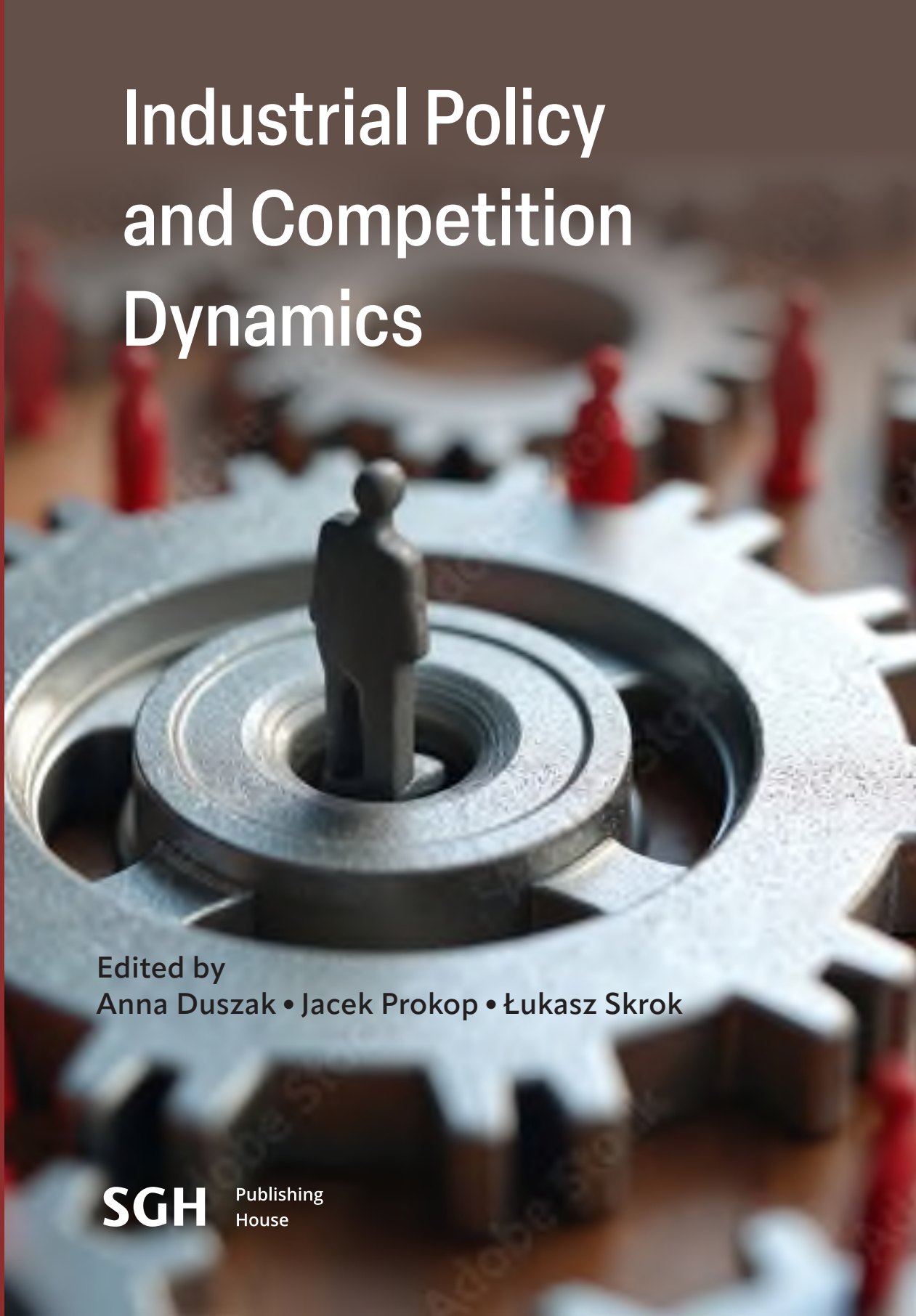


Industrial Policy and Competition Dynamics

Edited by
Anna Duszak • Jacek Prokop • Łukasz Skrok

SGH Publishing House

Industrial Policy and Competition Dynamics

SGH

Reviewers
Teresa Kamińska
Ludwik Wicki

Editor
Mirosław Szymański

First Edition

ISBN 978-83-8030-773-5

SGH Publishing House
162 Niepodległości Ave., 02-554 Warsaw, Poland
www.wydawnictwo.sgh.waw.pl
e-mail: wydawnictwo@sgh.waw.pl

Cover design and production
Magdalena Limbach

DTP
DM Quadro

Print and binding
QUICK-DRUK s.c.

Order 150/XI/25

CONTENTS

INTRODUCTION

Anna Duszak, Jacek Prokop, Łukasz Skrok

In the first chapter entitled *Old and New Industrial Policy in the World*, Anna Duszak, following Evenett, Jakubik, Martín and Ruta [2024], argues that industrial policy, in a broad sense, has been omnipresent in advanced economies. It is particularly common in the case of endeavours characterised by substantial economies of scale (e.g. infrastructural), risky projects with high potential gains (e.g. innovative), connected with national safety (e.g. related to the critical infrastructure) and those with substantial positive externalities (e.g. having substantial social impact). This book includes texts which provide examples of such situations. In the chapter entitled *Political Competition and Private Participation in Infrastructure*, Marian Moszoro and Gonzalo Araya discuss involvement of private entities in partially publicly funded infrastructural project. The chapter entitled *The Impact of Patent Rights on Industry Competition – An Overview* written by Jacek Prokop and the following chapter *Markets and Competition Dynamics with Imperfect Patent Protection* by Marek Dietl concern innovative products – the ones that can gain patent protection, while others are related to public procurement. The chapter entitled *AI and the Energy Dimension – The Development of Artificial Intelligence as an Opportunity and a Challenge for the Energy Sector* written by Łukasz Kryśkiewicz concerns the AI and energy sectors and in their chapter entitled *Subsidy Competition in European Football: A Case of Poland*, Jędrzej Lubasiński and Łukasz Skrok analyse the importance of public subsidies for the development of football clubs, also at the semi-professional level.

Furthermore, our analyses illustrate the changing nature of industrial policy, which has been adapted to a more complex structure of modern economies, reflecting technological progress as well as evolving social norms and introduction of new ideas within governmental structural and policy toolboxes. Anna Duszak in her chapter refers to the article by Aiginger and Rodrik [2020], in which they point out to four main differences between traditional and modern industry policy.

Firstly, in line with evolving economy structure in the most developed countries, the service sector has also a more prominent role, not only the manufacturing industry.

This concerns both newer and more traditional business – Łukasz Kryśkiewicz discusses the importance of the AI sector, while the study done by Jędrzej Lubasiński and Łukasz Skrok refers to the sports sector.

Secondly, governments tend to delegate production to the private sector rather than to the fully owned state companies. This aspect is reflected in chapters about private involvement in infrastructural projects by Marian Moszoro and Gonzalo Araya, about public procurement by Marek Dietl and about subsidising sports by the local government units by Jędrzej Lubasiński and Łukasz Skrok.

Thirdly, modern industrial policy tends to be more integrated into broader social and economic policies. We provide such examples in the analyses of patents made by Jacek Prokop and Marek Dietl – a key element of the traditional innovation policy, which illustrate potentially conflicting policy aims (supporting innovation and growth and protecting consumers and markets from monopolisation and cartelisation), as well as an analysis presented by Marian Moszoro and Gonzalo Araya of interaction between institutional characteristics of political system and resulting intensity of competition between political parties, and state capacity to conduct more complex projects. The work done by Jędrzej Lubasiński and Łukasz Skrok refers to promotion of sports activity.

Lastly, modern industrial policy is often shifted towards supporting enhancements of resources and energy use as well as environmental and labour market goals. In line with these topics, Bartłomiej Wiśnicki and Marek Szyl investigate the empirical relation between gender diversity of board levels in companies and their financial performance in their chapter entitled *Gender Diversity in the Company Management and its Financial Performance*. Łukasz Kryśkiewicz discusses the interplay between AI and energetic efficiency of the economy.

Anna Duszak also points out that one of the limitations of designing industry policies is the limited data availability that hinders possibilities of rigorous empirical evaluations. Indeed, at the state level, with the complexities of economic processes and structures, a relatively low number of comparable countries and impracticalities of conducting macroeconomic experiments, the identification problem is a crucial consideration [e.g. Nakamura, Steinsson, 2018]. Therefore, as proved by the development of both experimental [e.g. Bhanerjee, Duflo, 2012] and quasi-experimental [e.g. Angrist, Pischke, 2008] in some contexts, local application of policies might provide a testing ground. While our analyses are more modest and do not employ tools allowing for causal inference in the context of potential reciprocal causality, we do provide examples of empirical analyses at the microeconomic level – companies (Wiśnicki and Szyl), projects (Moszoro and Araya) and local government units (Lubasiński

and Skrok). In particular, in the latter case, spatial interaction between the scale of sports-supporting policies of nearby local governments is shown to have been significant. Indeed, as Kahn [2000], and Chan, Savage and Torgler [2020] argued, sports industry can provide a laboratory for more general policies and economic theories.

Nevertheless, empirical analyses by Moszoro, Lubasiński and Skrok, Wiśnicki and Szyl contained in this book further confirm that the complexity of the social and political context sometimes hinders clear identification of hypothesised impact of relatively straightforward measures (e.g. that of political worldview or partisan support as well as gender diversity) on economic outcomes.

Finally, a common theme of the majority of chapters provided by us further emphasise a well-known – at least in economics – truth, that competition matters a lot. Intensity of market competition matters for assessment of patent policy (Prokop), while introduction of market competition as such might be socially inefficient (Dietl). Political competition matters for publicly overseen projects (Moszoro and Araya). Market structure, through the size of companies, matters for social dynamics of managerial framework in companies (Wiśnicki and Szyl). Spatial competition from neighbouring regions matters for effectiveness of local governments in supporting developing quality-of-life-enhancing industries (Lubasiński and Skrok).

REFERENCES

Angrist, J.D., Pischke, J.S. (2008). *Mostly Harmless Econometrics*. Princeton: Princeton University Press.

Aiginger, K., Rodrik, D. (2020). Rebirth of Industrial Policy and an Agenda for the Twenty-First Century, *Journal of Industry*, Competition and Trade, 20, pp. 189–207. DOI: 10.1007/s10842-019-00322-3.

Banerjee, A., Duflo, E. (2012). *Poor Economics*. New York: PublicAffairs.

Chan, H.F., Savage, D.A., Torgler, B. (2020). Sports as a Behavioral Economics Lab. In: *Behavioural Sports Economics: A Research Companion* (pp. 11–51), H. Altman, M. Altman, B. Torgler (Eds.). London: Routledge.

Evenett, S., Jakubik, A., Martín, F., Ruta, M. (2024). The Return of Industrial Policy in Data, *The World Economy*, 47(7), pp. 2762–2788. DOI: 10.1111/twec.13608.

Kahn, L.M. (2000). The Sports Business as a Labor Market Laboratory, *The Journal of Economic Perspectives*, 14(3), pp. 75–94.

Nakamura, E., Steinsson, J. (2018). Identification in Macroeconomics, *Journal of Economic Perspectives*, 32(3), pp. 59–86. DOI: 10.1257/jep.32.3.59.

OLD AND NEW INDUSTRIAL POLICY IN THE WORLD

Anna Duszak
SGH Warsaw School of Economics
Collegium of World Economy
Department of Business Economics
e-mail: anna.duszak@sgh.waw.pl

ABSTRACT

Industrial policy refers to the government actions undertaken for various economic reasons. An increase in interest in industrial policy research in recent years has been pushed by the growing number of government interventions. The aim of this chapter is to summarise the literature findings regarding industrial policy. The analysis focuses on the goals of industrial policy, its effects and the reasons for the renewed interest in industrial policy.

JEL Classification: L50, L52, F13, O14

Keywords: government policy, import substitution, industrial policy, new industrial policy

Introduction

In the twentieth century, many emerging markets adopted industrial policies. In Latin America, Import Substitution Industrialisation (ISI) was a common tool, which consisted in substituting imported production by the domestic production. ISI was also present in Europe and the United States in the middle and the second half of the nineteenth century. In East Asia, government interventions fuelled rapid industrialisation and export-led growth.

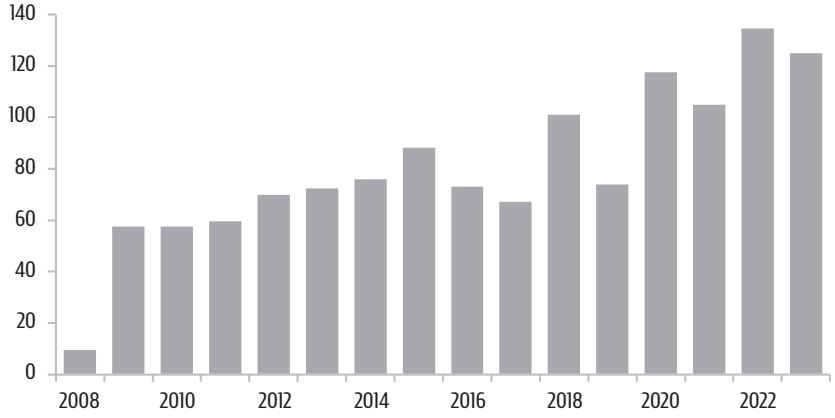
Industrial policy has, therefore, usually been associated with interventions of governments in developing countries aiming at fostering the economic development and

structural change. Those interventions were to help poor countries avoid the poverty trap [Rodrik, 2004]. The aims of those policies included accelerating industrialisation, diversifying those economies and reducing reliance on primary commodities.

After years of scepticism about the effectiveness of industrial policy, we can observe a growing number of policy interventions in the world (Figure 1). In addition, the recent renewal of industrial policies has been pushed by advanced countries [Evenett et.al., 2024]. The reasons for the resurgence in popularity of government interventions include the global financial crisis, COVID-19 pandemic, climate change and geopolitical tensions.

Due to the multitude of instruments used by different countries, industrial policy has many definitions. Hence, we can refer it to the government interventions implemented for various economic reasons. While originally industrial policy was inseparably connected with the manufacturing sector, the new industrial policy has become more broadly understood as supporting also sectors like services.

Figure 1. Number of unilateral commercial policy interventions in 2008–2023 in the world (in thousands)



Source: Author's own complilation based on Global Trade Alert.

This chapter aims to review the literature concerning industrial policy. It focuses on historical context as well as recent actions undertaken by governments. In particular, it underlines the differences between "old" and "new" industrial policies and approaches undertaken by various economies. It is structured as follows. Section 2 defines industrial policy and its aims. Section 3 focuses on import substitution in Latin America. Section 4 describes the experiences of East Asia. Section 5 underlines the role of the new industrial policy. Section 6 makes conclusions.

Industrial policy and its aims

According to the OECD definition, industrial policy "refers to government assistance to businesses to boost or reshape specific economic activities, especially to firms or types of firms based on their activity, technology, location, size or age." In the context of China, Naughton [2021] defines industrial policy as "an intentional effort on the part of government policymakers to change the sectoral structure of the economy."

There are various goals of industrial policies implemented by governments. The most important of them include stimulating economic growth, fostering structural transformation, addressing market failures or accelerating green transition.

Market failures are a commonly cited reason in favour of industrial policy. Di Maio [2009] shows how industrial policies enable structural transformation in low-income economies. He stresses the historical perspective of government interventions. In the 1950s, such actions were aimed at accelerating industrialisation. In fact, the author demonstrates that all presently developed countries utilised industrial policy in the past. He concludes that the most effective government interventions in terms of boosting economic growth are aimed at fostering investments in education and innovation. Lin and Chang's [2009] debate articulates the role of government intervention in promoting growth and development by industrial upgrading as well the role of comparative advantage.

However, many economists doubt whether market failures should be an area of the government intervention. They criticise the universal approach to industrial policy and suggest that it should be tailored [Di Maio, 2009; Aghion, Boulanger, Cohen, 2011]. Rodrik [2008] observes that there is no scepticism regarding the government intervention targeted at education, health, social insurance or macroeconomic stabilisation. The question that is mostly asked by governments or researchers is how to do it instead of whether or not to do it. Since many governments use industrial policy in various forms, the debate in this area should also shift from "whether or not" to "how". Aghion et al. [2011] stress the importance of the refocusing industrial policy given the debate on climate change, the global financial crisis and the strengthening position of China in the world. They argue that policymakers should revise industrial policy. In particular, Mazzucato [2016] emphasises that government actions regarding innovation policy have recently become mission oriented. The government should also concentrate on shaping markets rather than only try to correct market failures. Hence, the proposed approach to public policy shifts the highlight from the reactive to proactive and strategic approach.

Latin America

Import substitution consists in substituting imported production by domestic production. It aims to reduce dependency on imported goods and support domestic industrial development. As noted by Baer [1972], Latin America widely adopted Import Substitution Industrialisation in 1950s and 1960s. The goal of the strategy was to accelerate the region economic growth and modernisation. However, the questions about the effectiveness of such policies emerged in the 1970s. While ISI was used by the United States or in Europe in the middle and the second half of the nineteenth century, it became popular in Latin America much later. ISI was aimed at enabling the region to manufacture previously imported goods domestically. The reason why Latin America did not adopt ISI earlier was principally due to its socio-economic structure [Baer, 1972]. Traditionally, Latin America exported food and raw materials, while it imported goods from the United States and Europe. The region leaders did not have incentives to change this division, as there existed the market for the region export. Furthermore, the country lacked the appropriate human resources, market size and infrastructure to deal with the process of industrialisation. Most goods consumed prior to World War I came from abroad or from small domestic workshops. Domestic production concentrated mostly in larger countries, such as Brazil, Argentina or Mexico. The region activity came largely from primary export, but also from small workshops and industries.

