also mentioned among the financial crises triggers [16]. Corporations play a major role in innovation [17].

> "Corporate innovations are an important component in the process of technological change and economic growth and also lead to positive externalities. Whereas the society benefits from innovations, the costs have to be predominantly borne by a single firm. As a consequence, these externalities could result in a suboptimal extent of innovations".[6]

There is a general consent among economists that innovations are crucial during financial and economic crises [18].

> "Joseph Schumpeter famously argued that the process of “creative destruction”, while painful, fosters innovation and progress by discarding the old and familiar for the new and better. From this perspective, the downturn may be a source of

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[5] *L. von Mises* ***The Causes of the Economic Crisis*** *(Ludwig von Mises Institute, 1931) 162-163*

[6] *A. Ziegler "Disentangling Specific Subsets of Innovations: A Micro-Econometric Analysis of their Determinants"* ***Swiss Federal Institute of Technology Zurich*** *(2008) 2, http://www.esee2009.si/papers/Ziegler-Disentangling.pdf*

> opportunities for innovators and innovation systems."[7]

There are, however, arguments that the crisis environment does not favor innovation [19]:

> "From one side there were those who claimed that radical innovations are more likely to be carried out during the crises (Mensch, 1979 [20]). While on the other side, there were those who answered back that what matters for the economy is mostly the diffusion of innovations, which takes place during the growing phases of the business cycles".[8]

Innovation is so important, since companies, struggling for survival, should simultaneously take care of their future after crisis. There is a belief that crisis environment creates demand pull for innovation [21].

> "Demand-pull arguments have been suggested both in favor and against the cyclical hypothesis. On the one hand, it has been argued that established firms might delay the introduction of innovations as it requires a diversion of resources from on-going activities because they prefer to exploit the value of their existing rents (Mensch, 1979). Given that the value of existing rents decreases in a recession, in that case firms might be encouraged to introduce new products and processes. On the other hand, two arguments based on the role of demand suggest that innovations are more likely to be introduced during business cycle upswings. The first claims that rising demand during a boom provides more favorable conditions to absorb new products than a recession. The second argument suggests that because firms have only a limited period of time to appropriate the returns from their innovations, they are more likely to introduce new products and processes in an expanding market regardless when they produce them."[9]

Environment change to technology push after the crisis results in better market position for the companies investing in innovation [22].

> "Basic or major innovations are unequally distributed in time. They tend to cluster in

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[7] *Innovation in the crisis and beyond* ***OECD Science, Technology and Industry Outlook*** *(2012) 24,* *http://www.oecd.org/sti/sti-outlook-2012-chapter-1-innovation-in-the-crisis-and-beyond.pdf*

[8] *A. Filippetti, D. Archibugi "Is the Crisis Striking Innovation? Evidence from Europe"* ***CIMR*** *(2012) 2,* *http://www.kites.unibocconi.it/wps/allegatiCTP/FILIPPETTI%20is_the_crisis_striking_innovation_ArchiFil_july_2009.pdf*

[9] *A. Filippetti, D. Archibugi "Innovation in Times of Crisis: The Uneven Effects of the Economic Downturn across Europe"* ***Italian National Research Council CNR IRPPS*** *(2010) 5* *http://mpra.ub.uni-muenchen.de/22084/*

"B-periods" of economic distress."[10], and:

"Basic innovations are defined as giving the basis for new and rapidly growing industries or, (as process innovations) to lead to radical changes in already existing industries. When several new growth industries are initiated at about the same time, their rise may give the basis for a longer lasting period of relative prosperity."[11]

Jeremy Rosie, Director of Thomson Reuters IP Solutions is very sharp [23]:

"If history is any guide, companies that invest in intellectual property in a recession come out of the experience stronger than those who choose to wait for the economy to improve"[12].

He is convinced that:

"For companies with cash and ideas, history shows that downturns can provide enormous strategic opportunities."[13]

Furthermore:

"To truly understand the corollary between economic uncertainty and the creation of breakthrough IP, you have to look at the inventions themselves. Here too, the evidence is pretty strongly stacked in favor of intra-recession IP investment. Consider the following timeline of recession-era inventions:

• 1929-1939 – television, nylon, neoprene, photocopies, electric razor.

• 1973-1975 – Japanese auto industry, personal computers.

• 1990-1991 – the internet economy.

• 2001-2003 – the iPod.

• 2007-present – green energy, telecom, computing convergence, nanotech.[14]

And finally:

"If there is one universal truth in business, it is that companies that continually invest in innovation are in a better position to ride out economic storms and come out the other end stronger. With the newfound perspective of having seen some of the world's most tangible asset evaporate – residential real estate and global banking institutions to name a couple – we turn to our intangible assets as the lifeblood of economic growth. Any company that is active in the IP lifecycle and is weighing the

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[10] *A. Kleinknecht "Prosperity, Crisis, and Innovation Patterns: Some More Observations on Neo-Schumpeterian Hypotheses"* ***Researchmemorandum*** *(1981) 3*
[11] *Ibid.*
[12] *J. Rosie "The value of IP in a recession"* ***Intellectual Asset Management*** *(July/August 2009) 7*
[13] *Ibid.*
[14] *Ibid.*

> value of investing into the recession versus waiting out the storm needs to think hard about the lessons of creative destruction. We are at a moment in history when active investment in innovation and intellectual property is the ultimate competitive advantage. IP is about agility, the ability to capitalize on the opportunities the recession will create. The alternative is waiting for the world to change around you."[15]

Having said that, we should remember that in the crisis environment companies find themselves under conditions of constraint financial resources and their real dilemma is a tough choice between short-term goals of survival and long-term of innovation, actually, between cash and ideas, as Mr. Rosie mentioned above .

1.3. Patenting activities by companies

Patenting activity is regarded as a relevant, but not ultimate indicator of innovation [24].

> "The most traditional indicators of a firm's technological innovation activity have been based on analyzing information on R&D expenditure and patent data."[16]

Patenting activity of the company is a direct consequence of its R&D efforts, so both mentioned indicators are certainly causally connected, one constituting input value, another – output, both requiring significant expenses. There are, however, essential differences between them. R&D efforts do not assure real innovation.

> "It can therefore be stated that inputs are a necessary condition, but not sufficiently so to guarantee that the process is carried out successfully. This base itself is the main common limitation of indicators based on innovation input, although this has not prevented them being used in various studies".[17]

Patenting activity as an output indicator seems more relevant, but also with limitations.

> "Despite its widespread use, some limitations on it as an indicator of company technological innovation output should be stressed. First and foremost, patents are a reflection of invention rather than innovation. If we bear in mind that a technological innovation can be defined as a commercially successful invention and that inventions are protected by means of patents that restrict or impede their manufacture,

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[15] *Ibid.*

[16] *M.L. Flor, M.J. Oltra "Identification of innovating firms through technological innovation indicators: an application to the Spanish ceramic tile industry"* ***Research Policy*** *33 (2004) 323*

[17] *Ibid., 324*

> commercialization and sale, patents remain an intermediate indicator of an innovative result, as they do not guarantee this success".[18]

R&D expenditures include costs that cannot be cut immediately; nevertheless they can be reduced significantly and quickly. Patenting expenses, on the other hand, include future long-term liabilities (e.g. maintenance fees) that cannot be substantially reduced without risk of significant (and possibly irreversible) damage to company's intangible assets. Therefore company's decisions regarding patenting activity in the situation of constrained financial resources seem strategic ones, indicating that the propensity of the company to innovate prevails on short-term financial difficulties. In the crisis environment the company has to thoroughly choose its patenting activities in order to save money. Two issues should be thoroughly considered: what to patent and where to patent. When the company applies for patent, two considerations constitute the major incentives: strength of potential competitors and number of potential consumers. When the crisis is spread globally, both incentives are significantly reduced in eventually all targeted countries. Since patenting pursues long-term goals, choice of countries to apply for patent should be made taking into account post-crisis market recovery prospects.