ISI emerged in Latin America during World War I, the Great Depression and World War II. It resulted from shortages of imported goods as supply-side problems emerged in the United States and Europe. ISI concerned mostly light consumer goods. However, for example in Brazil, it also included other industries, such as steel and capital goods; Brazil, Argentina, or Mexico imported some textile goods. The peak of ISI occurred in the 1950s and 60 s. It arose from insecurity of commodities and food export and aimed to make the region more independent from the world.

East Asia

Industrial policy was a foundation of East Asia's economic transformation in the 1980s. It facilitated growth and structural change. This was part of the strategy adopted by the region, called a developmental state (DS) model. It can be described as a model that assumes government interventions, while maintaining the market structure close to a free market [World Bank, 1993]. Alternative definitions of DS and

change in its perception are to be found in Stubbs [2009]. The countries pursuing a DS model accumulated physical and human capital and then allocated it to highly productive investments and to acquire and develop technology. Cherif and Hasanov [2009] suggest that the success of industrial policies introduced in the East Asia consisted in generous support for domestic sophisticated industries, export orientation and the drive for intense competition while keeping rigorous accountability. In particular, it is visible in the case of South Korea and Taiwan.

Nicolas, Thomsen and Bang [2013] identify four phases of the Korean economic development. Until 1962, South Korea relied on foreign assistance, primary from the United States. The country used import substitution, however, it was not successful in boosting growth. In the 1960s, the policy became more export-oriented, where funds were granted to firms with the highest export potential. In 1973, the Heavy and Chemical Industry (HCI) Drive was launched. It accelerated growth of large industrial conglomerates called *chaebols*. The last phase, which started in the 1980s, was FDI liberalisation due to excess investment and capacity in targeted industries.

The 1973–1979 HCI Drive was a pivotal initiative in South Korea. It focused on transiting from commodity and light manufacturing to heavy industry [Choi, Levchenko, 2025]. Even though the policy promoted the expansion of targeted industries, it facilitated a shift in the country's manufacturing base toward more advanced markets. The main policy tool used in South Korea's strategy was allocating foreign credit to targeted firms. After getting the approval of foreign credit, the government guaranteed such a loan, and the firms benefited from lower interest rate than in the case of domestically granted loans. Then, the firms reported to the government on the loan contracts and the planned allocation of funds. The strategy aimed at ensuring that only the most efficient enterprises were to thrive.

Similarly to the situation in South Korea, we can distinguish four stages of development in Taiwan. The first period was import substitution in the 1950s. Then, in the 1960s and 70s, it started to promote export and use secondary import substitution. In the 1980s, it transited to the high-tech sector. In the 1990s, Taiwan allowed for liberalisation and globalisation [Chu, 2019].

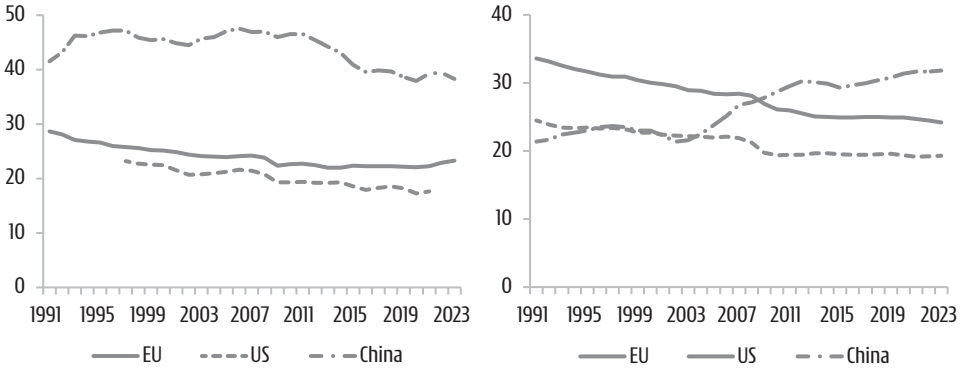
Taiwan's industrial strategy diverged from South Korea's in its emphasis on SMEs, rather than on large conglomerates. Many firms specialised in a small high-tech segment and conducted R&D. The firms that launched a joint venture with foreign companies were usually public [Weiss, 2005].

New industrial policy

After many years of scepticism, industrial policy regained attention of governments of policy makers, in particular, in advanced economies. The resurgence of interest in industrial policy in recent years reflects its growing significance in addressing contemporary economic, technological and environmental challenges. In this section, we will focus on the characteristics of the new industrial policy (NIP) and its most pronounced examples, such as those implemented in China, the United States and Europe. NIP differs from the industrial policy used in past. Aiginger and Rodrik [2020] distinguish four main undermentioned characteristics of NIP.

We can see that in the last 30 years, the gross value added in industry as a share of GDP has been decreasing. The same trend has been recorded in employment in industry as a share of total employment in the European Union and the United States, while in China it has been increasing (Figure 2). Aiginger and Rodrik [2020] argue that employment deindustrialisation will proceed in both advanced and middle-income economies, as the economies shift away from manufacturing to services. Hence, industrial policy needs to be adjusted and go beyond manufacturing. The term industrial policy itself can be misleading, as it currently includes also approaches that aim at supporting development, structural change or innovation in other sectors, such as services.

Figure 2. Gross value added in industry as percentage of GDP (left panel) and employment in industry as per cent of total employment (right panel) in the EU, the US and China



Source: Author's own compilation based on the World Bank *World Development Indicators*.

Nowadays, governments are more prone to delegate production or distribution of goods or services to private firms, rather than engaging in those activities entirely

by themselves. This tendency stems from both ideological issues and seeking value for money [OECD, 2008]. Aiginger and Rodrik [2020] recommend modern policies should less rely on top-down approach, but focus on public-private cooperation that addresses long-term productivity and social goals. Similarly, Rodrik [2008] underlines that collaboration and coordination between the private and public sectors should improve the efficiency of interventions.

NIP needs to be integrated into broader economic or social strategies. Although industrial policy and other policies, such as policies aimed to protect consumers or accelerate growth, use different tools and have different goals, especially in the short run, they can have convergent goals in the long run. Sometimes, the goals of various policies are perceived as conflicting. Aiginger and Rodrik [2020] highlight that the policies should be coordinated more systematically.

Finally, Aiginger and Rodrik [2020] argue that NIP should shift is aims from increasing labour productivity to productivity in other sectors, namely resource and energy. In industrialised economies, the focus should be placed on environmental and labour friendly policies. In emerging economies, the approach may differ depending on the stage of development and particular challenges those countries want to address. Hence, the policies should be tailored and have clear set of economic, societal and environmental objectives.

China's industrial policy barely falls within any definitions of industrial policy [Naughton, 2021; Naughton, Xiao, Xu, 2023]. In particular, Naughton [2021] argues that China cannot be compared to the Asian countries that used a DS model. One of the reasons for that was that China was a dysfunctional command economy and the government needed to carefully implement market reforms. In contrast, the Asian Tigers were more free-market and smaller economies. Since China invested much more resources in targeted sectors (as a share of GDP and in absolute terms), the aims of Chinese industrial policy had been different than those of the other Asian economies as well. The new industrial policy in China has been implemented since 2010. China's goal has been to gain leadership in the sectors where no clear technological leadership is established and where there are not many competitors in advanced economies. In the other Asian economies, industrial policies were aimed at catching up with the leaders in targeted sectors.

Since the beginning of the 21st century, China has been one of the most important players in the manufacturing sector. In order to support the sector, in 2015, the country announced a 10-year strategic plan known as Made in China 2025. However, the strategy encompasses also development of human capital as well as R&D. As noticed by Li [2018], the Chinese strategy was a response to the wave of global

reindustrialisation and Germany's strategy Industry 4.0. China has targeted a variety of products: from high-tech goods (e.g. personal computers or mobile phones) to consumer goods (e.g. air conditioners). The plan is to be the first stage of a broader strategy, which should include three 10-year phases. Each phase should bring China closer to becoming a global manufacturing power. Aiginger and Rodrik [2020] maintain that despite slowing economic growth in China, it may soon become the largest economy in the world, primarily thanks to its large manufacturing sector and export-oriented industrialisation.

To evaluate the effects of industrial policy in China, Chen and Xie [2019] use data from the Chinese Law and Regulation Database from 2003 to 2015. They examine empirically the impact of industrial policy on economic growth. They find that industrial policy significantly increases GDP growth in China driven by industrial structure rationalisation mechanism. Barwick, Kalouptsidi and Zahur [2019] utilise global shipyard data and develop a dynamic model to assess firm behaviours. They find that the effectiveness of policy instruments depends on the type of the instruments used. While the interventions helped increase China's investment and global market share, they resulted in significant market distortions.

Evenett et al. [2024] find that recent industrial policies have been led by advanced economies. They emerged as an answer to consequences of financial crisis, COVID-19 pandemic and resulting supply problems. Although, the interest of advanced economies in government intervention has been based on strategic competitiveness, there are many other reasons why those economies rely on government interventions. However, Aiginger and Rodrik [2020] emphasise the role of American response to the China's policy. As China has become more export-oriented, companies in the United Stated report uneven market access and unfair trade practices. In contrast, the reasons behind government interventions in Europe are less related to China.

The assessment of industrial policy, even that implemented a long time ago, is challenging. The lack of data is a big problem for analysing the impact of industrial policies. Recently, Evenett et al. [2024] introduced the New Industrial Policy Observatory (NIPO) dataset. The paper documents the new industrial policy implemented by countries in 2023 and finds that the most popular type of intervention are subsidies.

However, Aiginger and Ketels [2024] highlight that economists in Europe and the US have been more careful about the effectiveness of the economic effects of industrial policies. They claim the policies may work in theory, while they are tough to implement in practice. Agarwal [2023] underlines a trilemma between policy goals that industrial policies try to resolve: establishing national champions through industrial policy, assuring financial and fiscal stability and promoting economic growth.

Conclusions

An increase in the number of policy interventions in the world has attracted interest of researchers. While it seemed that government interventions in the economy ended in the 20th century, nowadays, policy makers have become enthusiastic about industrial policy and are willing to implement it. The aims of industrial policy refocused from correcting market failures to more mission-oriented approach. Various regions and economies have different approaches to industrial policy. ISI in Latin America made the region economies more closed, while the policies in the East Asia were more export-orientation and assumed free market. While industrial policies theoretically boost economic development, it is tough to implement the policies effectively. Modern approaches to industrial policy usually go beyond conventional definitions and aim to subsidise also sectors other than manufacturing. However, researchers agree that policies should be tailored any time they are to be implemented. In particular, different strategies may be needed depending on the stage of development of the country implementing industrial policies. The lack of data is a significant obstacle in assessing the efficiency of various industrial policies.

REFERENCES

Agarwal, R. (2023). *Industrial Policy and the Growth Strategy Trilemma, IMF Finance and Development*, https://www.elibrary.imf.org/downloadpdf/view/journals/022/0060/003/article-A-013-en.pdf (accessed: 22.01.2025).

Aghion, P., Boulanger, J., Cohen, E. (2011). Rethinking Industrial Policy, *Bruegel Policy Brief*, 4, https://www.bruegel.org/system/files/wp_attachments/pb_2011-04__final.pdf (accessed: 22.01.2025).

Aiginger, K., Rodrik, D. (2020). Rebirth of Industrial Policy and an Agenda for the Twenty-First Century, *Journal of Industry, Competition and Trade*, 20, pp. 189–207. DOI: 10.1007/s10842-019-00322-3.

Aiginger, K., Ketels, C. (2024). Industrial Policy Reloaded, *Journal of Industry, Competition and Trade*, 24(1), pp. 1–10. DOI: 10.1007/s10842-024-00415-8.

Baer, W. (1972). Import Substitution and Industrialization in Latin America: Experiences and Interpretations, *Latin American Research Review*, 7(1), pp. 95–122. DOI: 10.1017/S0023879100041224.

Barwick, P.J., Kalouptsidi, M., Zahur, N.B. (2019). China's Industrial Policy: An Empirical Evaluation, *National Bureau of Economic Research Working Paper*, w26075, https://www.nber.org/system/files/working_papers/w26075/w26075.pdf (accessed: 22.01.2025).

Chen, J., Xie, L. (2019). Industrial Policy, Structural Transformation and Economic Growth: Evidence from China, *Frontiers of Business Research in China*, 13(1), p. 18. DOI: 10.1186/s11782-019-0065-y.

Cherif, R., Hasanov, F. (2019). The Return of the Policy That Shall Not Be Named: Principles of Industrial Policy, International Monetary Fund, *IMF Working Paper*, 074.

Choi, J., Levchenko, A.A. (2025). The Long-Term Effects of Industrial Policy, *Journal of Monetary Economics*, 152. DOI: 10.1016/j.jmoneco.2025.103779.

Chu, W.W. (2019). How Taiwan Managed to Grow: Structural Transformation and Industrial Policy. In: *The Oxford Handbook of Structural Transformation*, C. Monga, J.Y. Lin (Eds.). Oxford: Oxford University Press. DOI: 10.1093/oxfordhb/9780198793847.013.25.

Di Maio, M. (2009). Industrial Policies in Developing Countries: History and Perspectives. In: *Industrial Policy and Development: The Political Economy of Capabilities Accumulation* (pp. 107–143), M. Cimoli, G. Dosi, J.E. Stiglitz (Eds.). Oxford: Oxford University Press.

Evenett, S., Jakubik, A., Martín, F., Ruta, M. (2024). The Return of Industrial Policy in Data, *The World Economy*, 47(7), pp. 2762–2788. DOI: 10.1111/twec.13608.

Li, L. (2018). China's Manufacturing Locus in 2025: With a Comparison of "Made-in-China 2025" and "Industry 4.0", *Technological Forecasting and Social Change*, 135, pp. 66–74. DOI: 10.1016/j.techfore.2017.05.028.

Lin, J., Chang, H.J. (2009). Should Industrial Policy in Developing Countries Conform to Comparative Advantage or Defy It? A Debate between Justin Lin and Ha-Joon Chang, *Development Policy Review*, 27(5), pp. 483–502. DOI: 10.1111/j.1467-7679.2009.00456.x.

Mazzucato, M. (2016). From Market Fixing to Market-Creating: A New Framework for Innovation Policy, *Industry and Innovation*, 23(2), pp. 140–156. DOI: 10.1080/13662716. 2016.1146124.

Naughton, B. (2021). *The Rise of China's Industrial Policy, 1978 to 2020*. México: Universidad Nacional Autónomica de México, Facultad de Economía.

Naughton, B., Xiao, S., Xu, Y. (2023). The Trajectory of China's Industrial Policies, *IGCC Working Paper*, 6, https://escholarship.org/content/qt28f568zv/qt28f568zv.pdf (accessed: 22.01.2025).

Nicolas, F., Thomsen, S., Bang, M.H. (2013). Lessons from Investment Policy Reform in Korea, *OECD Working Paper on International Investment*, https://www.oecd.org/content/dam/oecd/en/publications/reports/2013/07/lessons-from-investment-policy-reform-in-korea_g17a233d/5k4376zqcpf1-en.pdf (accessed: 22.01.2025).

OECD (2008). *Public-Private Partnerships. In Pursuit of Risk Sharing and Value for Money*. Paris: OECD Publishing, https://www.oecd.org/content/dam/oecd/en/publications/reports/2008/05/public-private-partnerships_g1gh8c7d/9789264046733-en.pdf (accessed: 22.01.2025).

Rodrik, D. (2004). Industrial Policy for the Twenty-First Century, *John F. Kennedy School of Government Working Paper Series*, rwp04–047, https://www.hks.harvard.edu/publications/industrial-policy-twenty-first-century (accessed: 22.01.2025).

Rodrik, D. (2008). *Normalizing Industrial Policy* (vol. 3), International Bank for Reconstruction and Development, https://documents1.worldbank.org/curated/en/524281468326684286/pdf/577030nwp0Box31ublic10gc1 wp10031web.pdf (accessed: 22.01.2025).

Stubbs, R. (2009). What Ever Happened to the East Asian Developmental State? The Unfolding Debate, *The Pacific Review*, 22(1), pp. 1–22. DOI: 10.1080/09512740802650971.

Weiss, J. (2005). Export Growth and Industrial Policy: Lessons from the East Asian Miracle Experience, *ADBI Discussion Paper*, 26, https://www.adb.org/sites/default/files/publication/156779/adbi-dp26.pdf (accessed: 22.01.2025).

World Bank (1993). *The East Asian Miracle, Economic Growth and Public Policy*. New York: Oxford University Press.

AI AND THE ENERGY DIMENSION – DEVELOPMENT OF ARTIFICIAL INTELLIGENCE AS AN OPPORTUNITY AND A CHALLENGE FOR THE ENERGY SECTOR

Łukasz Kryśkiewicz
SGH Warsaw School of Economics
Collegium of World Economy
Department of Business Economics
e-mail: lkrysk@sgh.waw.pl

ABSTRACT

This paper analyses the impact of AI on the energy sector. Artificial intelligence is an essential element of modern technologies, benefiting individuals and the entire economy. The author puts forward a hypothesis that the AI development is crucial for the Polish as well as European economies. On the one hand, AI solutions can help develop the energy sector, and on the other hand, the sudden increase in the importance of these systems is a threat to the existing energy infrastructure burdened with excessive energy consumption. Energy security is a strategic element for our country and its citizens.

JEL Classification: D02

Keywords: AI, artificial intelligence, energy, energy intensity, energy sector

Introduction

Artificial intelligence is an essential element of modern technologies that can significantly benefit individuals, organisations and society as a whole, provided it is developed in a human-centred, sustainable way and in accordance with fundamental rights and values.

AI technologies have the potential to increase the efficiency and ultimately the competitiveness of the European industrial sector. In addition, AI can play a key role in solving significant societal challenges, including climate change, environmental degradation, sustainability challenges and demographic change.

The author puts forward a hypothesis according to which the development of artificial intelligence has a dual significance for the Polish and European economies: on the one hand, solutions based on AI can help develop the energy sector, and on the other, the dynamic growth in the importance of these systems poses a serious risk to the existing energy infrastructure burdened with excessive electricity consumption. In order to determine the correctness of this hypothesis, the author analyses the literature and reports prepared by industry organisations presenting the forecast level of electricity consumption in connection with the use of solutions based on artificial intelligence. It will all be supplemented with the section on energy presenting the essence of artificial intelligence and basic information about the National Energy System. In this context, the author will address questions such as: What are the key characteristics of artificial intelligence? In what areas can solutions based on artificial intelligence improve the operation of entities in the energy sector? To what extent can the growth of interest in AI affect the increase in electricity consumption?

According to the author, this approach to the analysed problem is a kind of novelty, because considerations regarding artificial intelligence focus primarily on issues related to copyright or the possibility of using AI to optimise business processes. If they refer directly to the energy sector, they usually concern the possibility of implementing solutions based on artificial intelligence in entities in this sector or the problem of increased energy consumption.

Artificial Intelligence – Basic Theoretical Approach

When it comes to changes taking place in the modern globalised economy, one should take into account, first of all, the dynamic development of digital technologies, particularly in the field of computer science related to artificial intelligence [Bugaj, 2016].

The literature on the subject offers numerous definitions of this phenomenon. It is generally accepted that artificial intelligence includes machines and software whose work replicates that of human brain. This concept was proposed in 1955 by John McCarthy et al. [2006].

In this sense, AI encompasses systems that operate in ways that mimic human behaviour [Chen et al., 2020]. The Nesta report emphasises that AI is not a single system, but a collection of diverse solutions that can be applied in many different contexts.

Andreas Kaplan defines artificial intelligence as the ability of computer systems to analyse data, learn from them and use the acquired knowledge to accomplish creative tasks [Kaplan, Haenlein, 2019].

Artificial intelligence, defined in this way, aims not only to imitate human senses, but also to perceive the world in a way that goes beyond "numerical algorithmisation" [Flanagin et al., 2023].

Tomasz Zalewski notes that, for a long time, artificial intelligence was the domain of theoreticians and science fiction writers. However, in recent years, this concept has gained wide popularity, largely due to the availability of AI solutions for average users. It is no exaggeration to say that artificial intelligence is a key factor in shaping social changes, models of organisational management and economic development.

National Energy System (KSE) – basic information

The National Power System (KSE) is a complex set of devices operating in Poland, designed for the production, transmission, distribution, storage and use of electricity. All these elements are interconnected so as to allow for a continuous and uninterrupted supply of electricity in the country.

The system structure is divided into the following subsystems:

- Generation subsystem (power plants).
- The transmission network, which consists of power lines and stations with voltages of 750 kV, 400 kV and 220 kV. It is a nationwide network, managed by the transmission system operator (TSO– Polskie Sieci Elektroenergetyczne SA.
- Distribution (switching) networks, which include 110 kV (high voltage), medium voltage and low voltage power lines and stations. These networks are regional and are managed by regional distribution system operators, such as Enea, Energa, PGE, Innogy and others. The 110 kV network, although formally part of the distribution network, due to the way it works (often in the form of a meshed or closed network), functions similarly to a transmission network, and its operations are coordinated largely by the TSO [PSE, 2013].

The National Power System, as a key element of critical infrastructure in Poland, requires continuous modernisation to meet the growing challenges related to the dynamically changing demand for energy and the integration of renewable energy

sources. In the 21st century, artificial intelligence (AI) can play a special role in this process. The use of AI in energy system management enables:

- precise forecasting of energy demand,
- optimisation of power plant operation,
- increasing the efficiency of energy transmission and distribution processes.

AI algorithms can analyse significant amounts of data in real-time, which allows for faster response to failures and better management of energy flow, minimising the risk of network congestion. In addition, AI can support decision-making processes in the area of planning network expansion and investment in new technologies, which is crucial for the stability and reliability of energy supplies in the long term.

The importance of artificial intelligence in the energy sector in the light of the report of the THINKTANK Digital Transformation Observatory

The conclusions from the report entitled *How Artificial Intelligence Can Accelerate the Transformation of the Energy Sector* published by the THINKTANK Digital Transformation Observatory indicate that further transformation of the energy sector and in particular changing the energy mix and improving energy system management are closely dependent on the effectiveness of digitalisation in the industry.

Increasing the pace and effectiveness of digitalisation and the benefits it brings requires better organisation of processes supporting digital transformation in companies. This task should go beyond the scope of IT departments by being included in the strategic priorities in the activities of the bodies responsible for managing companies (i.e. company boards).

Table 1. Possibilities of using artificial intelligence in the energy sector

Artificial intelligence functions in the energy sector	Characteristics
Structural optimisation	Entities belonging to the broadly understood energy sector should analyse the position of IT, cybersecurity and system automation departments in their organisational structures. It is necessary to create more optimised models: ▪ supporting cooperation and business development, ▪ enabling better aggregation of knowledge and strategic cooperation with the environment and suppliers. Digitalisation should be treated as a strategic priority, and the assumptions of actions implemented in this area should be established directly by management boards

Artificial intelligence functions in the energy sector	Characteristics
Development of digitalisation strategy	Companies operating in the energy sector should develop a comprehensive digitalisation strategy, including an implementation methodology and a way to manage results
Development of competences	An important aspect is the expansion of competence development systems, including training programmes focused on preparing employees to perform in an increasingly digital environment. These programmes should cover all organisational levels, from technicians to network control engineers, emphasising interdisciplinarity and understanding of digital transformation processes specific to the energy sector
Change management	Companies in the sector should prepare processes and competencies that enable more effective change management, which will accelerate the scaling of solutions from the pilot level to implementation in the entire organisation. A key element is the acquisition of knowledge by managers and HR teams of the principles of digital transformation, taking into account the dynamics of digital changes in the organisational culture of energy companies
Developing a culture of data use	Building a culture based on effective use of data is a major challenge, requiring actions to improve data management competencies at all levels of the organisation and to implement data management systems and tools
Innovation support	Companies in this sector should promote a more open organisational culture that supports innovation, communication within industry groups both nationally and internationally, and enable better collaboration with other sectors, including IT and automotive sectors

Source: Author's own compilation based on Klekowski [2023].

Digital transformation tasks should become priorities for operational management, human resources, innovation and IT departments. In particular, from an organisational perspective, companies should focus on the following issues (Table 1).

The development of artificial intelligence is also a challenge for the energy sector

In the future, the energy demand generated by artificial intelligence systems may exceed the electricity consumption observed in some smaller countries. It is estimated that, by 2027, AI systems will have required between 85 and 134 TWh (terawatt-hours) per year to power them. These values are comparable to current electricity consumption in countries such as Finland or Belgium (at a lower level) and Argentina and Sweden (at a higher level). For comparison, total electricity production in Poland in 2023 was 163 TWh.

This means that within the next few years, AI systems may consume from over half to as much as 82% of the annual electricity production in Poland.

The AI model training phase, considered the most energy-intensive, has been the focus of AI sustainability research to date. SemiAnalytics found that OpenAI used 3617 NVIDIA HGX A100 servers with 28,936 graphics processing units (GPUs) to power ChatGPT, which translates to the energy demand of 564 MWh/day during the usage phase and 1287 MWh/day during the training phase. GenAI alone consumes 10 to 100 times more energy per query than sending an email. Furthermore, other companies currently developing or planning to create AI-based software and solutions will also generate significant energy demands in their quest to gain a competitive advantage [de Vries, 2023; Verdecchia, Sallou, Cruz, 2023].

The use of artificial intelligence in the light of European Union analyses

As part of the AI Strategy for Europe, the European Commission proposed to work with member states to develop a coordinated AI plan to be completed by the end of 2018. The aim of this initiative was to:

- optimise the impact of investments at both EU and national levels,
- promote synergies and cooperation within the EU,
- exchange of best practices,
- jointly define future steps that will enable the EU to compete effectively on the global arena.

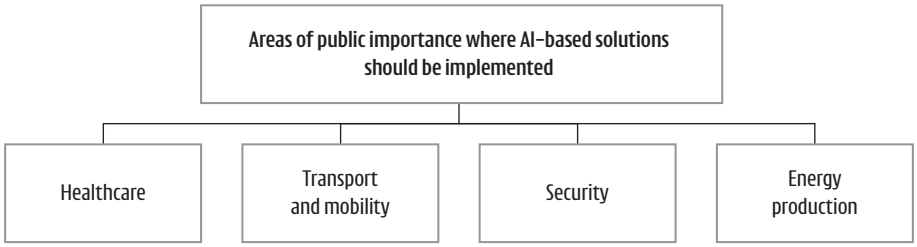
The proposal for a coordinated plan built on the declaration of cooperation on artificial intelligence announced in April 2018, was signed by all member states and Norway and endorsed by the European Council in June 2018. The member states, as part of the Group on Digitising European Industry and Artificial Intelligence, together with Norway, Switzerland and the European Commission, developed the plan in several meetings held between June and November 2018.

The Exchange of views also took place during the meetings of the Competitiveness Council chaired by Austria during its EU Presidency. During these meetings, the member states and the Commission agreed on several joint actions:

- increase in investment,
- collecting data – the key raw material for artificial intelligence,
- supporting talent development,
- building trust.

Priority was given to areas of particular public importance, including the segments shown in Figure 3, as well as key economic sectors (manufacturing, financial services, etc.).

Figure 3. Areas of public importance where AI-based solutions should be implemented



Source: Author's own compilation based on Oleksiewicz [2020].

The result of this joint effort was the Coordinated Plan on Artificial Intelligence. Some initiatives in this Plan were implemented in 2019–2020, followed by the adoption of the White Paper on Artificial Intelligence, which established a European approach to excellence and trust [Oleksiewicz, 2020].

Undoubtedly, the changes related to the use of artificial intelligence in the energy sector will have a direct impact on global energy stability and economic development. For example, the implementation of artificial neural networks plays a key role for energy companies, enabling the improvement of efficiency, quality, production safety and stability of electricity supply. For example, Google used DeepMind's artificial intelligence in its data centre, which allowed for 40% energy savings [Evans, Gao, 2016]. However, despite the increasing adoption of artificial intelligence technology and its growing presence in the energy sector, the research on artificial intelligence in the context of energy is still insufficient for its full scientific use.

From a technical point of view, in the area of energy and electrical engineering, AI technologies, including expert systems, neural networks and fuzzy logic, are used to solve a variety of technical problems [Bose, 2017], including

- forecasting energy demand [Johannesen, Kolhe, Goodwin, 2019],
- analysing prices on energy markets,
- detecting failures in power networks,
- managing energy flows in buildings,
- control of smart home systems,
- data security in intelligent networks,
- processing solar energy (possible, for example, thanks to modelling of solar phenomena) [Brancucci Martinez-Anido, Botor, Florita, Draxl, Lu, Hamann, 2016].

The use of machine learning can increase the accuracy of solar energy forecasting by several dozen per cent compared to the traditional predictive models [Gawer, 2014].

Table 2. AI tools in the energy sector – functionality

Functionality	Description	Example of solutions
Forecasting energy demand	Accurately predicted energy consumption based on historical data, weather conditions and current consumption trends, allowing for better planning of grid operations and infrastructure investments	Siemens PSS®SINCAL
Analysing prices in energy markets	Dynamic analysis of wholesale energy prices and identification of the most advantageous moments to buy or sell, supporting risk management and optimisation of operating costs	EPEX SPOT
Detection of faults in power networks	Real-time network monitoring to quickly detect faults, short circuits and overloads, allowing for immediate reaction and reduction in power outages	ABB Ability ™ Network Manager
Managing energy flow in buildings	Optimising energy consumption and distribution within commercial and residential buildings to reduce costs, improve efficiency and achieve sustainable development goals	Honeywell Energy Manager
Controlling smart home systems	Automation of everyday home processes, such as managing lighting, air conditioning and security, providing users with greater comfort and savings	Google Nest
Data security in smart grids	Protecting critical infrastructure and user data from cyber threats by implementing modern security standards and constant monitoring of threats	Fortinet OT Security
Solar energy processing	Modelling solar radiation and forecasting production from photovoltaic installations to increase the efficiency of RES systems and better balance the network	SMA Sunny Portal

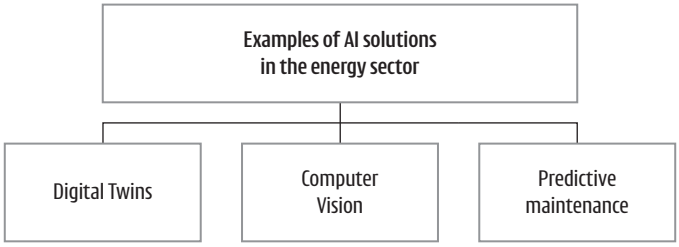
Source: Author's own compilation based on Brancucci Martinez-Anido et. al. [2016], Siemens [2025], epexspot [2025], ABB [2025], Honeywell [2025], Google Store [2025], Fortinet [2025], Sunny [2025].

AI Tools in the Energy Sector

AI-based technologies are used, for example, in areas related to energy production, distribution and management. One of the key applications of artificial intelligence in the energy industry is predictive maintenance. Thanks to advanced machine learning algorithms, it is possible not only to continuously monitor the technical condition of devices, but also to effectively predict potential faults before they can affect the continuity of operational processes. In practice, this means a significant increase in the efficiency of machine use (increase in the OEE indicator), extension of the equipment service life and a significant reduction in costs related to failure and repair. Energy companies can therefore manage risk much better, plan service work to minimises downtime and effectively optimise budgets allocated to infrastructure maintenance.

One of the solutions to be implemented in the energy sector thanks to AI is the concept of Digital Twins. It is nothing more than a digital, extremely accurate copy of real objects, processes or entire systems operating in the energy sector. Digital Twins collect data using various sensors mounted on physical devices and infrastructure, and then process them, creating dynamic computer models [Johannesen et al., 2019, pp. 555–558]. This enables conducting simulations, testing various scenarios and optimising processes in real time, without the need to introduce risky changes in the real world. Virtual replicas are not static – on the contrary, they are constantly updated based on new data, thanks to which they perfectly reflect real working conditions [Gawer, 2012, pp. 1242–1245]. Such a solution allows for faster detection of irregularities, forecasting the development of the situation and effectively responding to the changing environment, which in the context of Industry 4.0 becomes the absolute basis for building competitive and change-resistant business models.

Figure 4. Areas of public importance where AI-based solutions should be implemented



Source: Author's own compilation based on Wiącek [2024].

It is also worth paying attention to the use of computer image recognition systems, which have become well-established in the energy sector. Computer Vision, which uses artificial intelligence to analyse images and video materials, now enables fully automated inspections of energy infrastructure. An example of this is drones equipped with specialist cameras, which can conduct quick and accurate inspections of transmission lines, transformer stations or renewable energy installations such as wind or solar farms. Instead of time-consuming and expensive service visits, companies can monitor the technical condition of their assets in real time, detect potential damage or corrosion and react before more serious failures occur. These solutions are also used to supervise the safety of employees working in difficult or dangerous conditions, and image analysis allows for immediate detection of hazardous situations and rapid implementation of appropriate procedures [Gawer, 2014, pp. 1242–1245].

Computer Vision plays a role in the analysis of transmission data. Thanks to the use of vision technologies, the systems are able to automatically recognise anomalies in transmitted images and immediately alert operators about problems. Quick identification of irregularities in the operation of transmission networks allows to avoid dangerous failures and prevent extensive interruptions in the supply of energy. In addition, the use of advanced analytical algorithms allows for the creation of forecasts regarding the technical condition of the infrastructure based on the analysis of patterns appearing in photos and video recordings. Thanks to this, operators may not only manage the current state of the network better but also predict the need to modernise or replace infrastructure elements before they actually wear out.

Furthermore, predictive maintenance, supported by Artificial Intelligence, is becoming one of the most important tools of modern infrastructure management. Algorithms analysing data from sensors can predict potential failures of turbines, transformers or transmission systems with great precision, allowing companies to plan services before damage occurs. This approach not only reduces operating costs but also increases the safety and reliability of energy supplies.

To sum up, Artificial Intelligence in the energy sector opens up completely new possibilities, from digital twins that allow processes to be simulated and scenarios to be tested without risk, to computer vision systems that enable remote infrastructure inspections, to predictive maintenance of equipment that increases the safety and reliability of supply. This allows for better network management, faster response to failures, and lower operating costs. In practice, this means potentially significant improvements in energy efficiency, both in production and consumption, for example, through smart home systems or green offices. However, an important question arises: Do these benefits outweigh the additional energy demand associated with the operation of sensors, cameras, drones, servers and complex AI models? The energy balance of implementations remains uncertain. This is a clear research gap, as there are still no long-term reliable analyses showing whether AI actually reduces global energy consumption or merely shifts it to other areas. The industry itself is too young and dynamic to draw clear conclusions, so extensive research is needed to assess the actual impact of artificial intelligence on the energy balance in the coming decades.