Another issue to consider is the value of the technology to be patented. Patent protection is traded-off for disclosure; therefore weak patent that is barely enforceable and can be easily invalidated becomes actually an instruction for potential competitors [25].

> "Many patents are virtually worthless, either because they cover technology that is not commercially important, because they are impossible to enforce effectively, or because they are very unlikely to hold up if litigated and thus cannot be asserted effectively. A small number of patents are of enormous economic significance."[19]

Under crisis conditions companies should refrain from applying for weak patents, taking into account not only prosecution and maintenance, but also future litigation costs. According to these considerations one can expect significant shrinking of both R&D and patenting activities of companies during financial crises. Certainly these expected effects can vary dependent on country, field of technology, company size etc [26].

> "The results from the econometric analysis indicate that various characteristics of the innovation, the market, and the innovating firm have a significant effect on the propensity to patent. First, there appears to be a U-shaped relationship between firm

[18] *Ibid., 326*

[19] *M. A. Lemley, C. Shapiro "Probabilistic Patents"* ***Journal of Economic Perspectives*** *19(2) (2005) 75–98*

> size and the propensity to patent, which can be attributed to a relatively large extent to economies of scale in the patenting activity as well as to the relatively important role of patenting in start-up ventures. Second, the estimation results suggest that larger—that is, more novel and significant—innovations are patented more frequently than smaller ones. Third, technologically very complex innovations appear to be patented less often than others, while the fragmentation of intellectual property rights to cumulatively developing technology seems to entail high propensities to patent. Fourth, the econometric analysis produces weak evidence on a negative relationship between the propensity to patent and the product market competition."[20]

The factors, mentioned above, can be regarded as constants in the "propensity to patent formula". Economic and market conditions vary. It seems worth to study propensity to patent as a function of variable conditions; and financial crisis, providing sharp changes in these conditions, creates a rationale for case study.

1.4. Patent statistics and its use in economic analysis

Patent statistics is now available and valuable source of information, containing data organized in time series for a majority of countries [27-29]. Different data cross-sections can be found: by Office, by origin, by industry, applications, granted patents etc. These data can be used in the economic analysis [30, 31]:

> "Patents and patent statistics have fascinated economists for a long time."[21]

Jacob Schmookler [3] pioneered in attempts to connect patent statistics to economic growth indicators [32]:

> "Schmookler's finding of a strong relationship between investment in capital goods users industries and patent applications by capital goods producing sectors has been generally accepted by economists as evidence that patenting is a function of effective demand ("demand pull" hypothesis)."[22]

In order to effectively use patent statistics in economic analysis and discover some regularity, causalities or patterns, patent data should be compared with economic data that

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[20] *I. Mäkinen " The propensity to patent: An empirical analysis at the innovation level"* ***Submitted to the EPIP-2007 Conference Lund, Sweden*** *(20-21.09.2007) 23*

[21] *Z. Griliches* ***Patent Statistics as Economic Indicators: A Survey. Chapter 13 in: R&D and Productivity: The Econometric Evidence*** *(University of Chicago Press, 1998) 287*

[22] *A. Kleinknecht, B. Verspagen "Demand and innovation: Schmookler re-examined"* ***Research Policy*** *19 (1990) 387*

are also widely available in time series format. Various techniques can be applied for data analysis based on certain statistical hypotheses. When discovery of causality is targeted, its direction (assignment of independent and dependent variables) is of high importance. Causality may be unidirectional or bilateral. Economic data are considered independent variable when demand pull hypothesis is in mind, opposite assignment is in the case of technology push.

> "Apart from rendering questionable the conventional wisdom that patents are indicators of invention (as opposed to innovation), the above quotation raises further doubt about whether Schmookler's and Wyatt's [33] results indeed support a unidirectional causality from demand to inventive effort as implied in Schmookler's demand-pull hypothesis. An opposite direction of causality ("technology-push") appears to be at least equally plausible."[23]

In our case patent data should be defined as the dependent variable. Nevertheless, sometimes it makes sense to regard the issue in question from the point of view beyond its borders, possibly, above the hyper-plane of analysis. Creating a kind of additional dimension can help to better understand the problem from more generic position and discover some patterns not visible from inside. According to this approach it is sometimes worth to consider two-ways causality between properly chosen economic and patent indicators.

> "It can be added here that in the recent neo-Schumpeterian literature it has been suggested that the relative weight of "demand-pull" and "technology-push" may vary with the stage of the "life-cycle" of an industry and with the type of innovation; that is, "technology-push" may be more important for important innovative breakthroughs in the beginning of the life cycle, while "demand-pull" may be more important for subsequent ("secondary") innovations".[24]

Several considerations seem important when putting goals for patent – economy relationship. The first one is a proper choice of variables. What kinds of patent and economy data should be used? Should they include applications or granted patents? GDP or GNI? Gross or per capita values, or corrected by Purchase Power Parity (PPP)? Should the variables be absolute values or their growth rates? Is it worth to investigate simple or multi-variant relationships? These questions concerned multiple researchers that tried various combinations and achieved different conclusions.

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[23] *Ibid., 388*
[24] *Ibid, 388*

> "It follows from the above that, for testing of the "demand-pull" hypothesis measures of patenting and demand which are independent of sector sizes ought to be used. Principally, we see two theoretically plausible ways of doing this. The first would be to use ***partial*** correlations, relating (absolute) investment and patents to each other, the influence of sector size being kept constant; the second possibility would consist of using ***growth rates*** of investment and of patenting, arguing that the rise or decline of patenting activity is somehow related to ***changes in*** (as opposed to ***size of*** demand)."[25]

Another problem may be auto-correlation of data in time series format. From this point of view growth rates may be preferable, since they seem to be less tending to auto-correlation. On the other hand, absence of correlation between growth rate data says nothing about correlation between absolute data.

Economic analysis of patent data may be performed on different levels: company, industry, country, Patent Office, group of countries. Choice of level depends on the target of study. At different levels different economic indicators should be chosen.

> "How does one come to know whether patent statistics measure anything interesting? Input or output? One way is to look for correlations between patent counts and other variables that are thought to matter: input measures such as R&D expenditures, and output measures such as productivity growth, profitability, or the stock market value of the firm".[26]

Lower level allows deeper insight into incentives of the companies to apply for patents; the drawbacks are data availability limitations and limited value of this kind of case study. On the other side, global scale studies seem to be much less informative due to differences in the level of economic development and patent laws in different countries. For the sake of current study it seems worth to choose the country scale and investigate the issue for several countries belonging to one or two groups, in order to prevent undue ramifications. In this case gross economic indicators for each country should be used. Anyway, this study has to pursue limited goals and by no means to pretend being universal and exclusive.

The issues concerning particular choice of variables and applicable statistical analysis techniques will be discussed further in the methodology section.

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[25] *Ibid., 389*

[26] *Z. Griliches* ***Patent Statistics as Economic Indicators: A Survey. Chapter 13 in: R&D and Productivity: The Econometric Evidence*** *(University of Chicago Press, 1998) 289*

2. Methodology

2.1. Hypotheses for the study

This study is not just about the collision between cash and ideas, but rather about the collision between long-term goals of patent activity subjects and short-term constraints imposed by environment. Another paradigm can be drawn between long-term trends in the economy and in patenting activity and short-term disturbances brought by financial crisis. Therefore it makes sense regarding the issue in question from more general position for several reasons. Financial crisis creates sudden and sharp changes in economic conditions, and case study performed on such sharp changes is unlikely to provide insights on causalities between economic environment and patenting activity, or, more generally, innovation. On the other side, better understanding of smooth economic changes influence on patenting activity can shed some light on patenting behavior under crisis obstacles. Performing study in longer time interval, well beyond the limits of crisis, allows using larger amounts of data and applying powerful econometric and time series analysis techniques [34-39], allowing, prediction of some trends of patenting activity in connection with different crisis and recovery scenarios. The research target therefore can be more generally defined as study of economic conditions influence on patenting activity. Since economic conditions (including financial crisis) have global and national aspects, and patenting activity can be regarded on company or national levels, in order to find the common denominator, it makes sense to limit the study on national level, comparing the results for several countries belonging to one or two economy related groups, e.g. OECD and emerging economies. It is not worth to include developing countries in the study, since patenting activity in the most of them is marginal. Patenting activity indicators could include data by Office (targeted country for patent protection) and by origin (country of invention).

With these considerations in mind, three hypotheses can be formulated.

The basic hypothesis: There is no influence of economic conditions neither in the targeted countries, nor in the country of invention, on patenting activity.

The first alternative hypothesis: Economic conditions in the country affect filing of patent applications by country residents abroad.

The second alternative hypothesis: Economic conditions in the country affect filing patent applications by non-residents in the country.

These three hypotheses seem to properly cover incentives of economic entities in inventive and patenting activities of companies either in their country of residence or beyond its borders, depending on local and global economic environment. The basic hypothesis excludes two alternative ones, which, in turn, are not mutually exclusive.

2.2. Choice and justification of methodology

Quantitative methodology based on statistical data analysis was naturally chosen for this study. The choice of methodology was motivated by data availability from a variety of reliable sources [28, 40-43], as well as availability of comprehensive statistical and time series analysis techniques that allow assessment of interdependence, and, even, causality between economic conditions and patenting activity.

Quantitative analysis has some noticeable advantages, such as reliability, validity, generalizability, replicability, basing on clear and fixed rules, and providing verifiable results. Quantitative approach is very useful in formulating, testing, confirmation or falsification of hypotheses, settling disagreements between specialists, correcting some common delusions or misbelieves [44].

> "Quantification, in this view, goes hand in hand with systematization, rigor, precision, and exactitude in definitions and measurements, with objectivity and replication of procedures and findings, in other words, with a scientific approach to social science. And the goal of that scientific approach – to which content analysis is seen as an important methodological contributor – is to rigorously test hypotheses drawn from broader theoretical frameworks."[27]

Certainly, quantitative methodology has some drawbacks: a necessity of large data amount treatment, as well as statistical approach limitations. Statistics in general does not provide insights into roots of things and phenomena and causal relationship between variables. On the other hand, in the presence of variable and uncontrollable environmental factors, when deterministic model is unlikely to be allowable, statistical approach seems indispensable. In the conditions of uncertainty and lack of full information concerning phenomena to be studied, when deductive approach seems useless, statistical techniques based on induction may be especially valuable, within certain limitations regarding scope of conclusions and inference.

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[27] *R. Franzosi* ***Content Analysis: Objective, Systematic, and Quantitative Description of Content*** *(Ph.D. Thesis, 2011) xxi,* *http://www.unive.it/media/allegato/Scuola-Dottorale/2011/allegato/Content_Analysis_-_Introduction.pdf*

2.3. Economic and patent data and their sources

Economic and patent data are widely available over the internet. Since for the purpose of this study national statistics for different countries is of particular interest, major sources of economic data may include World Bank (WB), International Monetary Fund (IMF), CIA, UN [40-43]. Also WIPO provides some economic indicators [26]. Patent statistics can be found at WB and WIPO. Although it is possible to take both kinds of statistical data from the single source (WB or WIPO), it is worth for the sake of reliability to borrow the economic indicators data from WB, and patent data from WIPO.

Economic indicators chosen for this study include GDP, GDP per Capita, and GNI corrected by Purchase Power Parity (GNI-PPP), the latter seems the most relevant, because costs of goods and services depend on purchase power. Accordingly, these values can be deemed as relevant and contemporaneous indicators of the economic environment in the country, and, therefore, affecting directly and immediately the subjects of patenting activity. R&D expenditures or assets were not chosen, albeit they are widely discussed in the literature relatively to patent statistics [45-48], since their effect on patenting activity seems not to be direct and immediate, although there are some opposite indications.

> "Nevertheless, the evidence is quite strong that when a firm changes its R&D expenditures, parallel changes occur also in its patent numbers. The relationship is close to contemporaneous with some lag effects which are small and not well estimated (Hall, Griliches, and Hausman 1986 [48]). This is consistent with the observation that patents tend to be taken out relatively early in the life of a research project. Because the bulk of R&D expenditures are spent on development, most of the time-series variance in this variable must come from the differential success in the further development of existing projects rather than from the initiation of new ones. The relatively low correlations in the time dimension should, therefore, not be all that surprising, but they imply that patent numbers are a much poorer indicator of short-term changes in the output of inventive activity or the “fecundity” of R&D."[28]

Since R&D expenditures indicate an input value, and patenting activity – output, and there is a time lag between the two [49], while R&D productivity varies broadly depending not only on country, but also on industry, company size etc., taking this variable into

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[28] *Z. Griliches **Patent Statistics as Economic Indicators: A Survey. Chapter 13 in: R&D and Productivity: The Econometric Evidence** (University of Chicago Press, 1998) 302*

consideration will introduce indirect effects on patenting activities that can conceal direct influence of economic environment, therefore we will refrain from this choice.

Regarding patenting data, a variety of indicators is available. The main choice should be between applications and granted patents. Since prosecution lasts usually 2-3 years, the significant time lag between granting of patent and economic conditions at the time of making decision to patent makes the choice of patent applications more favorable for the purpose of the study. Furthermore, since not all the applications result in granted patents, the company's incentives to refrain from submitting weak applications is unlikely to be expressed in the granted patents data. Patent applications data available at WIPO are organized by Office and by origin, but for the purpose of testing both alternative hypotheses two indicators seem the most relevant on the country level: number of resident applications abroad and number of non-resident applications within the country. The former is relevant for the first alternative hypothesis, the latter – for the second alternative hypothesis. These kinds of data are available for the period 1994-2011 and include several local and at least one global financial crisis. In order to keep the study in the reasonable format, without undue ramifications, we will focus on the relationships of each one of the mentioned patent applications indicators with one economic variable, namely GNI-PPP. All three variables are represented in time series format (annually) and cover 18 years for a variety of countries. Countries belonging to OECD (USA, Germany, Japan, and Israel) and to the emerging economies (China, India, Brazil, and Russia) were specifically chosen for this study.

2.4. Statistical analysis tools

Statistical tools for data analysis and testing of statistical hypotheses are diverse. Since both economic and patent data are available in time series format, time series analysis is a natural choice to start with. It may include data visualization in time-property format, evaluation of trends, periodical deviations and white noise, auto-correlation analysis. Both economic and patent time series data can be presumed significantly auto-correlating. Deviations analysis, both periodical and non-periodical seems problematic due to time limitations of 18 years. Therefore our analysis can be limited to data visualization, trend estimation and auto-correlation analysis for all three variables. These tools can be referred to as exploratory data analysis [50].