Conclusions

The importance of artificial intelligence in the energy sector should be considered in two fundamental aspects:

- artificial intelligence as a tool facilitating the optimisation of business processes, including forecasting energy consumption or estimating the level of energy flow in individual areas of energy infrastructure,
- potential threats related to the dynamically increasing demand for electricity.

In the context of supporting energy companies, artificial intelligence enables, above all, more efficient resource management, demand prediction, monitoring of infrastructure condition and early detection of failure, which can lead to benefits such as

- reduced operating costs,
- reduced energy losses,
- increased overall energy efficiency.

Thanks to advanced machine learning algorithms, it is also possible to forecast energy production from renewable sources, which is crucial in managing energy from distributed sources, such as solar or wind farms, where production relies significantly on variable environmental factors.

However, the development of artificial intelligence carries certain risks, primarily related to the growing demand for energy resources. The computational processes necessary for advanced AI systems (in particular, chatbots and tools that enable the creation of advanced predictive models) require significant amounts of electricity. A good example here is ChatGPT, in which the generation of response by a language model itself involves greater electricity consumption than sending an email. In the long term, the mass implementation of artificial intelligence may lead to a further increase in energy demand, which calls into question the sustainable development of the energy sector and poses questions about responsible resource management and pursuit of climate neutrality.

In this connection, after analysing the literature and industry reports addressing the issues related to the possibilities of using artificial intelligence in business organisations (in particular enterprises in the energy sector; one of such documents is the report prepared by the THINKTANK Digital Transformation Observatory entitled *How Artificial Intelligence Can Accelerate the Transformation of the Energy Sector*) [Klekowski, 2023], the author confirms the research hypotheses presented in the introduction. At the same time, the considerations undertaken in this text can be continued, for example, to assess how much the increase in electricity consumption in connection with the operation of AI-based systems can affect the state of the natural environment.

REFERENCES

ABB (2025). *ABB Ability™ Energy Manager. Strike Your Sustainability and Efficiency Target*, https://new.abb.com/low-voltage/products/smart-power-digital-solutions/abb-ability-energy-manager (accessed: 28.04.2025).

Bose, B.K. (2017). Artificial Intelligence Techniques in Smart Grid and Renewable Energy Systems – Some Example Applications, *Proceedings of the IEEE*, 105(11), pp. 2262–2273. DOI: 10.1109/JPROC.2017.2756596.

Brancucci Martinez-Anido, C., Botor, B., Florita, A.R., Draxl, A., Lu, S., Hamann, H.F., Hodge, B. (2016). The Value of Day Ahead Solar Power Forecasting Improvement, *Solar Energy*, 129, pp. 192–203. DOI: 10.1016/j.solener.2016.01.049.

Bujalski, S. (2023), *Żarłoczna inteligencja. Niedługo AI będzie zużywać niewiele mniej energii niż Polska*, https://tech.wp.pl/s/ziemianarozdrozu-pl/zarloczna-inteligencja-niedlugo-ai-bedzie-zuzywac-niewiele-mniej-energii-niz-polska,6960581239820032a (accessed: 03.09.2024).

Chen, L., Chen, P., Lin, Z. (2020). Artificial Intelligence in Education: A Review, *IEEE Access*, 8, https://ieeexplore.ieee.org/document/9069875/ (accessed: 03.09.2024).

epexspot (2025). [Home], https://www.epexspot.com/en (accessed: 28.04.2025).

Evans, R., Gao, J. (2016). *DeepMind AI Reduces Google Data Centre Cooling Bill by 40%*, https://deepmind.google/discover/blog/deepmind-ai-reduces-google-data-centre-cooling-bill-by-40/ (accessed: 28.04.2025).

Flanagin, A., Bibbins-Domingo, K., Berkwits, M. (2023). Nonhuman Authors and Implications for the Integrity of Scientific Publication and Medical Knowledge, *Journal of American Medical Association*, 8(329), pp. 637–639. DOI: 10.1001/jama.2023.1344.

Fortinet (2025). *OT Security Solutions*, https://www.fortinet.com/solutions/ot-security (accessed: 28.04.2025).

Gawer, A. (2014). Bridging Differing Perspectives on Technological Platforms: Toward an Integrative Framework, *Research Policy*, 43(7), pp. 1239–1249. DOI: 10.1016/j.respol.2014.03.006.

Google Store (2025). A Smarter, Safer, More Helpful Home, https://store.google.com/gb/category/connected_home (accessed: 28.04.2025).

Honeywell (2025). *Honeywell Building Automation*, https://buildings.honeywell.com (accessed: 28.04.2025).

Johannesen, N.J., Kolhe, M., Goodwin, M. (2019). Relative Evaluation of Regression Tools for Urban Area Electrical Energy Demand Forecasting, *Journal of Cleaner Production*, 218, pp. 555–564. DOI: 10.1016/j.jclepro.2019.01.108.

Kaplan, K., Haenlen, H. (2019). Siri, Siri in My Hand, Who's the Fairest in the Land? On the Interpretations. Illustrations and Implications of Artificial Intelligence, *Business Horizons*, 62(1), pp. 15–25. DOI: 10.1016/j.bushor.2018.08.004.

Klekowski, T. (2023). How Artificial Intelligence Can Accelerate the Transformation of The Energy Sector, *THINKTANK Digital Transformation Observatory*, https://think-tank.pl/wp-content/uploads/2023/02/raport-energetyczny.pdf (accessed: 03.09.2024).

McCarthy, J., Minsky, M.L., Rochester, N., Shannon, C.E. (2006). *A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence*, http://jmc.stanford.edu/articles/dartmouth/dartmouth.pdf (accessed: 03.09.2024).

Oleksiewicz, I. (2020). Cybersecurity and Artificial Intelligence in the EU Energy Sector, *International Security Yearbook 2020*, 14(1).

PSE (2013). *Informacje o systemie*,

https://web.archive.org/web/20130916043756/http://www.pse.pl/index.php?dzid=79&did=22 (accessed: 03.09.2024).

Saleh, Z. (2019). Artificial Intelligence Definition, *Ethics and Standards*, https://www.researchgate.net/publication/332548325_Artificial_Intelligence_Definition_Ethics_and_Standards (accessed: 03.09.2024).

Siemens (2025). *PSS®SINCAL – Simulation Software for Electric and Pipe Networks*, https://www.siemens.com/global/en/products/energy/grid-software/planning/pss-software/pss-sincal.html (accessed: 28.04.2025).

Sunny (2025). *Sunny Portal*, https://www.sunnyportal.com/ (accessed: 28.04.2025).

Verdecchia, R., Sallou, J., Cruz, L. (2023). A Systematic Review of Green AI, *WIREs Data Mining and Knowledge Discovery*, 13(4), pp. 1–6. DOI: 10.1002/widm.1507.

Vries, A. de (2023). The Growing Energy Footprint of Artificial Intelligence, *Joule*, 7(10), pp. 2191–2194. DOI: 10.1016/j.joule.2023.09.004.

Wiącek, M. (2024). *Artificial Intelligence in Transformation Digital Energy Sector*, https://www.energetyka-rozproszona.pl/media/event_activity_presentations/2024_03_07_OTE_Prezentacja_MWiacek.pdf (accessed: 04.08.2025).

POLITICAL COMPETITION AND PRIVATE PARTICIPATION IN INFRASTRUCTURE

Marian W. Moszoro
International Monetary Fund
George Mason University and SGH Warsaw School of Economics
e-mail: mmoszoro@imf.org

Gonzalo Araya
RBB Economics
e-mail: gonzalo.araya@rbbecon.com

ABSTRACT

We assembled a large panel of project-level technical and financial data, as well as country-level economic, institutional and political variables to assess how political competition and policy insulation feasibility determine private participation in financing infrastructure in emerging markets and developing economies. Controlling for economic and institutional characteristics, we find that when policy insulation is costly, an increase in political competition is associated with an increase in private participation in infrastructure through greenfield projects, concessions, and management contracts, but not through divestitures and privatisations.

JEL Classification: D73, H54, L33, L51, R42

Keywords: political competition, political cooperation, private participation in infrastructure

Acknowledgement

We are grateful to Alex Jett for his support with the PPI Database, Francesca Guiso for assisting with the data analysis, and Conor Healy for sharing digitalised data on Disputes. We are also thankful to Richard Boylan, Elisabetta Iossa, Tewodaj Mogues, Paul Precorino, Fernanda Ruíz-Nuñez, and Arthur Silve and participants in

the presentations at Harvard University for helpful comments. The views expressed in this paper are those of the authors and do not necessarily represent the views of the IMF, its Executive Board or the IMF management.

Introduction

How does the political environment – i.e. political competition across different regimes – affect private investments in infrastructure, beyond and above the economic and institutional setup?

On the one hand, the links between infrastructure and development are well established. They include the impact of infrastructure on poverty alleviation, equity, growth, and specific development outcomes, such as job creation, market access, health, and education [Straub, 2008; Calderón, Servén, 2004, 2008, 2010]. These relationships are complex and dynamic; even with respect to growth and job creation, infrastructure effects are felt through multiple channels.[1] The demand for infrastructure rises with the acceleration of globalisation and urbanisation. In the developing world, more than five million people migrate to urban areas every month. This trend is compounded by the growing need for low CO_2 and climate-resilient investments to combat the challenges of climate change. And with many governments facing fiscal constraints following the 2008 financial crisis, public budgets – traditionally the major source of financing infrastructure – cannot be expected to be the sole financers of infrastructure needs in emerging markets and developing economies (EMDEs). Therefore, private participation in infrastructure financing must play a more prominent role in future project delivery.

Although there has been a significant increase in private participation in infrastructure (PPI) annual commitments over the last two decades (from USD 22 million in 1990 to USD 150 million in 2013),[2] the current volume of private participation in financing infrastructure projects in EMDEs remains modest with respect to the OECD countries. According to the World Bank, total investment in projects with private participation represents less than 20% of the overall current level of investment in EMDE infrastructure.[3]

1 See Agénor and Moreno-Dodson [2006] for an overview, and Estache, Ianchovichina, Bacon, and Salamon [2013] and Schwartz, Andrés, and Dragoiu [2009] for a treatment of infrastructure effects on jobs and growth.

2 Private participation in infrastructure can be treated as equivalent to public-private partnerships, recognising that these numbers also include divestitures, asset sales and auctions.

3 "Investment" in this chapter refers to the resources the project company commits to disburse in facilities during the contract period. Investments can be either in new facilities or in the expansion and

A critical and overarching precondition to attracting private investors is a cooperation-enabling institutional framework, including peace and stability, the rule of law, the absence of corruption, clear property rights and enforceable contracts. From a public policy perspective, given the positive economic, social and environmental externalities that quality infrastructure can provide, efforts to lower the overall riskiness of infrastructure investments and enhance the availability of efficient risk-sharing instruments can have important implications for efficiency and distribution.

Against this background, this paper aims to assess the political determinants of the private financing of infrastructure. Controlling for economic and institutional conditions, we test several political economy hypotheses and identify areas in which additional efforts are required if the private sector were to play a larger role in financing infrastructure development in EMDEs. We contribute to the literature on political cooperation and infrastructure development by: (1) extending previous analyses with a cross-country panel of 130 developing countries from 1990 to 2010 for the transport, energy, telecoms and water sectors, and complementing these data with a novel dataset on quality of governance and number of PPI disputes;[4] (2) using simple but novel metrics – sector-specific moving averages – of investment commitments to account for discrete observations; (3) identifying institutional and political determinants of private infrastructure investments.

Economic and Institutional Determinants of PPI

Considerable economic and financial literature attempts to explain the determinants of investment and the relationship between investment and risk. As the main economic drivers of private investment in infrastructure, most of the theoretical literature points to access to capital [Esty, Sesia, 2010; Weber, Alfen, 2010], investment efficiency [Moszoro, 2014], social (as opposed to financial) discount rate [Arrow, Lind, 1970; Grout, 2003], operational efficiency [Grout, 2003], bundling of

modernisation of existing facilities. Data entry varies across sectors: For projects other than telecommunications and large energy utilities, the total cost of developing or expanding the facility during the contract period is entered as investment data during the year of financial closure (for which data are typically available). For telecommunications projects and some large energy utilities, annual investments on facility expansion and modernisation are entered as investment data in the year of investment when information is publicly available. Investments are recorded in millions of US dollars in either the year of financial closure or the year of investment, as indicated above.

4 Previous literature has only used the number of calendar days to resolve a payment through courts from Djankov, McLiesh and Shleifer [2007], but not PPI disputes specifically.

investment and operations [Iossa, Martimort, 2012], risk allocation [Engel, Fischer, Galetovic, 2001] and contract flexibility [Iossa, Martimort, 2012].

The empirical literature on infrastructure investments and risk remains relatively sparse due to the limited number of projects per jurisdiction. However, there are still notable contributions in cross-country studies. An increase in a country's sovereign risk score is associated with an increase in the probability of having private participation in infrastructure commitment and a greater level of investment in dollar terms within the energy sector [Araya, Schwartz, Andrés, 2013]. Lower levels of corruption and a more effective rule of law are associated with more public-private partnership projects [Hammami, Ruhashyankiko, Yehoue, 2006]. Institutional framework and regulation matter the most as determinants of PPI for Latin America and the Caribbean [Kirkpatrick, Parker, Zhang, 2006].

Furthermore, PPI is greater in larger markets where the ability to pay is higher, governments are fiscally constrained, property rights protected, and quality of the bureaucracy high [Jensen, Blanc-Brude, 2006]. Similarly, property rights and bureaucratic quality play a significant role in promoting PPI. Countries with higher levels of corruption, however, are associated with more PPI, suggesting that corrupt countries with inefficient governments seem to be associated with more PPI in infrastructure [Banerjee, Oetzel, Rupa, 2006]. Finally, the development of the financial sector plays a significant role in private investors' decisions to enter infrastructure sectors [Ba, Gasmi, Noumba, 2010].

Political Competition, Cooperation and PPI

The literature on political competition and political cooperation offers important insights into how political factors may affect PPI. Investors may lobby for the creation of specialised political governance structures or rely on general political mechanisms to influence policy on an ongoing basis [Henisz, Zelner, 2004]. A lack of political competition leads to policies that hinder economic growth; conversely, political competition is associated with a higher level of infrastructure spending [Besley, Persson, Sturm, 2010].

Electorally weak groups attempt to protect their policies by insulating them from political control [Moe, 1989]. When policy insulation is not durable (because it can be easily overturned) or too costly to implement (because the rule of law is strong), political parties have an incentive to cooperate, i.e. not to overturn each other's policies when the opportunity presents itself. Therefore, when policy insulation

is not feasible, cooperation becomes more likely as political uncertainty increases; but when policy insulation is feasible, cooperation becomes less likely as political uncertainty increases [de Figueiredo, 2002].

Most political competition models deal with two-party systems. In a multi-party system, the composition of the opposition matters for policy stability. The cost of a challenge to the incumbent politician is borne by the challenger, but the benefits of taking the incumbent politician out of office are spread to all political competitors [Moszoro, Spiller, 2019]. Therefore, a fragmented opposition will strengthen the prospects of the incumbent politicians and lower their incentives to cooperate with the opposition.

While there have been some empirical tests involving political competition and political cooperation [e.g. Spiller and Tommasi, 2005; Volden, 2002], none have used PPI as a measure of political cooperation. According to the World Bank, PPI is constituted of:

a) Greenfield Projects: a private entity or a public-private joint venture builds and operates a new facility for the period specified in the project contract. The facility may be returned to the public sector at the end of the concession period.
b) Concessions: a private entity takes over the management of a state-owned enterprise for a given period, during which it also assumes significant investment risk. Concessions are also called "brownfield projects."
c) Management and Lease Contracts: a private entity takes over the management of a state-owned enterprise for a fixed period while ownership and investment decisions remain with the state.
d) Divestitures: a private entity buys an equity stake in a state-owned enterprise through an asset sale, public offering or mass privatisation programme.

Greenfield projects, concessions and management-and-lease contracts (GCM)[5] require a stable and cooperative political environment, i.e. no investor will invest in a long-time horizon if they foresee a high probability of opportunistic renegotiation, contract termination, expropriation or substantial adverse changes in regulation [Henisz, 2000b]. Therefore, GCM can be considered a display of inter-temporal political cooperation.

In contrast, infrastructure policy insulation may be implemented either through endowing independent agencies (which we assume to be the status quo) or by divestitures, i.e. fully privatizing the assets and taking them out of public domain.

5 These contracts can be included in the spectrum of public-private partnerships (PPP).

Drawing from the aforementioned literature on political competition and political cooperation, we formulate several testable hypotheses. First, we check the overall effect of political competition on PPI:

- Hypothesis 1: *Greater political competition is associated with higher GCM.*

In other words, we test a naïve proposition that political competition increases GCM regardless of the political system and institutional environment.

Next, we introduce a two-dimensional space of cooperation bounded by policy insulation feasibility and political competition:

- Hypothesis 2: *In countries where policy insulation is not durable or costly, political competition increases GCM.*

Prior research showed that public actors have difficulty changing policies when there are multiple independent centres of authority with veto powers on policy change [Henisz, 2000a]. A parliamentary system is characterised by few veto points – i.e. whoever holds the majority in the parliament can easily undo previous legislation and pass new legislation [Moe and Caldwell, 1994]. In contrast, in a presidential system the majority in parliament is constrained by the possible veto of the president. Therefore, policy insulation is less durable in parliamentary systems than in presidential systems. Likewise, the cost of undoing previous legislation is higher in states with a strong rule of law. Political actors may encounter the veto of the judiciary when discretionarily introducing new legislation.

We operationalise Hypothesis 2 in two working hypotheses:

- Hypothesis 2a: *In parliamentary systems, political competition increases GCM; in presidential systems, political competition decreases GCM.*
- Hypothesis 2b: *When the rule of law is strong, political competition increases GCM; when the rule of law is low, political competition decreases GCM.*

Finally, we turn our attention to the partisan composition. In a multi-party system, an increase in opposition fractionalisation decreases the incentives each particular opposition party has to challenge the incumbent ruler and the actual incentives of the ruling party for competition. Therefore, we predict:

- Hypothesis 3: *An increase in the opposition fractionalisation decreases GCM.*

For robustness of our hypotheses, we check whether our results are inverted for divestitures (as a proxy for insulation) and whether foreign direct investments follow the same pattern as GCM.

Data Description

The data are an unbalanced panel assembled from the World Bank's Private Participation in Infrastructure dataset, Quality of Government dataset, UNCTAD Database of Treaty-Based Investor-State Dispute Settlement Cases, and country-level economic variables from the World Development Indicators Database.

In order to obtain PPI levels, we used the World Bank's Private Participation in Infrastructure Database [World Bank, 2016]. This source offers detailed information by year, country, sector, and form of public-private arrangement. Within sectoral categories, it distinguishes among primary and secondary sectors by investment.[6] The database notes total project size in commitments, later adjusted to actual disbursements, investments or transfers, where information is available. These commitments combine private and, in many cases, public sources. Only projects that have come to a financial closure are included in the database. The database does not include purely public investments carried out in tandem with private operators or private management contractors. All project figures are noted in the year that the project comes to financial closure.

Taking the data from the PPI database, we gather information regarding 130 developing countries from 1990 to 2010. The panel was complemented with data from World Development Indicators including variables, such as GDP, GDP growth, inflation, trade, and population.

The Quality of Governance Standard Database [Teorell et al., 2013] is a panel dataset that draws on a number of freely available data sources related to quality of governance and political data. This is our source for the following variables: freedom from corruption, rule of law, and political regimen – parliamentary democracy, mixed (semi-presidential) democracy, presidential democracy, civilian dictatorship, military dictatorship, royal dictatorship – largest government party vote share, largest opposition vote share, and opposition fractionalisation. A detailed description of these variables is presented in Appendix A.

We rely on the UNCTAD Database of Treaty-Based Investor-State Dispute Settlement Cases to construct the variables on a number of disputes and average time to solve them by sector and country. This database contains 394 observations covering disputed cases pending and concluded, which were disclosed by the parties or arbitral institutions from 1987 to 2010. Summary statistics and cross-correlations of independent variables are presented in Tables 1 and 2.

6 For example, Energy and Transport are "primary sectors", whereas Electricity Distribution and Airports are "secondary sectors."

Identification Strategy

The World Bank's Private Participation in Infrastructure dataset reports private investment commitments to finance infrastructure in a discretionary fashion – i.e. at the time of financial closure, but not as disbursements happen in time. Therefore, previous literature has measured either the probability of a commitment, the number of projects closed in a certain period, or the level of investment subject to financial closure.

To circumvent the problem of discretionary observations (with consequent multiple zeros and time mismatching between independent and dependent variable observable changes), we calculated sector-specific moving averages of investment commitments. Commitments of investments in infrastructure are disbursed throughout several years, rather than in the year of the financial closure. In our moving averages, we used 15 years for water projects, 10 years for energy (plants and transmission) projects, 8 years for transport projects, and 5 years for telecom projects – roughly one third of the depreciation time estimated by the World Bank and arguably an approximation of refurbishing time – as in equation 1:

$$GCM_{it} = \frac{1}{15}\sum_{t=-14}^{0} Water\_GCM_{it} + \frac{1}{10}\sum_{t=-9}^{0} Energy\_GCM_{it} + \frac{1}{8}\sum_{t=-7}^{0} Transport\_GCM_{it} + \frac{1}{5}\sum_{t=-4}^{0} Telecom\_GCM_{it}. \quad (1)$$

The underlying rationale is that the rise of a long-term average signifies sustainable change more strongly than do investment picks. To avoid losing observations and hold the data comparable, at the beginning of each time series we used the elapsed number of years to that point in time as the moving average denominator.

We then log-transformed the sum of sector-specific moving averages. This composite captures the level and change in commitments, which we use in our basic regression specification:

$$\ln GCM_{it} = \alpha_i + \sum_j \beta_j \boldsymbol{X_{itj}} + \sum_k \beta_k \boldsymbol{Y_{itk}} + \sum_l \beta_l \boldsymbol{Z_{itl}} + \epsilon_{it}, \quad (2)$$

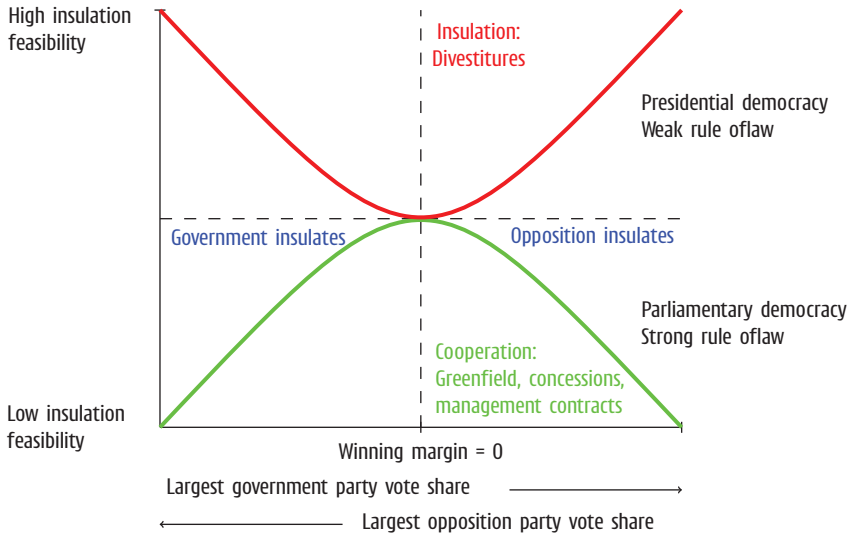
where $\ln GCM_{it}$ equals the natural logarithm of the moving average of private investments in greenfield projects, concessions and management contracts for country i in year t; X_{itj} is the vector of economic variables, which includes the GDP purchasing power parity in current US millions dollars for country i in year $t-1$, i.e. lagged to account for endogeneity of GDP and investments; GDP growth; population size; inflation as a proxy of monetary instability; net exports over GDP as proxy of the open-

ness of the country; and access to commercial bank credit; Y_{itk} is the vector of institutional variables, which includes freedom from corruption, number of court disputes, and rule of law; and Z_{itl} is the vector of political variables, which includes political regimens such as parliamentary democracy, mixed (semi-presidential) democracy, presidential democracy, civilian dictatorship, military dictatorship, and royal; and political competition such as winning margin (i.e. the difference between the largest government and the largest opposition parties vote shares) and opposition fractionalisation. Regressions with divestitures follow the same regression specification.

We run OLS regressions with country-fixed effects and year dummies to account for geographical specificities (i.e. legal regimes) and changes over time that are common across countries (e.g. the financial crisis), respectively.

Figure 5 presents a graphical representation of our tests: policy equilibria of cooperation (GCM) and insulation (divestitures), given the type of democracy, rule of law, and political competition. The horizontal axis represents the largest government party vote share from left to right and the largest opposition party vote share from right to left. The difference between the two is the winning margin, which equals zero at the centre of the axis. The vertical axis represents insulation feasibility: in parliamentary regimes and when the rule of law is high (lower quadrants), insulation is short-lived and costly; in presidential regimes and when the rule of law is low (upper quadrants), insulation is feasible.

Figure 5. Policy equilibria of cooperation (GCM) and insulation (divestitures)



Source: Author's own compilation based on de Figueiredo [2002].

Results

The results of the regressions of private participation in infrastructure – separate for greenfield projects, concessions, and management contracts (GCM) and divestitures (privatisations) – on the variables discussed above are presented in Table 5. All specifications control for the main economic characteristics as customary in the literature: GCM tends to be common in larger markets where demand is greater; GCM is prevalent in countries with stable macroeconomic conditions (i.e. low inflation environments appeal to investors), open countries (proxied by trade) are more likely to attract big foreign investors, and countries with higher levels of public debt are more likely to require the private sector to invest in infrastructure.[7]

Some of the institutional and regulatory variables are statistically significant and provide interesting insights. Access to commercial bank credit is positively associated with GCM, but negatively associated with divestitures. While freedom from corruption facilitates GCM, it does not seem to significantly affect divestitures (the effect is rather negative, if at all). Regarding disputes, our estimation indicates that a greater number of disputes results in lower levels of investments: an increase in an additional project going to court decreases investments by 3%.[8] In these specifications, the overall R-squared are around 50%, a high value for panel data, which validates our reduced form models.

Political Environment Supportive of GCM

To test our hypotheses, we included selected political variables that proxy the level of political competition and the feasibility and cost of political insulation.[9] The results considering winning margins, type of democracy, rule of law, and opposition fractionalisation are shown the in the lower part of Table 5.

Model 1 does not provide support for Hypothesis 1; political competition alone (i.e. narrower winning margins in electoral races) does not increase GCM. Model 2 provides evidence in support of Hypothesis 2a. The interaction term that captures the effect of political competition in parliamentary democracies is significant and of the expected direction: when winning margins decrease by 1% (higher political

7 Indebted countries could be perceived, however, as a greater risk of default by the private sector. As a debt measure, we use the total debt service divided by the gross national income.

8 We used the number of disputes in the 10 years before the commitment to capture the countries' reputation in this matter.

9 A description of these variables can be found in Appendix A.

competition), GCM rises by 3.1%. Likewise, Model 3 shows that when the rule of law is strong (making insulation costly), an increase in political competition is associated with greater cooperation in GCM (Hypothesis 2b).

Opposition fractionalisation is negatively correlated with GCM, supporting Hypothesis 3 that cooperating on policy is sustainable when the incumbent political party faces an actual risk of overturn from a strong opposition; the coefficient, however, is not significant.

Divestitures

Once privatised, assets do not remain in the public domain. Therefore, divestitures can be used as a form of policy insulation – when the incumbent politician is overturned, she retains control of the privatised assets. To check whether divestitures follow a different pattern than GCM, we re-run our regressions with divestitures as the dependent variable (Table 5, Models 4–6).

Generally, the results show that political competition is associated with lower divestitures (inverted to GCM). Also, a weak and fragmented opposition is unable to stop insulation.

Thus, assuming that GCM and divestitures are disjunctive alternative modes of private participation in infrastructure, our results can be read as support for Hypotheses 1–3 *a contrario*.

Foreign Direct Investments

Foreign direct investments (FDI) are a controlling ownership in a business enterprise in one country by an entity based in another country. It is a more liquid investment than PPI, and less subject to government intervention and business regulation. To check whether our dependent variable GCM captures long-term political cooperation, or is just correlated with a general investment trend, we run the same regressions, but with FDI as the dependent variable.

The results in Table 6 show that GCM follows a different pattern than does FDI regarding the political competition environment. While a wider winning margin attracts more FDI (Models 1 and 2), this correlation disappears once the rule of law is taken into account (Model 3), at which time it becomes the only relevant institutional variable that explains increases in FDI.

Left versus Right-Wing Politics

Left-wing administrations are associated with social programmes and higher redistribution, while right-wing governments are associated with pro-market/pro-private sector reforms. If this association holds true, we should observe a differential result for left- and right-wing administrations.

In Table 7, we run regressions separately for left- and right-wing governments.[10] Right-wing administrations seem to attract more GCM in large economies, while left-wing administrations seem to resort to GCM in populated countries and to counteract trade deficit.

On the institutional level, freedom from corruption seems to be a more important factor to attract GCM in right-wing administrations.

The political variable estimates regarding left- and right-wing administrations are similar to the aggregate estimates shown in Table 5, suggesting that the political leaning of political competition and insulation feasibility does not affect the propensity for GCM.

Greenfield and Brownfield Projects

Greenfield projects require more capital expenditures and time than comparable brownfield projects (concessions). They are also subject to administrative permits and support from the local community. In Table 8, we run our regressions separately for greenfield investments versus concessions to determine whether some of our explanatory variables affect more one type of investment than the other.

The estimates related to greenfield projects (Models 1–3) are in line with our hypotheses: in parliamentary democracies and when the rule of law is high, political competition is associated with an increase in greenfield projects. The institutional variables estimates are also as expected: access to finance, freedom from corruption, and fewer disputes increase greenfield investments.

Concessions alone show a different gauge. Access to finance seems to be the only relevant institutional variable. Neither corruption nor the number of disputes appear to have an impact on brownfield investments. Also, a higher winning margin in parliamentary democracies is correlated to higher brownfield investments. This could be due to the fact that concessions require less capital investments, and are thus subject less to political cooperation, and may be a tool for exchanging favours.

10 We do not have enough centre-leaning administrations.

Limitations

Our empirical tests are limited by several factors. First, we measure private-sector investment commitment at financial closure, as we do not have data on actual disbursements nor on whether the projects were discontinued.

Second, we do not observe the counterfactual, i.e. traditional public-sector procurement and investment. Also, our data on the percentage of public financing is incomplete. Thus, our results may be interpreted as either facilitators or alternatives of PPI conditional on private investment.

Third, we measure political uncertainty and competition by the results of the last elections. A more accurate measure would require real-time opinion polls.

Fourth, our proxies of cost of insulation are imperfect. Our data do not distinguish hybrid political systems (e.g. some parliamentary systems have a presidential veto which can only be overturned by a qualified super-majority) from the rest.

Conclusions

In this paper, we tested whether political competition and insulation feasibility affect private participation in infrastructure, distinctively for greenfield projects, concessions, and management contracts on the one hand, and privatisations (divestitures) on the other.

The results of our regressions support the hypothesis that an increase in political com- petition facilitates cooperation among political parties in carrying out infrastructure projects only when policy insulation is not feasible, i.e. in parliamentary systems and/or when the rule of law is strong, an increase in political competition is associated with an increase in greenfield projects, concessions, and management contracts.

In a similar manner, we analyse different specifications where political competition facilitates cooperation. Neither left- nor right-wing parties present a distinct pattern; there is, however, a difference between greenfield and concession projects, suggesting that the former are those that are really the product of political cooperation.

Moreover, the evidence shows that no matter the political regimen, countries with less competitive political elections tend to have more privatisation of infrastructure, which serves as a form of policy insulation. The policy insulation materialised through infrastructure divestitures can be seen regardless of the political regimen and becomes likely as the political competition decreases.

These results highlight the importance of the political competition and its impact in determining the form of private participation in infrastructure. Governments interested in boosting public-private partnerships should propitiate a fair and competitive political environment.

Finally, foreign direct investments (FDI) follow a different pattern regarding political competition. A larger margin of winning in electoral races is associated with more FDI, suggesting that this kind of investment is not subject to political cooperation. This relationship, however, disappears when the rule of law is considered. In other words, when it comes to FDI, the extent to which the rules of the country are abided is more important than political competition.

Appendix A. Definition of Institutional and Political Variables

Freedom from corruption relies on Transparency International's Corruption Perceptions Index (CPI), which measures the level of corruption in 152 countries to determine the freedom from corruption scores of countries that are also listed in the Index of Economic Freedom. The CPI is based on a 10-point scale, in which a score of 10 indicates very little corruption, and a score of 0 indicates a very corrupt government. In scoring freedom from corruption, the authors convert each of these raw CPI data to a 0–100 scale by multiplying the CPI scores by 10.

Number of disputes is the number of international disputes in 10 years before the commitment and captures the countries.

Rule of law includes several indicators that measure the extent to which agents have confidence in and abide by the rules of society. These include perceptions of the incidence of crime, the effectiveness and predictability of the judiciary, and the enforceability of contracts. Together, these indicators measure the success of a society in developing an environment in which fair and predictable rules form the basis for economic and social interactions and the extent to which property rights are protected. This indicator is part of the World Bank worldwide governance indicators project.

Regimen classifies systems of government into parliamentary democracy, mixed (semi- presidential) democracy, presidential democracy, civilian dictatorship, military dictatorship and royal dictatorship. This classification was elaborated upon by Cheibub, Gandhi, and Vreeland [2010].

Government Vote Share is the total vote share of all government parties in percentage points.

Largest Government Party Vote Share is the total vote share of all government parties in percentage points.

Largest Opposition Party Vote Share is the share of votes of the largest opposition party in percentage points.

Margin is the difference between the largest government party vote share and the largest opposition party vote share.

Opposition fractionalisation measures the probability that two randomly chosen deputies belonging to the parties in the opposition will be of different parties.

Annex B. Additional tables

Table 3 presents summary statistics of economic, institutional, and political variables in our sample. Data are an unbalanced panel assembled from the World Bank's Private Participation in Infrastructure dataset, Quality of Government dataset, UNCTAD Database of Treaty-Based Investor-State Dispute Settlement Cases, and country-level economic variables from the World Development Indicators Database.

Table 3. Summary Statistics

Variable	Count	Mean	Std. dev.	Min	Max
ln GDP$_{-1}$	7388	22.77	2.41	15.99	30.34
ln Inflation$_{-1}$	6588	1.95	1.40	−13.44	10.19
ln Trade$_{-1}$	6938	4.14	0.64	−1.18	6.13
Debt$_{-1}$	4242	4.93	6.77	0.00	208.10
Growth$_{-1}$	7140	2.05	6.01	−50.29	92.59
ln Population	8178	15.34	2.11	8.98	21.02
Access to finance	2291	7.47	17.92	0.00	150.00
Freedom from corruption	2987	40.07	23.22	0.00	100.00
Number of disputes	4780	0.69	3.30	0.00	65.00
Rule of law	2492	−0.07	0.99	−2.67	2.00
Largest government party vote share	4832	42.40	33.26	0.00	100.00
Largest opposition party vote share	4992	14.81	15.89	0.00	57.10
Margin	4742	27.07	36.65	−34.80	100.00
Opposition fractionalisation	3950	0.45	0.29	0.00	1.00

Source: Authors' own work.