In order to study regularities in the mutual behavior of economic and patent indicators, regression techniques can be applied [35]. The simplest case could be linear regression, but other types of dependences (exponential, polynomial, etc) can be considered. In the literature absolute values of economic or patent data are often represented in the logarithmic scale, but this is not so important, taking into account a possibility of exponential regression. Regression techniques for time series data require special procedures, including testing of auto-correlations and choice of the appropriate model. Auto-correlated data can significantly deviate trend lines, therefore Box-Jenkins approach of using lagged variables is applicable in this case instead of ordinary least squares (OLS) regression approach [51]. In multivariate regression case all explanatory variables should be linearly independent; otherwise variables will invariantly correlate with target function, even if there is no dependence. Regression analysis of the dependence between patent variables and chosen economic variable will be performed for each chosen country, and then countries of different groups will be compared in order to justify or falsify the hypotheses. Regression equations and, particularly, regression coefficients for different countries will be compared as well in order to evaluate the propensity to file patent applications [26].

Granger causality test [52-59] will be applied to estimate causality between patent and economic data. Granger causality test is generally used to test the hypothesis that one time series is useful to forecast another one. A time series X is believed to Granger cause Y if certain statistical tests (F-statistics or t-statistics) made on lagged values of X provide statistically significant forecast for the future values of Y. The test is performed in several steps. First, the auto-regression of Y is built using proper time lags. Then the auto-regression is augmented by including lagged values of explanatory variable. Then all individually insignificant (from the viewpoint of t-statistic) lagged X values are excluded from auto-regression, following by F-test performed to confirm that jointly X-lags add explanatory power to the regression model. Null hypothesis (no Granger causality) is accepted when no lagged X values remained in the regression model, otherwise null hypothesis is rejected and X is thought Granger causing Y. The test can be used in one-way or two-ways mode.

There are some evidences about using Granger causality test in the field of our interest. R&D versus productivity dynamics was investigated by Rouvinen [60]:

> "We study four issues in R&D–productivity dynamics: does R&D Granger cause productivity, is there a lag between R&D and its productivity effects, does the potency of R&D vary in timing and magnitude, and what is the role of R&D spillovers and aggregate shocks. The results suggest that R&D causes productivity

> but not vice versa, productivity responds to changes in R&D with a considerable lag".[29]

Another study in the same domain was performed in Sweden [61]:

> "As expected, the results showed evidence of a strong and highly significant relationship between R&D and productivity through innovation output, measured as share of sales associated with new product and processes at the firm level."[30]

The IMF study was performed by using Granger causality approach to test technology shocks influence on productivity and was based, among others, on patent applications data as a measure of technological progress [62]:

> "This paper has argued that patent application data can be used as a valid measure of technological progress. Using vector auto-regressions on data from 1889 to 2002, this paper concludes that when examining the full sample period aggregate labor productivity responds negatively in the short run after technological progress occurs. This result is robust to several different methodological specifications and to utilizing the stock of patent applications and R&D data as alternative measures of technology..."[31]

Patent output and economic growth data were analyzed for Jiangsu province in China, and co-integration of corresponding time series was found [63].

> "The empirical results show that patent output of Jiangsu Province has a strong correlation on economic growth."[32]

Similar research concerning Taiwanese high-tech and non-high-tech industries demonstrated significantly different result [64]:

> "Our results indicate that bilateral causality between capital investment and market performance normally holds, while such a bilateral causal relationship between

[29] *P. Rouvinen "R&D–Productivity Dynamics: Causality, Lags, and "Dry Holes""* ***Journal of Applied Economics*** *V(1) (2002) 123*

[30] *A. Heshmati, H. Lööf "Investment and Performance of Firms: Correlation or Causality?" (2006) 28, http://www.infra.kth.se/cesis/documents/WP72.pdf*

[31] *L. E. Christiansen* ***Do Technology Shocks Lead to Productivity Slowdowns? Evidence from Patent Data*** *(International Monetary Fund, 2008) 26, http://www.imf.org/external/pubs/ft/wp/2008/wp0824.pdf*

[32] *Lu Lu, Yan-Juan Pan, Jun Yang " Cointegration Analysis between Jiangsu Patent Output and Economic Growth"* ***Journal of Intellectual Property****, 1(2) (2012) 21*

> patents and production value can only be found in the high-tech electronics industry in Taiwan."[33]

Granger causality tests allows in some cases to estimate one-way relationships in the cases when the dependence between factors seems symmetric [65]:

> "The state panel causality tests we perform in this paper conclude that there is a one way causal relationship between state entrepreneurial activity and venture capital investment, but that the direction of this causal relationship is that entrepreneurial activity causes an inflow of venture funding, and not vice versa. Because entrepreneurial activity tends to be the underlying factor that automatically and naturally attracts more venture capital to an area, economic development policies should focus on creating an environment attractive to individual entrepreneurs, rather than on attracting venture capital."[34]

Closely to our target, the dynamic link between patent and GDP growth using quarterly data for G7 countries has been made [55]:

> "ARDL model showed that there exist positive relationship in long run between quarterly growth of patents and quarterly GDP growth."[35]

These examples show that Granger causality test is a valuable statistical instrument to investigate time series interdependencies, providing unique for statistical tools possibility to shed light onto causal relationship between variables.

2.5. Scope of the research and its limitations

The research will be performed using statistical data (both patent an economic) for eight countries belonging to OECD group and emerging economies (BRICS group) to the depth of 18 years back from 2011 to 1994. Time series data will be restricted to GNI-PPP and patent applications (abroad and non-resident) annual values for each of said eight countries, and data analysis will be performed per country. Time limits are restricted because of limitations in the reliable patent statistics data for longer period. Analysis of time series will

[33] *Gee San, Ya-ling Huang "Innovation, Performance and Capital Investment: A Causal Analysis of Taiwan's High-tech and Non-High-tech Industries" (2007) 1, http://www2.southeastern.edu/orgs/econjournal/index_files/JIGES%20JUNE%202010%20SAN%20HUANG%2025-40.pdf*

[34] *S. F. Kreft, R. S. Sobel "Public Policy, Entrepreneurship, and Economic Growth" (2003) 22, http://www.cato.org/sites/cato.org/files/serials/files/cato-journal/2005/11/cj25n3-15.pdf*

[35] *D. Josheski, C. Koteski "The causal relationship between patent growth and growth of GDP with quarterly data in the G7 countries: cointegration, ARDL and error correction models" (2011) 1, http://mpra.ub.uni-muenchen.de/33153/*

be limited to exploratory data analysis (including data visualization and auto-correlation investigation), regression analysis according to Box-Jenkins approach, and Granger causality test. The latter will be limited to one-way causality, e.g. GNI-PPP will be chosen as an explanatory variable, and patent applications number abroad – as a target variable. This kind of analysis relates to demand pull concept in Schmookler's sense. Popular in modern economic science concepts, such as "technology shocks", supposing predominantly innovation influence on economic developments, and operating variables such as total factor productivity (TFP), R&D expenditures, etc, will be left beyond the limits of current study.