Table 4. Pairwise Correlations

	ln GDP$_{-1}$	ln Inflation$_{-1}$	ln Trade$_{-1}$	Debt$_{-1}$	Growth$_{-1}$	ln Population	Freedom from corruption	Rule of law	Access to finance	Number of disputes	Largest government party vote share	Largest government opposition vote share	Margin	Opposition fractionalisation
ln GDP$_{-1}$	1.00													
ln Inflation$_{-1}$	0.00	1.00												
ln Trade$_{-1}$	−0.58	0.01	1.00											
Debt$_{-1}$	−0.02	0.19	0.12	1.00										
Growth$_{-1}$	−0.12	−0.12	0.19	−0.14	1.00									
ln Population	0.80	0.14	−0.58	−0.08	−0.05	1.00								
Freedom from corruption	0.36	−0.13	−0.15	0.15	−0.15	0.01	1.00							
Rule of law	0.24	−0.10	−0.10	0.06	−0.13	−0.03	0.77	1.00						
Access to finance	0.32	0.02	−0.09	0.24	−0.10	0.20	0.14	0.15	1.00					
Number of disputes	0.60	0.00	−0.41	0.02	−0.05	0.52	0.10	0.06	0.16	1.00				
Largest government party vote share	−0.24	0.01	0.34	0.03	0.14	−0.16	0.10	0.06	−0.06	−0.31	1.00			
Largest government opposition vote share	−0.15	−0.02	0.19	−0.01	−0.04	−0.17	0.04	0.11	−0.14	−0.05	−0.25	1.00		
Margin	−0.10	0.02	0.16	0.03	0.12	−0.03	0.06	−0.01	0.03	−0.20	0.87	−0.70	1.00	
Opposition fractionalisation	0.36	−0.03	−0.27	0.04	−0.03	0.29	0.02	−0.07	0.16	0.17	−0.15	−0.55	0.17	1.00

Source: Authors' own work.

Table 4 presents pairwise correlations of economic, institutional and political variables in our sample.

Table 5 presents multivariable OLS regressions of the political determinants of private participation in infrastructure. The dependent variable is the natural logarithm of total private investments in infrastructure grouped in two categories:

greenfield projects, concessions management contracts (GCM) and divestitures (privatisations). Controls include economic and institutional variables, year dummies and country fixed effects.

Table 5. Political Determinants of PPI

	GCM			Divestitures		
	1	2	3	4	5	6
ln GDP$_{-1}$	0.561***	0.529***	0.595***	0.941***	0.608**	0.823***
	(4.24)	(3.47)	(3.67)	(4.48)	(2.29)	(3.09)
ln Inflation$_{-1}$	−0.0510*	−0.0681**	−0.00271	−0.0539	−0.0515	−0.0204
	(−1.72)	(−2.19)	(−0.08)	(−1.21)	(−0.92)	(−0.41)
ln Trade$_{-1}$	0.241	0.185	0.0276	0.393	0.173	0.131
	(1.36)	(0.94)	(0.13)	(1.30)	(0.46)	(0.37)
Debt$_{-1}$	0.00522	0.00903	0.000369	0.00470	0.00620	0.00226
	(1.03)	(1.19)	(0.08)	(0.48)	(0.58)	(0.21)
Growth$_{-1}$	−0.0143**	−0.0137*	−0.00866	−0.0139	−0.0135	−0.0190*
	(−2.20)	(−1.95)	(−1.28)	(−1.35)	(−1.03)	(−1.70)
ln Population	−0.776	−1.167*	−0.952	−0.0916	−0.397	−0.251
	(−1.27)	(−1.84)	(−1.38)	(−0.09)	(−0.33)	(−0.20)
Access to Finance	0.00334	0.00726***	0.00210	−0.00433*	−0.00498	−0.00247
	(1.62)	(3.20)	(0.92)	(−1.66)	(−1.60)	(−0.84)
Freedom from corruption	0.0139***	0.0136***	0.0112**	−0.00370	0.000340	0.00414
	(3.81)	(3.62)	(2.51)	(−0.60)	(0.05)	(0.53)
Number of disputes	−0.0325***	−0.0244**	−0.0344***	−0.0232*	−0.0324**	−0.0189
	(−3.23)	(−2.36)	(−2.88)	(−1.94)	(−2.34)	(−1.25)
Margin	−0.000257	0.00108	−0.00266	0.00735***	0.00875***	0.0181***
	(−0.14)	(0.51)	(−0.80)	(3.36)	(3.04)	(4.19)
Parliamentary democracy		0.393			1.149**	
		(1.28)			(2.20)	
Parliamentary democracy × Margin		−0.0311***			−0.000531	
		(−3.41)			(−0.04)	
Rule of law			0.0690			0.106
			(0.35)			(0.35)
Rule of law × Margin			−0.0107***			0.0120**
			(−2.76)			(2.14)

cont. Table 5

	GCM			Divestitures		
	1	2	3	4	5	6
Opposition fractionalisation		−0.243	−0.124		0.483**	0.678***
		(−1.56)	(−0.74)		(2.08)	(2.90)
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.629	0.676	0.586	0.277	0.246	0.301
Number of countries	94	78	79	59	53	53
Observations	880	654	584	500	399	379

Note: t-statistics in parenthesis, * p < 0.1; ** p < 0.05; *** p < 0.01.
Source: Authors' own work.

Table 6 presents multivariable OLS regressions of the political determinants of foreign direct investments (FDI). The dependent variable is the natural logarithm of FDI. Controls include economic and institutional variables, year dummies, and country fixed effects.

Table 6. Foreign Direct Investments

	FDI		
	(1)	(2)	(3)
ln GDP_{-1}	0.0667	0.127	0.130
	(0.41)	(0.70)	(0.55)
ln $Inflation_{-1}$	−0.0280	−0.0625	0.0276
	(−0.72)	(−1.51)	(0.54)
ln $Trade_{-1}$	0.756***	0.680***	0.587*
	(3.31)	(2.77)	(1.80)
$Debt_{-1}$	0.00860**	0.0114**	0.00657
	(2.13)	(2.52)	(0.82)
$Growth_{-1}$	0.0268***	0.0250***	0.0342***
	(3.49)	(2.97)	(3.17)
ln Population	−0.197	−0.115	−0.999
	(−0.27)	(−0.14)	(−0.98)
Access to Finance	0.00164	0.00398	0.00467
	(0.56)	(1.20)	(1.19)
Freedom from corruption	0.00266	0.00261	0.000121
	(0.59)	(0.56)	(0.02)

	FDI		
	(1)	(2)	(3)
Number of disputes	−0.0400***	−0.0401***	−0.0496***
	(−2.92)	(−2.67)	(−2.73)
Margin	0.00735***	0.00625**	0.00213
	(3.25)	(2.39)	(0.43)
Parliamentary democracy		0.446	0.211
		(1.20)	(0.36)
Parliamentary democracy × Margin		−0.00370	−0.00418
		(−0.33)	(−0.31)
Rule of law			0.845***
			(2.65)
Rule of law × Margin			−0.00698
			(−1.09)
Opposition fractionalisation			−0.202
			(−0.80)
Country fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
R^2	0.322	0.335	0.431
Number of countries	99	98	79
Observations	931	835	511

Note: t-statistics in parenthesis, * p < 0.1; ** p < 0.05; *** p < 0.01.
Source: Authors' own work.

Table 7 presents multivariable OLS regressions of greenfield projects, concessions, and management contracts (GCM) by partisan leaning (left- or right-wing). The dependent variable is the natural logarithm of total private investments in greenfield projects, concessions, and management contracts (GCM). Controls include economic and institutional variables, and year fixed effects.

Table 7. GCM by Partisan Leaning

	Left			Right		
	(1)	(2)	(3)	(4)	(5)	(6)
ln GDP_{-1}	0.579**	−0.0850	−0.0792	1.160***	1.116***	1.694***
	(2.16)	(−0.22)	(−0.20)	(5.21)	(4.85)	(5.78)
ln $Inflation_{-1}$	−0.0370	−0.127**	0.0534	−0.0585	−0.0299	−0.0127

cont. Table 7

	Left			Right		
	(1)	(2)	(3)	(4)	(5)	(6)
	(−0.73)	(−2.30)	(0.87)	(−1.30)	(−0.66)	(−0.19)
ln Trade$_{-1}$	−0.514*	−1.546***	−1.907***	0.202	0.163	0.655
	(−1.80)	(−4.36)	(−4.54)	(0.64)	(0.50)	(1.33)
Debt$_{-1}$	0.0313*	0.0360*	0.0332*	−0.00382	0.0000847	0.00681
	(1.83)	(1.95)	(1.88)	(−0.45)	(0.01)	(0.68)
Growth$_{-1}$	−0.00729	−0.0214*	−0.00528	−0.0366***	−0.0168	−0.00305
	(−0.63)	(−1.71)	(−0.40)	(−3.30)	(−1.43)	(−0.18)
ln Population	4.480***	5.188***	3.067**	2.157*	2.000	−0.341
	(3.26)	(3.46)	(2.09)	(1.75)	(1.32)	(−0.21)
Access to Finance	0.000329	0.00742**	0.00389	0.00856	0.00478	−0.00315
	(0.11)	(2.26)	(0.96)	(1.54)	(0.85)	(−0.35)
Freedom from corruption	0.00127	0.00340	0.0109	0.0280***	0.0231***	0.0189**
	(0.19)	(0.46)	(1.34)	(5.06)	(4.04)	(2.29)
Number of disputes	−0.0141	−0.00478	−0.0127	0.0542**	0.0559*	−0.0968
	(−1.11)	(−0.36)	(−0.93)	(2.03)	(1.83)	(−0.88)
Margin	−0.00180	0.000513	−0.0100	−0.0122*	−0.00761	−0.00226
	(−0.48)	(0.12)	(−1.45)	(−1.93)	(−1.04)	(−0.23)
Parliamentary democracy		0.856**			0	
		(2.47)			–	
Parliamentary democracy × Margin		−0.0360***			−0.0384**	
		(−2.94)			(−2.17)	
Rule of law			0.498			−0.779
Rule of law × Margin			(1.36) −0.0148*			(−1.57) −0.0377***
			(−1.86)			(−2.75)
Opposition fractionalisation		−0.0653	0.590*		0.440	0.406
		(−0.24)	(1.74)		(1.24)	(0.79)
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.619	0.709	0.684	0.779	0.754	0.742
Number of countries	38	31	31	30	27	28
Observations	305	209	196	196	181	130

Note: t-statistics in parenthesis, * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Source: Authors' own work.

Table 8 presents multivariable OLS regressions of greenfield projects and concessions. Controls include economic and institutional variables, year dummies, and country fixed effects.

Table 8. Greenfield Projects versus Concessions

	Greenfield			Concessions		
	(1)	(2)	(3)	(4)	(5)	(6)
ln GDP$_{-1}$	0.559***	0.401**	0.441**	−0.0484	0.742*	1.325***
	(3.91)	(2.38)	(2.44)	(−0.16)	(1.94)	(3.08)
ln Inflation$_{-1}$	−0.0491	−0.0771**	0.00769	−0.173***	−0.0563	−0.109
	(−1.52)	(−2.22)	(0.20)	(−2.73)	(−0.80)	(−1.28)
ln Trade$_{-1}$	0.511***	0.221	0.00869	−0.0878	0.540	0.987**
	(2.67)	(1.01)	(0.04)	(−0.23)	(1.25)	(2.02)
Debt$_{-1}$	0.00650	0.0109	0.00281	0.000231	0.00512	0.0109
	(1.20)	(1.31)	(0.54)	(0.01)	(0.20)	(0.44)
Growth$_{-1}$	−0.0176**	−0.0194**	−0.0121	−0.0305**	−0.0138	−0.0503***
	(−2.50)	(−2.48)	(−1.61)	(−2.26)	(−0.91)	(−3.43)
ln Population	0.416	0.165	0.437	−0.126	−1.160	−2.538
	(0.63)	(0.23)	(0.56)	(−0.07)	(−0.51)	(−1.13)
Access to Finance	0.00136	0.00532**	0.00137	0.0161***	0.0181***	0.0159***
	(0.62)	(2.13)	(0.54)	(4.18)	(4.16)	(3.46)
Freedom from corruption	0.0234***	0.0229***	0.0194***	0.00269	0.00171	0.00896
	(5.93)	(5.44)	(3.84)	(0.32)	(0.20)	(0.81)
Number of disputes	−0.0303***	−0.0216*	−0.0276**	0.00570	−0.0172	−0.00308
	(−2.82)	(−1.90)	(−2.08)	(0.35)	(−0.96)	(−0.14)
Margin	0.00134	0.00329	−0.00191	−0.00309	−0.000504	0.00869
	(0.69)	(1.40)	(−0.52)	(−0.83)	(−0.10)	(1.16)
Parliamentary democracy		0.516			1.787*	
		(1.53)			(1.94)	
Parliamentary democracy × Margin		−0.0359***			0.240***	
		(−3.56)			(3.67)	
Rule of law			0.0635			−0.338
			(0.29)			(−0.73)
Rule of law × Margin			−0.0123***			0.0124
			(−2.84)			(1.28)

	Greenfield			Concessions		
	(1)	(2)	(3)	(4)	(5)	(6)
Opposition fractionalisation		−0.190	0.0537		0.0406	0.0621
		(−1.09)	(0.28)		(0.12)	(0.17)
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.620	0.642	0.557	0.265	0.382	0.255
Number of countries	94	78	79	62	55	57
Observations	865	644	576	491	373	356

Note: t-statistics in parenthesis, * p < 0.1; ** p < 0.05; *** p < 0.01.
Source: Author's own work.

REFERENCES

Agénor, P.R., Moreno-Dodson, B. (2006). Public Infrastructure and Growth: New Channels and Policy Implications, *World Bank Policy Research Working Paper*, 4064, http://documents.worldbank.org/curated/en/485431468141267544 (accessed: 20.01.2025).

Araya, G., Schwartz, J., Andrés, L. (2013). The Effects of Country Risk and Conflict on Infrastructure PPPs, *World Bank Policy Research Working Paper*, 6569, http://documents.worldbank.org/curated/en/241991468159603304 (accessed: 20.01.2025).

Arrow, K.J., Lind, R.C. (1970). Uncertainty and the Evaluation of Public Investment Decisions, *American Economic Review*, 60(3), pp. 364–378. DOI: 10.1016/B978-0-12-214850-7.50031-0.

Ba, L., Gasmi, F., Noumba, P. (2010). Is the Level of Financial Sector Development a Key Determinant of Private Investment in the Power Sector? *World Bank Policy Research Working Paper*, 5373, http://documents.worldbank.org/curated/en/200741468331267691 (accessed: 20.01.2025).

Banerjee, S.G., Oetzel, J.M., Rupa, R. (2006). Private Provision of Infrastructure in Emerging Markets: Do Institutions Matter? *Development Policy Review*, 24(2), pp. 175–202. DOI: 10.1111/j.1467-7679.2006.00321.x.

Besley, T., Persson, T., Sturm, D.M. (2010). Political Competition, Policy and Growth: Theory and Evidence from the US, *Review of Economic Studies*, 77(4), pp. 1329–1352.

Calderón, C., Servén, L. (2004). The Effects of Infrastructure Development on Growth and Income Distribution, *World Bank Policy Research Working Paper,* 270, World Bank, https://hdl.handle.net/10986/14136 (accessed: 20.01.2025).

Calderón, C., Servén, L. (2008). Infrastructure and Economic Development in Sub-Saharan Africa, *World Bank Policy Research Working Paper* 4712, World Bank, https://hdl.handle.net/10986/6988 (accessed: 20.01.2025).

Calderón, C., Servén, L. (2010). Infrastructure in Latin America, *World Bank Policy Research Working Paper,* 5317, World Bank, https://documents1.worldbank.org/curated/en/438071468270620526/pdf/535230WP0P10941060Report02009105129.pdf (accessed: 20.01.2025).

Cheibub, J.A., Gandhi, J., Vreeland, J.R. (2010). Democracy and Dictatorship Revisited, *Public Choice*, 143 (1–2), pp. 67–101. DOI:10.1007/s11127-009-9491-2

Djankov, S., McLiesh, C., Shleifer, A. (2007). Private Credit in 129 Countries, *Journal of Financial Economics*, 84(2), pp. 299–329. DOI: 10.1016/j.jfineco.2006.03.004.

Engel, E., Fischer, R., Galetovic, A. (2001). Least-Present-Value-of-Revenue Auctions and Highway Franchising, *Journal of Political Economy*, 109(5), pp. 993–1020. DOI: 10.1086/322832.

Estache, A., Ianchovichina, E., Bacon, R., Salamon, I. (2013). *Infrastructure and Employment Creation in the Middle East and North Africa*, World Bank Publications, http://documents.worldbank.org/curated/en/170091468299225391 (accessed: 20.01.2025).

Esty, B.C., Sesia, A. (2010). An Overview of Project Finance and Infrastructure Finance – 2009 Update, *Technical Note*, 210–061, Harvard Business School, https://www.hbs.edu/faculty/Pages/item.aspx?num=47358 (accessed: 20.01.2025).