3. Results and discussion

3.1. Time series analysis of economic and patent data

Time series economic data for eight selected countries are represented on Fig.1 (Appendix A). This data visualization (taken for the depth of 18 years back from 1994 till 2011) shows nearly linear GNI-PPP growth for OECD countries with pronounced failure in 1997-1999 and 2008-2009, while for emerging economies economic growth was nearly exponential without significant failures (except Russia). This difference in behavior reflects strength of the last financial crisis which started in the USA and spread to European and other OECD countries, but cause less damage extent for Chinese or Indian economy. Russian economy, much stronger depending on European economic developments, demonstrates significant slow-down in the last four years, following the failure of 2008. Substantially coherent behavior of the developed economies may be regarded as an evidence for either strong interdependence of these economies, or global character of the crisis.

The respective patenting activities for these countries are represented on Fig. 2 and 3. Fig. 2 (Appendix B) represents time series of residents' patent applications abroad for four OECD countries and four emerging economies. The trends for OECD countries are similar to those of GNI-PPP, with two pronounced failures that seem longer and sharper than those of economic trends. For emerging economies nearly exponential trend is observed with two significant failures for Russia and Brazil, one failure in 2009 for India, and smooth trend for China. These trends can be interpreted in terms of high sensitivity of this kind of patenting activity to deteriorating of economic and financial conditions in the country.

Fig. 3 (Appendix C) demonstrates trends for non-resident patent application filed in the chosen countries. For OECD countries nearly linear trend similar to that of GNI-PPP is observed only for USA, while for emerging economies nearly linear trends with characteristic two failures can be traced. These traces resemble more the GNI-PPP trends in OECD countries than those in emerging economies themselves. The feeling is that economic conditions in the country affects residents patent applications filing abroad significantly stronger and stricter than non-resident applications filing in the country. In other words, data visualization seems to support the first alternative hypothesis vis-à-vis two others. In order to justify this assumption, additional tests should be done.

3.2. Regression analysis of relationships between variables

Regression analysis for data presented in time series format is complicated due to auto-correlation of the time series. The reason for this complexity is that two time series with similar trends can be considered linearly dependent even in the absence of causal relationship between two phenomena. This can lead to spurious results when using static (OLS) regression models. Therefore in time series regression analysis distributed lag models are usually applied. In these models not only contemporaneous, but also lagged in time values of the explanatory variable are taken into account. According to Box-Jenkins approach, when the variables are strongly auto-correlated, the auto-regressive (AR) model is preferable, where the target variable is dependent on several lagged values of the explanatory variable [66-67]. This approach presumes the choice of the model as a first step, followed by residuals calculation and checking the hypothesis of the residuals independence. Auto-correlation (ACF) and partial auto-correlation (PACF) functions are also calculated. For the sake of this study and on the base of the available data, linear second order auto-regressive model was chosen, according the following regression equation:

$$Yt = A+BYt\text{-}1+CYt\text{-}2+DXt\text{-}1+FXt\text{-}2+E \qquad \textbf{(1),}$$

where *Yt*, *Yt-1*, *Yt-2* – patent applications (abroad) data for years *t*, *(t-1)*, *(t-2)* respectively, *Xt-1* and *Xt-2* – GNI-PPP data for years *(t-1)* and *(t-2)* respectively, *A*, *B*, *C*, *D*, *F* – constants, and *E* – residuals. Second order model was chosen according to model selection criteria [68-71], taking into account that increase in number of lagged values decreases the available data sample size for statistical analysis. Model fit and residuals analysis for eight chosen countries is presented in Appendix D (Fig. 4-11). It can be seen that the model predicts failures in patent applications abroad (sometimes with one year time shift), residuals for all countries are stationary, fluctuating around zero, and auto-correlation function terms (second and higher) are reasonably small. All this indicates reasonable fit between model and data. Regression model parameters are summarized in Table 2 (Appendix D) and show very high correlation factor and reasonably high F-statistic values (except Japan).

3.3. Tests for Granger causality between economic and patenting data

One-way Granger causality test was applied for causality investigation between patenting and economic variables chosen for this study. Usually statistical models are not related to causality issues, disregarding essential relationships between different phenomena, and focusing on formal relationships that are proved to be non-occasional. Granger [72], however, argued that the test he proposed reveals some information concerning causality. A time series *X* is said to Granger-cause *Y* if it can be shown, usually through a series of t-tests and F-tests on lagged values of *X* (and with lagged values of *Y* also included), that those *X* values provide statistically significant information about future values of *Y* [73]., i.e. the model including explanatory variable lagged values *(X)* allows better prediction of future target variable values than auto-regressive model including lagged *Y* values only.

Therefore the target of this test was to compare the predictive power of the regression model (1) with that of simple auto-regressive second order model (2):

$$Yt = A+BYt\text{-}1+CYt\text{-}2+ E \qquad \textbf{(2).}$$

Granger causality includes two separate statistical tests. One of the predictive power of VAR model (1). In this test Granger basic hypothesis that GNI-PPP value does not Granger-cause patent applications abroad should be rejected. In the second test the basic hypothesis that there is no instantaneous causality between residuals of two variables in time should be accepted. Explanatory variable *X* is deemed to Granger-cause target variable *Y* if both tests provide the above mentioned result. Granger causality test results for explanatory variable GNI-PPP and target variable "Patent applications abroad" for eight chosen countries are summarized in Table 2 (Appendix E). It can be seen that Granger causality between two variables was proved for Brazil and India, and falsified for other six countries.

3.4. Discussion on relationship between economic and patenting data

As can be seen from the analysis described above, there are some evidences of the financial crisis influence on the specific kind of patenting activity, although causality between economic and patent statistical data was found only in two cases of eight investigated. Our attempt to understand these results could include the following considerations. First, we have seen that both economic and patent time series data are strongly auto-correlative. This means, inter alia, existing of strong and pronounced trends in these series. Time series is usually thought a particular realization of a stochastic process [74], including a collection of random variables, continuously changing in time. Existing of trend in time series can result from either existing a deterministic rule behind the stochastic process, or relatively slow changes in the random variables as compared to period in time series (in our case all the data are annual). Furthermore, assuming that economic processes behind GNI-PPP data (as well as GDP or other relevant economic indicator for certain country) have a slow component that is not very sensitive to short-term deviations (even strong enough, such as financial crises), we can explain the generally progressive trend in economic development (nearly linear in OECD countries or nearly exponential in China and India). Similar progressive trends we can see in the patent applications filing abroad data for eight chosen countries, but not in non-resident applications filing data having different trends for chosen countries. In both economic and patent time series we can observe failures corresponding financial or economic crises, contemporaneous and coherent for all chosen countries. The question is whether the observed patterns indicate causality between economic and patenting processes? Exploratory data analysis and data visualization cannot provide the unequivocal answer, because of strong auto-correlation observed in both time series. Apart from causality, similar trends in time series can result from similarity of the corresponding stochastic processes or from existence of a third process causing both. Actually, patenting activities, such as filing patent applications abroad, depend on long-term motivation for stronger market position and short-term constraints caused by financial crisis, including credit and cash flow shortages. And, as it can be seen from the data (especially, auto-correlation), long-term motivation seems stronger. Granger causality test applied to the chosen data series on the country basis provided mixed results: causality existence was found for Brazil and India and rejected for six other countries. These findings do not allow distinct conclusions concerning causality between economic and patenting statistical data, albeit intuitively such dependence may take place. There may be many possible reasons for vague result, including limited available time series length, choice of countries, choice of variables, impossibility to combine data for different countries, great variation of the data range for different countries etc. It is worth to mention that economic data for certain countries exist for long time, while reliable patent applications data is available since 1994, i.e. for 18 years. Therefore use of distributed lag models for this data is limited to few lagged terms, since an increase in lagged terms reduces sample size for each lag, making statistical consistency of the model problematic. In order to increase the sample size quarterly data series could be applied instead of annually ones, but, first, such data for patent applications is less available and reliable, and, second, quarterly data will not help much in terms of reflecting slow changes in random variables of corresponding stochastic processes. Positive Granger causality test for Brazil and India provide certain (albeit weak) indication that causality between economic development and patenting activity may exist. Current financial and economic crisis, being global and systemic, may provide a unique possibility to shed some light on the mutual dependences between economic development and patent activity, or, in wider sense, between economic development and innovation. Since the crisis is not yet over, this possibility should wait for further investigation few years later.

Conclusions

It was shown using various statistical techniques that financial crises affect patenting activity. The kind of patenting activity directly affected by negative short-term economic developments seems patent applications filing abroad, which was found to be strongly auto-correlated, containing nearly linear positive trend with negative fluctuations, contemporaneous to crisis events, and demonstrating a coherent behavior for different countries. Investigation of the dependence of this variable on economic variable, like GNI-PPP, in annual time series format has shown reasonably good fitting by means of linear second order distributed lag vector auto-regressive (VAR) model (with very strong correlation, except Japan). Granger causality test, performed for each of eight chosen countries, showed lack of causality for all four OECD countries and two emerging economies (China and Russia), while for Brazil and India causality test was positive. The limitations of current study allow neither generalization of these particular findings to other countries, nor deeper insight into the interrelationship between economic and patenting data.

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Appendix A. Economic trends for eight chosen countries

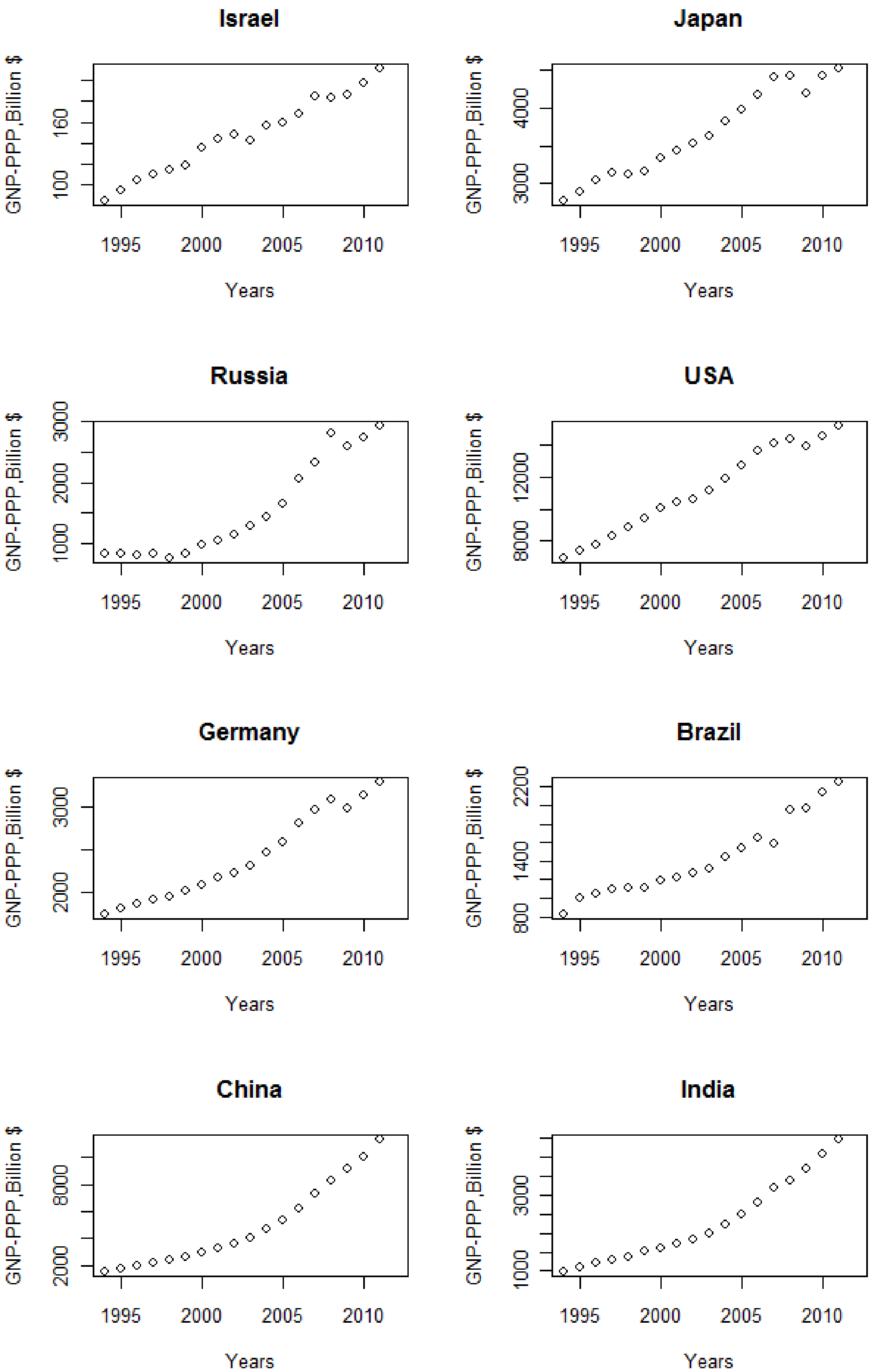

Fig.1

Fig.1 GNI-PPP trends for selected countries for years 1994-2011

Appendix B. Patent applications abroad for eight chosen countries

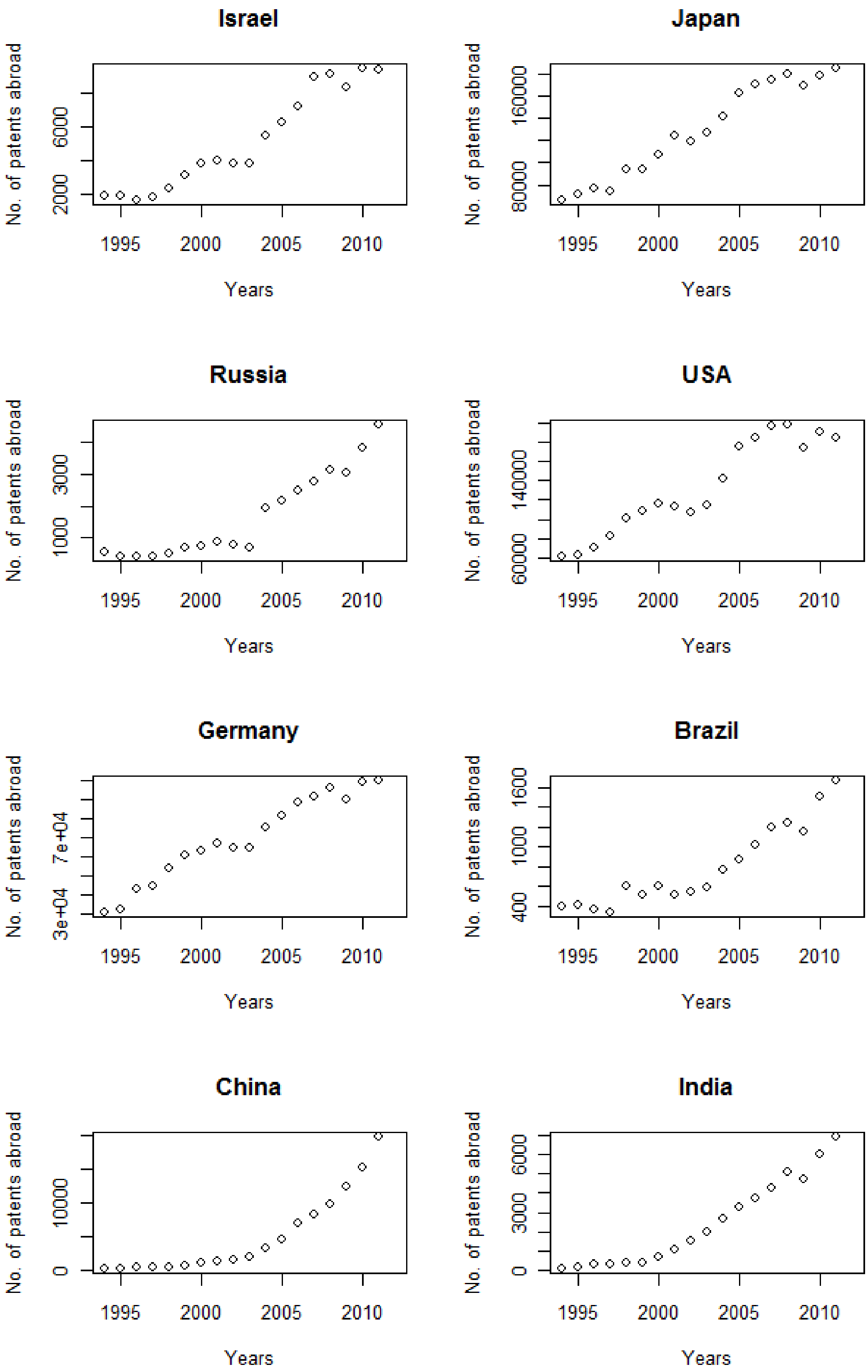

Fig.2 Patent applications abroad trends for selected countries for years 1994-2011.

Appendix C. Non-resident patent applications for eight chosen countries

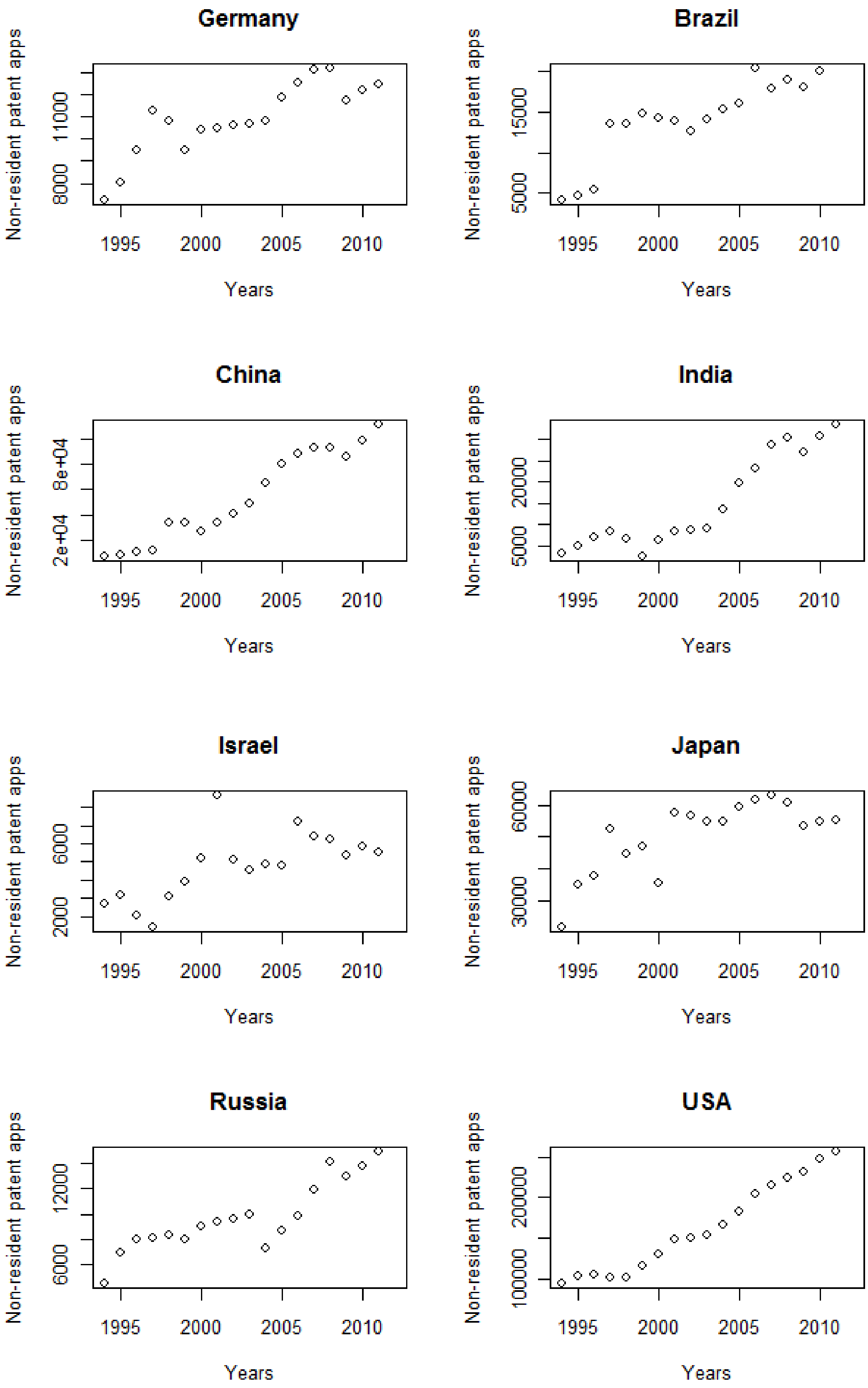

Fig.3 Non-resident patent applications trends for selected countries for years 1994-2011.