Figueiredo, R.J.P. de (2002). Electoral Competition, Political Uncertainty, and Policy Insulation, *American Political Science Review*, 96(2), pp. 321–333. DOI: 10.1017/S0003055402000199.

Grout, P.A. (2003). Public and Private Sector Discount Rates in Public-Private Partnerships, *Economic Journal*, 113(486), pp. C62-C68. DOI: 10.1111/1468-0297.00109.

Hammami, M., Ruhashyankiko, J.F., Yehoue, E.B. (2006). Determinants of Public-Private Partnerships in Infrastructure, *IMF Working Paper* WP/06/99, International Monetary Fund, DOI:10.5089/9781451863598.001.

Henisz, W.J. (2000a). The Institutional Environment for Economic Growth, *Economics & Politics*, 12(1), pp. 1–31. DOI: 10.1111/1468-0343.00066.

Henisz, W.J. (2000b). The Institutional Environment for Multinational Investment, *Journal of Law, Economics, and Organization*, 16(2), pp. 334–364. DOI:10.1093/jleo/16.2.334.

Henisz, W.J., Zelner, B.A. (2004). Explicating Political Hazards and Safeguards: A Transaction Cost Politics Approach, *Industrial and Corporate Change*, 13(6), 901–915. DOI: 10.1093/icc/dth036.

Iossa, E., Martimort, D. (2012). Risk Allocation and the Costs and Benefits of Public–Private Partnerships, *RAND Journal of Economics*, 43(3), pp. 442–474. DOI: 10.1111/j.1756-2171.2012.00181.x.

Jensen, O., Blanc-Brude, F. (2006). The Handshake: Why Do Governments and Firms Sign Private Sector Participation Deals? Evidence from the Water and Sanitation Sector in Developing Countries, *World Bank Policy Research Working Paper* 3937, https://hdl.handle.net/10986/8432 (accessed: 20.01.2025).

Kirkpatrick, C., Parker, D., Zhang, Y.F. (2006). Foreign Direct Investment in Infrastructure in Developing Countries: Does Regulation Make a Difference?, *Transnational Corporations*, 15(1), pp. 143–171. DOI: 10.22004/ag.econ.30703.

Moe, T.M. (1989). The Politics of Bureaucratic Structure. In: *Can the Government Govern*? (pp. 267–271), J.E. Chubb, P.E. Peterson (Eds.), Washington, DC: Brookings.

Moe, T.M., Caldwell, M. (1994). The Institutional Foundations of Democratic Government: A Comparison of Presidential and Parliamentary Systems, *Journal of Institutional and Theoretical Economics*, 150(1), pp. 171–195. https://www.jstor.org/stable/40753032.

Moszoro, M.W. (2014). Efficient Public-Private Capital Structures, *Annals of Public & Cooperative Economics*, 85(1), pp. 103–126. DOI: 10.1111/apce.12028.

Moszoro, M.W., Spiller, P.T. (2019). Political Contestability and Public Contracting, *Journal of Public Economic Theory*, 21(5), pp. 945–966. DOI: 10.1111/jpet.12325.

Schwartz, J., Andrés, L., Dragoiu, G. (2009). Crisis in Latin America Infrastructure Investment, Employment and the Expectations of Stimulus, *Journal of Infrastructure Development*, 1(2), pp. 111–131. DOI: 10.1177/097493060900100202.

Spiller, P.T., Tommasi, M. (2005). The Institutions of Regulation: An Application to Public Utilities. In: *Handbook of New Institutional Economics* (vol. 9, pp. 515–543), C. Ménard, M.M. Shirley (Eds.). Dordrecht: Springer.

Straub, S. (2008). Infrastructure and Growth in Developing Countries. *World Bank Policy Research Working Paper* 4460, DOI: 10.1596/1813-9450-4460.

Teorell, J., Charron, N., Dahlberg, S., Holmberg, S., Rothstein, B., Sundin, P., Richard, S. (2013). *The Quality of Government Dataset. Technical Report*, University of Gothenburg: The Quality of Government Institute, https://www.gu.se/en/quality-government/qog-data (accessed: 20.01.2025).

Volden, C. (2002). Delegating Power to Bureaucracies: Evidence from the States, *Journal of Law, Economics, and Organization*, 18(1), pp. 187–220. DOI: 10.1093/jleo/18.1.187.

Weber, B., Alfen, H.W. (2010). *Infrastructure as an Asset Class: Investment Strategies, Project Finance and PPP*. Hoboken: Wiley.

World Bank (2016). *Private Participation in Infrastructure Database*, http://ppi.worldbank.org/ (accessed: 20.01.2025).

GENDER DIVERSITY IN THE COMPANY MANAGEMENT AND ITS FINANCIAL PERFORMANCE

Bartłomiej Wiśnicki
SGH Warsaw School of Economics, Collegium of Economic Analysis
Institute of Econometrics
Applied Econometrics Unit, e-mail: bwisni@sgh.waw.pl

Marek Szyl
SGH Warsaw School of Economics
PhD Candidate at the SGH Doctoral School
e-mail: ms79957@doktorant.sgh.waw.pl

ABSTRACT

The aim of the study is to deepen knowledge of gender diversity in the management and supervisory boards of companies listed on the WSE over recent years. The analysis showed that although gender parity is increasing in company authorities, the share of women is still far below 50%. The share is much lower in masculinised industries such as automotive and IT.

The analysis of the relationship between the financial performance of companies and the participation of women in the company's governing bodies shows no significant correlation between these variables. This means, on the one hand, the absence of a simple causal relationship in this regard. On the other hand, the analysis gives room for more in-depth research, including the use of more sophisticated methods to study these relationships. It may also be valuable to focus on the analysis of specific companies and the impact of different personnel on changes in their performance and, consequently, financial results.

JEL Classification: G34, J16, L25

Keywords: corporate governance, financial performance, gender diversity

Introduction

Gender diversity in corporate governing bodies is playing an increasingly important role in today's business world. With the growing emphasis on social justice, sustainability and inclusiveness, companies are increasingly obliged to ensure gender equality at all levels of management.

The purpose of this study is to examine in detail the impact of gender diversity on the financial performance of companies listed on the Warsaw Stock Exchange (WSE). The study covers the period from 2010 to 2022 and focuses on the analysis of management and supervisory boards. Specifically, the paper seeks to answer questions about the change in the proportion of women on management and supervisory boards in time and between economic sectors. In addition, the study will seek to compile, at the micro level, financial data on companies with women on their boards of directors and supervisory boards.

In recent years, many studies have focused on examining the relationship between gender diversity on boards of directors and corporate financial performance. In theory, greater gender diversity could lead to better quality decision-making, greater innovation and better understanding of the needs of a wide range of stakeholders. In practice, however, empirical results are mixed. Some studies show a positive effect of gender diversity on financial performance, while others show no significant relationship or even a negative effect.

The article is structured as follows. Chapter 2 conducts a literature review of research on gender diversity in corporate governance. Chapter 3 describes the methodology of the study, including data sources and analysis methods. Next, the results of the analysis are presented, including trend analysis, sector analysis and the results of correlation analysis. Finally, the results of the study are discussed, pointing out practical implications and directions for future research.

Literature review

Gender diversity on corporate boards and management is a topic gaining more attention in both academic research and corporate governance practice. Increasing women's participation in decision-making bodies is considered a way to improve the quality of decision-making and increase innovation, which can ultimately translate into better financial performance of companies. This literature review will present key research findings on the impact of gender diversity on corporate financial

performance, including those indicating positive and those indicating neutral or negative effects.

There is ample evidence in the literature that gender diversity on boards of directors can have a positive impact on company financial performance. A study by Amin et al. [2021] on a sample of publicly traded Pakistani firms found that the presence of women on boards is associated with higher financial performance indicators, such as return on assets (ROA) and return on equity (ROE). These results suggest that greater diversity on boards can lead to a better use of company resources and better decision-making.

Similar results were obtained in a study by Gordini and Rancati [2017], which was conducted on Italian listed companies. These researchers noted that gender diversity, as measured by the percentage of women on boards of directors, has a positive impact on the market value of companies, as measured by the Q-Tobin index. Investors may perceive companies with more diverse boards of directors as more innovative and better equipped to deal with market challenges, contributing to a higher market valuation.

Although many studies suggest a positive effect of gender diversity on financial performance, some studies indicate that there is no significant relationship between these variables. For example, Rose [2007] in a study of Danish listed companies found no significant relationship between women's participation on boards and financial performance as measured by the Q-Tobin index. The study authors suggest that this may be due to the socialisation process of minorities on boards, where women may align their decisions with the dominant organisational culture, limiting the potential benefits of diversity.

Also, Campbell and Mínguez-Vera's [2008] research in Spain indicates a differential impact of gender diversity on company performance. The authors found that the presence of women on boards does not in itself directly lead to higher firm value, but that greater gender diversity, as measured by the Blau and Shannon indices, has a positive impact on financial performance. This indicates the need to consider not only the presence of women, but also the degree of diversity as an important factor influencing management effectiveness.

The impact of regulations on gender diversity on boards of directors and supervisory boards has been the subject of much research. The introduction of gender quotas in some countries has had a significant impact on increasing women's participation in decision-making bodies. The research by Vafaei, Ahmed and Mather [2015] on the 500 largest listed companies in Australia shows that after the introduction of new ASX regulations in 2010, gender diversity on boards increased significantly.

What's more, the research indicates that companies with greater gender diversity performed better financially, suggesting that regulation can support corporate growth by promoting more diverse and better performing boards.

The introduction of regulations has also had a significant impact on gender diversity in Europe. The research by Ahern and Dittmar [2012] on Norway, which was one of the first countries to introduce gender quotas, shows that initially the introduction of quotas had a negative impact on companies' financial performance, which may have been due to a rapid pace of changes in the board composition.

The impact of gender diversity on company financial performance may vary depending on the sector in which the company operates. A study by Liu, Wei and Xie [2014] of a sample of Chinese companies indicates that gender diversity has a more positive impact on financial performance in sectors that require more innovation and creativity, such as information and communications technology. In sectors where innovation is a key success factor, diversity on boards of directors can lead to better use of diverse skills and perspectives, resulting in higher operational efficiency.

Adams and Funk [2012] found in their study of European companies that gender diversity has a stronger impact on the financial performance of companies in sectors that are characterised by intense competition and a rapid pace of technological change. In sectors such as heavy industry or finance, the impact of gender diversity on financial performance may be less pronounced, possibly due to more traditional management structures and less organisational flexibility.

The literature suggests that gender diversity on boards can contribute to management effectiveness through diversity of perspectives, leadership styles and decision-making skills. The research by Adams and Ferreira [2009] indicates that women on boards often take a different approach to management and oversight, which can contribute to more meticulous monitoring of board decisions and to improving the effectiveness of strategic decisions made. In addition, gender diversity can increase the creativity and innovation of management teams, which is particularly important in rapidly changing market environments.

Other studies such as that of Nielsen and Huse [2010] highlight the importance of gender diversity in terms of making more sustainable decisions. Women on boards of directors can contribute to greater consideration of social and environmental aspects in business decisions, which in the long run can contribute to the sustainability of companies and increase their market value.

Despite numerous studies confirming a positive impact of gender diversity on the financial performance of companies, there are also studies that do not unequivocally confirm this relationship. This may be due to a variety of research methodolo-

gies, the peculiarities of research samples and the cultural and regulatory context in which the studied companies operate. It is also worth noting the possibility of a reverse causality effect, where companies with better financial performance may be more inclined to implement policies that promote gender diversity, which may affect the results of empirical studies.

Research work has also been done on the companies listed on the Warsaw Stock Exchange (WSE). The research conducted by Aluchna et al. [2017] covers a seven-year period (2008–2014) and indicates that the share of women on supervisory boards in companies listed on the WSE remains stable at 10–11%. However, it is worth noting that women are present on at least half of the supervisory boards. In particular, the presence of women on supervisory boards shows a correlation with the Treasury's share of ownership, while no such correlation exists for other types of shareholders.

Another study, conducted by Blaszczyk [2021], examined the impact of the presence of women on the health of companies over the period 2010–2019. Measures of the percentage of women on boards of directors and supervisory boards were used, which made it possible to analyse the impact of this presence on the financial performance of companies. Blaszczyk [2020], on the other hand, continued his research on the impact of women's presence on the statutory bodies of public companies on their financial performance. In this case, more sophisticated analyses were used, such as correlation and regression analysis. This research aimed not only to assess the impact of women on the financial health of companies, but also to create taxonomic measures reflecting these results.

Dobija, Arena, Kozłowski, Krasodomska and Godawska [2023] analysed the international orientation of directors and its impact on the scope of non-financial disclosures in company supervisory structures. They used a sample of 98 companies from the period 2014–2018, which allowed for an analysis which showed that diversity, including the presence of women, has a significant impact on increasing the scope of non-financial disclosures. Marciniak's [2023] research indicates a lack of sophistication in sustainability, despite the increasing participation of women on the boards of listed companies. The analysis showed that women mainly serve in advisory roles, and their role as managers is still marginal.

Słomka-Gołębiowska [2018] identified the determinants of women's presence on the boards of listed companies, using the non-parametric Kruskal-Wallis test. The study included all companies listed on the WSE between 2012 and 2014, which allowed for a detailed analysis of the impact of ownership structure on the presence of women on management and supervisory boards.

The analysis carried out in this chapter represents a significant expansion and update of the research conducted so far. First of all, the data were obtained from the National Court Register, which is a reliable source of data on the composition of boards supervisory and management boards of companies. In addition, the analysis is carried out on a full database of companies listed on the WSE over a fairly long-time horizon.

The consideration of impact of gender diversity on boards and management on corporate financial performance reveals the complexity of the issue. While many studies point to positive effects of diversity, there are also findings suggesting no significant relationship or even negative effects. A key factor appears to be the context in which the company operates, including sector, regulatory and cultural specificities. Thus, further research is needed to better understand under what gender diversity can contribute to improve corporate financial performance and how best to implement policies that promote diversity in corporate management.

Methodology

Description of the database and data collection

The survey covered 370 Polish listed companies listed on the Main Market of the Warsaw Stock Exchange as of 22/04/2024. The source of the financial data was the Refinitiv service, while the structure of the personal composition of the company bodies and their changes – the National Court Register.

The Refinitiv service contains data on public and non-public companies, including data from financial statements, both consolidated and unconsolidated. Consolidated financial data are used in the study. The National Court Register (KRS) is a public register, maintained by Polish registration courts, which contains data on companies, NGOs, associations and other entities. The study used information from full copies of the KRS, which is a detailed document showing the current and past legal status of an entity registered with the KRS, including information about its shareholders, members of the management and supervisory boards, share capital and any changes that have taken place in the history of the entity. Data from the KRS of the surveyed companies are entered on an ongoing basis and updated in real time, allowing access to complete KRS copies at any time. Information on the period and composition of public companies' governing bodies is practically available on a minute-by-minute basis, ensuring its continuous relevance.

Data downloading and processing were carried out in several stages. In the first stage, all full KRS copies were downloaded for the entire set of companies under study, a total of 370. In the second stage, a list of persons holding positions in the companies was created. Using scripts in R language, information on members of supervisory and management boards (name and surname, PESEL (Universal Electronic System for the Registration of Population), company) was extracted, along with information on when the function began and finished. Then, based on data from the PESEL name database, gender was assigned to the person. At the end of this step, a summary of data on persons serving on company boards was created, along with information on the periods the person held the function. The compilation contained information on 14,916 people. In the third stage, a list of companies was created with the number and gender structure of supervisory boards and management boards in the annual interval for the period 2010–2022. Finally, the period of analysis was narrowed down to 2010–2022. The list of public companies contains 370 records, along with information on the number of women and men on supervisory and management boards. This dataset was finally subjected to detailed statistical analysis.

It should be emphasised that the designed survey from the source of information (the National Court Register) on the composition of company bodies is the most up-to-date accurate and complete study of the subject and time structure of supervisory and management boards of listed companies compared to surveys or studies based on paid services or services collecting information from various sources.

In order to carry out the necessary analysis of financial data, information on total assets, net sales revenue and equity was downloaded from Refinitiv for the companies under study. The data were downloaded as of 10.10.2024.

Methods of analysis

The collected data were subjected to quantitative analysis. First of all, an attempt was made to answer the question about the state of gender diversity in supervisory and management boards of companies. Simple descriptive statistics were used for this purpose. Particular attention was paid to differences in women's participation in various sectors.

Next, an assessment was made of whether the current state is the result of long- and medium-term trends. To this end, an analysis of changes in indicators over time was carried out using statistical and econometric methods.

A key element of the analysis is an attempt to answer the question of the relationship between gender diversity in the company authorities and its financial

performance. To this end, a correlation analysis was performed between the share of women in the company authorities and basic financial variables. It is worth mentioning that the study does not aim to analyse the casual relationship between the above phenomena. On one hand, the correlation between women's participation in the company authorities could suggest a positive or negative influence of managers of one gender on the company's financial performance. On the other hand, however, the relation could be the opposite: in companies which are doing well there is a lot of competition to lead them which is not characteristic of financially troubled companies. Also, those companies have greater resources to fund CSR campaigns to promote gender equality in the workplace. Thus, the following analysis should be treated as a description of the current phenomenon rather than an attempt to explain its cause.

In addition, a sectoral analysis was performed to try to answer the question of what effect women's participation in company bodies might have on sector affiliation, size, capital intensity or financing structure.