Appendix D. Second order distributed lag AR models for eight chosen countries

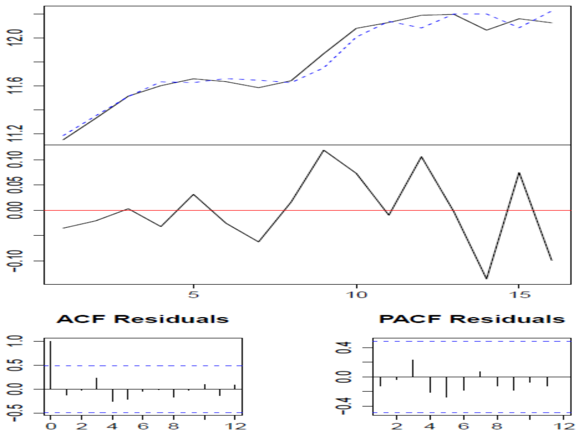

Fig.4 Model fit and residuals for USA

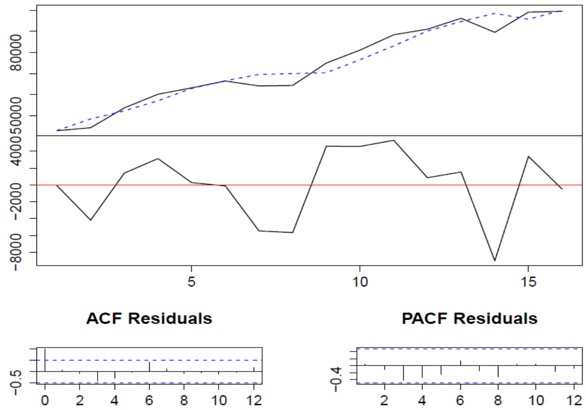

Fig.5 Model fit and residuals for Germany

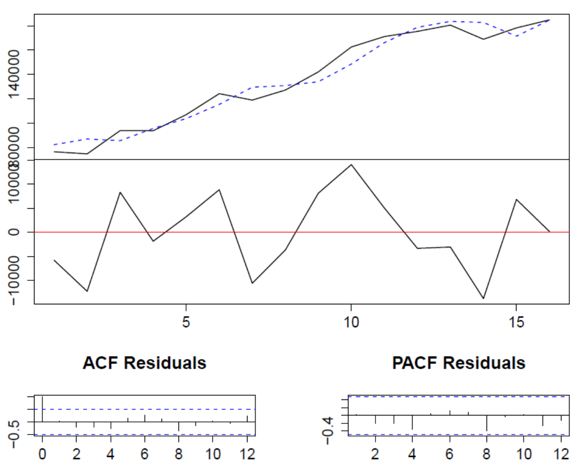

Fig.6 Model fit and residuals for Japan

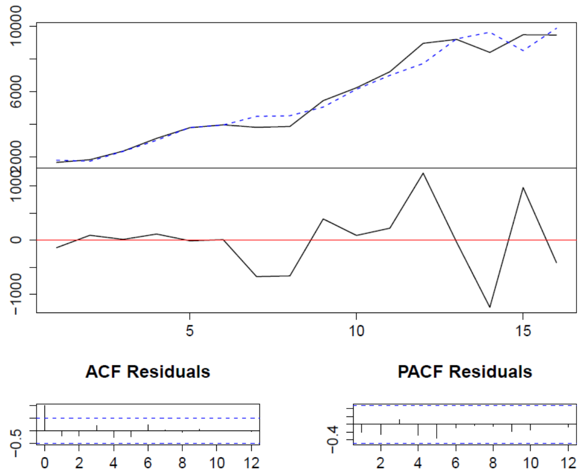

Fig.7 Model fit and residuals for Israel

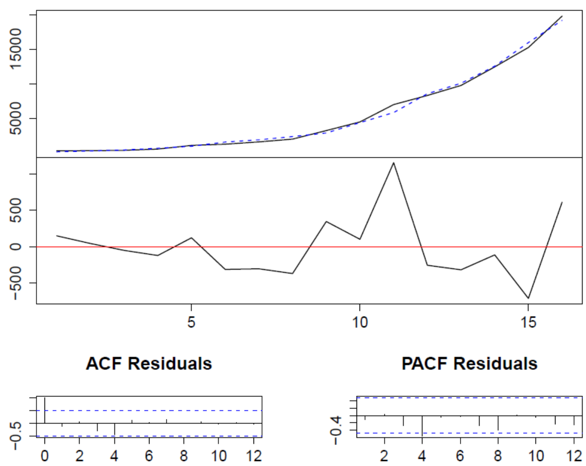

Fig.8 Model fit and residuals for China

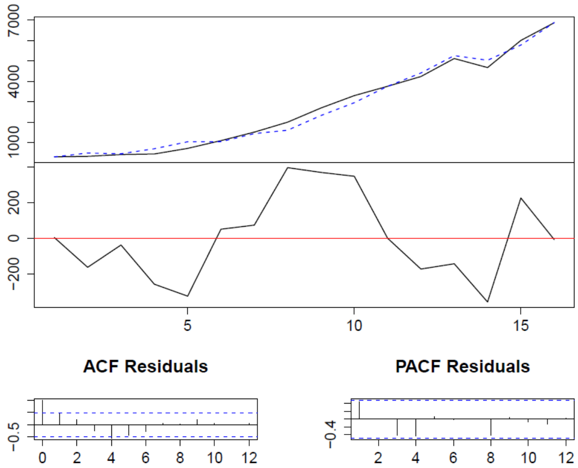

Fig.9 Model fit and residuals for India

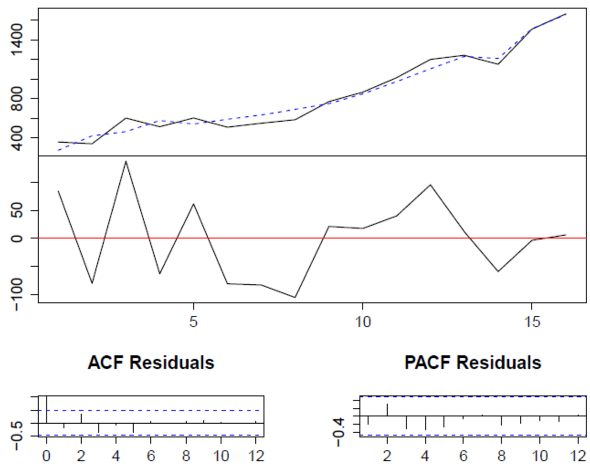

Fig.10 Model fit and residuals for Brazil

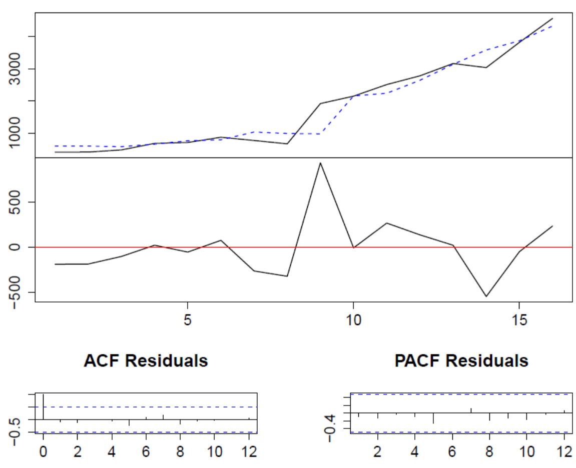

Fig.11 Model fit and residuals for Russia

Table 1. Regression model parameters

Country	A	B	C	D	F	R-squared	F-statistic
USA	1.05426	-0.84998	-5.9101	18.9769	-30243.9	0.938182	41.73509
Germany	0.25973	0.415595	12.23164	-1.95128	3000.609	0.95253	55.18158
Japan	0.119917	0.214741	-4.16608	14.4996	-2478.15	0.687119	6.039293
Israel	1.129939	-0.41179	-28.3856	50.71493	-1215.55	0.956938	61.11179
China	1.073617	-0.08863	-1.29246	1.958649	-930.58	0.994731	519.1744
India	-0.05192	0.354869	5.29122	-4.06117	-1508.34	0.988224	230.766
Brazil	0.2432	-0.1007	0.1486	0.8926	-673.9607	0.9680	83.0666
Russia	0.831488	-0.16945	-0.10271	0.86742	-303.946	0.942853	45.37153

Appendix E. Granger causality test

Table 2. Granger causality test summary

Country	Granger Causality		Instantaneous Causality		Granger Causality Exists
	F-test	p-value	Chi-squared	p-value	
USA	1.8943	0.1742	5.3022	0.0213	No
Germany	0.4596	0.6375	6.2372	0.01251	No
Japan	0.5157	0.6041	4.0611	0.04388	No
Israel	1.4847	0.2484	3.9867	0.04586	No
China	1.5518	0.2342	6.2031	0.01275	No
India	6.0186	0.008225	1.7193	0.1898	Yes
Brazil	9.5927	0.0101	0.0143	0.905	Yes
Russia	0.8881	0.4257	3.9396	0.04716	No