Results

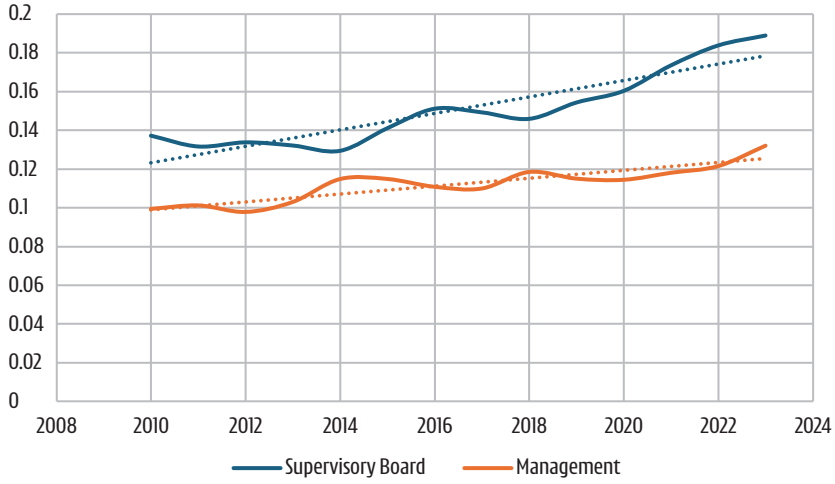
Trend analysis

First, it was examined how the share of women on supervisory and management boards changes over years. Figure 6 shows the shares of women on these bodies from 2010–23.

Unambiguously, one can observe that the shares of women on both boards are significantly lower than 50%. In the case of supervisory boards, the share was between 12% and 19%, in the case of boards of directors between 10% and 13%. It is also significant that for supervisory boards the ratio is significantly higher than for boards of directors (the t-statistic for equality of shares in the sample is 6.67, *p*-value less than 0.01).

Although the share of women is well below gender parity, there is an upward trend in the years studied. For both authorities, there is an improvement in women's shares, as shown by the trend regression lines (in both cases, the coefficient on the time variable is statistically significant for any real level of significance). However, this does not imply a drastic improvement over time. According to the calculated coefficients, with the assumed linear trend, the share of women would level off to 50% in 73 years, and for boards in 181 years. Of course, these figures are a description of the weakness of the trend rather than a forecast of future developments.

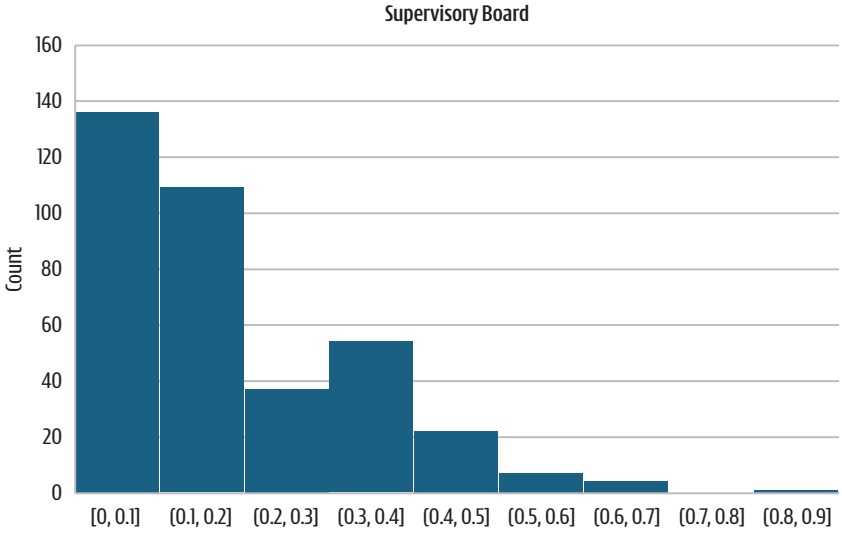
Figure 6. Participation of women in supervisory and management boards of companies in 2010–2023

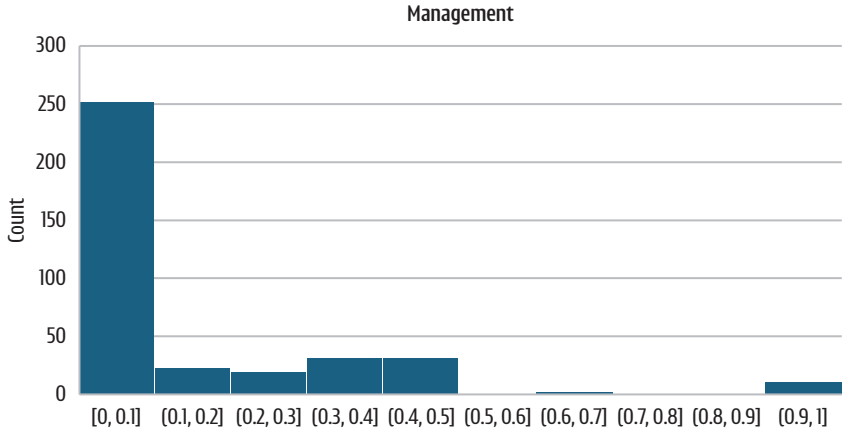


Note: The dashed line shows the trend line determined by linear regression.
Source: Authors' own work.

When we analyse the shares of individual entities in the selected year (we chose to analyse the most recent data), we observe a large share of companies that do not have women on their management bodies (see Figure 7).

Figure 7. Distribution of women's representation on boards of directors and supervisory boards at the end of 2023





Source: Authors' own work.

This is particularly evident in boards of directors where more than two thirds of the companies do not have any women on the board. In contrast, the share of maximally masculinised boards is relatively smaller (about half), so the average described above is also higher.

Sectoral analysis

A sectoral analysis of women's participation in supervisory boards and management boards of listed companies was conducted on the basis of a three-digit sector classification developed and used by the Warsaw Stock Exchange. Data aggregation was carried out at the level of the first and first two digits of the above classification.[1] In order to distinguish the degree of aggregation of sectors, the sectors extracted at a higher level of aggregation in the text were defined as "meta-sectors", while those at a more detailed level of aggregation as "sectors". The analysis was conducted for Polish listed companies listed on the WSE Main Market as of the end of 2023. The period covered by the analysis includes annual data from 2010 to 2022.

Classification at the level of the first digit made it possible to classify 370 companies into all 8 meta-sectors, and at the level of the first two digits into 41 of the 49 sectors (see Table 9).

At the higher aggregation level, the numerically dominant meta-sectors were industrial production and construction and assembly, respectively, with one in four

1 Sectoral classification can be obtained at GPW [2024].

companies categorised in this sector (91 companies). In contrast, one in five companies was broadly finance (76), while one in six was trade and services (56).

Table 9. Structure of meta-sectors of Polish companies listed on the WSE at the end of 2023

Meta-sector	Count
1) Finances	76
2) Fuels and energy	15
3) Chemistry and raw materials	25
4) Industrial and construction production	91
5) Consumer goods	39
6) Trade and services	56
7) Health care	30
8) Technologies	38
Total	370

Source: Authors' own work.

The largest number of positions between 2010 and 2022 in corporate bodies were filled in the largest sectors. In the industrial production and construction and assembly meta-sector, an average of 749 positions were filled in control and management bodies, including 490 in councils and 258 in boards. In the financial meta-sector, 685 and, respectively, 443 in councils and 242 in boards. The fewest positions in this regard were filled in the fuel and energy meta-sector (147: Supervisory Board – 97, Management Board – 50) and health care (188: Supervisory Board – 127, Management Board – 61).

In the meta-sectors studied, the shares of women on supervisory boards were lower than on management boards (see Table 10), although in the financial meta-sector the difference was small. On average, the feminisation ratio in financial company boards was 14.4%, while in management boards it was 13.8%. High ratios could also be observed on the boards of companies in the fuel and energy meta-sector (19.5%), health care (16.8%) and consumer goods (15.8%). In the chemical and raw materials meta-sector as well as industrial production and construction and assembly, the lowest proportions of women on boards were observed (7.1% and 9.2%).

The variability of the feminisation coefficients over the study period for the meta-sectors analysed was relatively low. In the finance and chemical meta-sectors, more volatility was observed in boards than in the other meta-sectors. At the same time, the volatility on the boards of financial companies was relatively low, while

in chemical companies it was much higher. A large disparity in volatility was characterised by the health care meta-sector, where the volatility of the share of women on boards was quite low, while on boards it was very high. In the case of consumer goods companies, the volatility of women's participation in both bodies was at a low and stable level.

Table 10. Structure of meta-sectors of Polish companies listed on the WSE at the end of 2023 (in %)

Sector	Supervisory Board						Management Board					
	min	Q1	median	Q3	max	mean	min	Q1	median	Q3	max	mean
1) Finances	9.4	10.3	14.3	17.2	20.4	14.4	11.4	12.7	13.6	14.1	17.8	13.8
2) Fuels and energy	11.8	17.5	19.6	21.2	25.5	19.5	8.2	11.9	13.5	15.9	16.3	13.6
3) Chemistry and raw materials	9.2	12.9	14.9	15.6	22.4	15.1	3.9	6.6	6.7	8.3	10.1	7.1
4) Industrial and construction production	11.9	13.4	13.9	15.0	17.1	14.0	6.7	8.1	9.0	10.3	11.2	9.2
5) Consumer goods	14.4	15.1	15.4	16.2	19.2	15.8	10.7	11.2	12.1	13.3	14.8	12.3
6) Trade and services	11.9	13.0	14.4	15.7	16.7	14.2	8.7	9.4	10.4	12.0	13.4	10.9
7) Health care	13.2	15.5	17.2	18.3	21.5	16.8	6.7	9.4	11.8	12.9	16.7	11.8
8) Technologies	10.3	11.8	15.1	15.9	18.2	14.3	7.8	8.8	10.1	11.4	11.8	10.1

Source: Authors' own work.

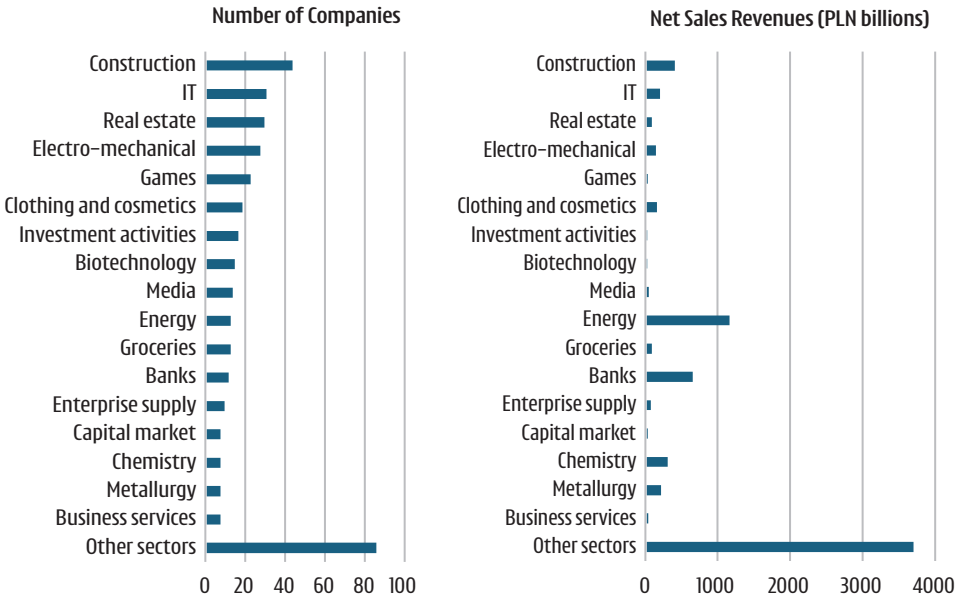
At a more detailed aggregation level (the WSE two-character sector code), the numerically dominant sectors were: construction (43), information technology (30), real estate (29), electrical machinery (27) and gaming (22). The largest sectors, in turn, as measured by the size of average net sales revenues for the 2010–2022 period, were energy (PLN 1,144 billion), banking (PLN 632 billion), construction (PLN 389 billion), chemicals (PLN 291 billion) and steel (PLN 194 billion).

The analysis of data on the average share of women on the supervisory boards and management boards of listed companies in Poland indicates significant differences between sectors. Sectors with the highest average shares of women on boards during the period under review included insurance 27.4%, telecommunications 26.9%, and receivables 26.1% (see Table 11). At the same time, there were sectors where not a single woman served on a board (e.g. rubber and plastics manufacturing, wholesale trade and drug distribution). In the case of supervisory boards, the proportion of women was mostly higher than on boards of directors.

Sectors with the highest average shares of women 2010–2022 on company boards included drug distribution 56.8%, rubber and plastics manufacturing 41.3% or insurance 27.8% (see Table 12). The lowest percentage of women was observed

in the wood and paper manufacturing sector 5.5%, the capital market 3.8% and the sector focusing on retail chains 3.6%. At the same time, there were sectors where the percentage of women on boards was higher than on councils (e.g. business services, telecommunications, receivables).

Figure 8. Sector structure of Polish companies listed on the WSE at the end of 2023



Source: Authors' own work.

Table 11. Average share of women on the boards of listed companies by sector from 2010 to 2022

Sector	Code	Min (in %)	Q1 (in %)	Median (in %)	Q3 (in %)	Max (in %)	Mean (in %)	Count
Drug distribution	74	37.5	50.0	60.0	60.0	66.7	56.8	1
Rubber and plastics	35	20.0	20.0	40.0	60.0	60.0	41.3	2
Insurance	12	20.0	26.1	28.6	30.4	35.3	27.8	3
Fuels and gas	21	11.1	17.6	25.0	33.3	38.1	25.5	3
Hospitals and clinics	71	16.7	18.2	20.0	30.0	40.0	24.8	2
Enterprise supply	44	20.0	23.4	25.0	26.5	31.3	24.6	9
Wholesale trade	61	12.5	20.8	21.7	25.0	35.0	21.9	4
New technologies	83	13.3	15.2	22.2	29.4	36.4	21.4	6
Remaining health care	79	0.0	0.0	20.0	29.2	40.0	19.6	1
Energy	22	11.9	16.7	17.9	20.5	22.1	18.1	12

cont. Table 11

Sector	Code	Min (in %)	Q1 (in %)	Median (in %)	Q3 (in %)	Max (in %)	Mean (in %)	Count
Recycling	37	6.7	12.5	20.0	26.7	28.6	17.9	3
Banks	11	6.5	15.2	16.3	20.2	30.6	17.8	11
Medical equipment and supplies	72	5.6	14.3	17.9	19.4	25.0	17.8	6
Financial intermediation	17	10.0	10.0	10.0	20.0	40.0	17.7	2
Clothing and cosmetics	52	14.8	16.5	17.3	17.8	20.2	17.2	18
Investment activities	18	7.2	9.8	18.6	23.2	25.0	17.0	16
Home furnishing	53	0.0	11.8	12.5	26.7	26.7	16.3	3
Media	64	11.3	15.3	16.7	17.8	20.3	16.2	13
Groceries	51	10.8	15.2	16.2	17.6	23.4	16.1	12
Recreation and leisure	63	7.4	12.0	13.8	20.0	25.0	15.7	6
Other sectors		10.1	11.2	11.9	12.4	15.8	12.3	237

Source: Authors' own work.

Table 12. Average share of women on the management boards of listed companies by sector in 2010–2022

Sector	Code	Min (in %)	Q1 (in %)	Median (in %)	Q3 (in %)	Max (in %)	Mean (in %)	Count
Insurance	12	9.1	25.0	30.0	30.8	33.3	27.4	3
Telecommunications	81	9.1	11.1	33.3	35.7	35.7	26.9	2
Claims	16	22.2	23.8	26.3	27.8	31.3	26.1	6
Business services	45	16.7	19.0	23.1	25.0	31.6	22.4	7
Media	64	9.7	15.2	17.6	23.1	27.0	18.8	13
Wood and paper	36	10.0	14.3	20.0	20.0	25.0	18.2	3
Leasing and factoring	15	0.0	0.0	0.0	50.0	50.0	17.1	1
Medical equipment and supplies	72	8.3	14.3	15.4	18.8	21.4	16.2	6
Recreation and leisure	63	10.5	13.3	16.7	20.0	21.4	16.1	6
Fuels and gas	21	0.0	14.3	16.7	18.2	22.2	15.8	3
Banks	11	9.9	14.3	15.3	17.3	20.5	15.2	11
Drug manufacturing	73	8.3	11.8	15.4	17.6	18.8	14.9	6
Recycling	37	11.1	12.5	14.3	16.7	20.0	14.6	3
Groceries	51	6.7	9.7	12.9	20.0	21.2	14.3	12
Energy	22	5.6	10.5	13.5	15.2	18.2	13.0	12
E-commerce	66	0.0	7.1	12.5	20.0	28.6	12.9	4
Clothing and cosmetics	52	5.0	7.5	15.4	17.1	22.2	12.9	18

Sector	Code	Min (in %)	Q1 (in %)	Median (in %)	Q3 (in %)	Max (in %)	Mean (in %)	Count
Real estate	14	7.1	10.3	11.9	13.9	19.5	12.3	29
Hospitals and clinics	71	0.0	0.0	12.5	20.0	33.3	11.7	2
Capital market	13	3.1	6.7	13.0	14.8	15.4	10.6	8
Other sectors		6.1	6.9	7.4	7.7	8.4	7.4	215

Source: Authors' own work.

In the studied set of sectors, there are also some characterised by a high stability of women's participation in company bodies and a relatively high proportion of them. Such sectors include insurance, oil and gas and telecommunications. At the same time, the share of women in the construction, electrical machinery or transportation and logistics sectors is stable, with low levels of feminisation of bodies. In the sectors of financial intermediation, mining or e-commerce, there are highly variable shares of women in organs with low participation during the period under review.

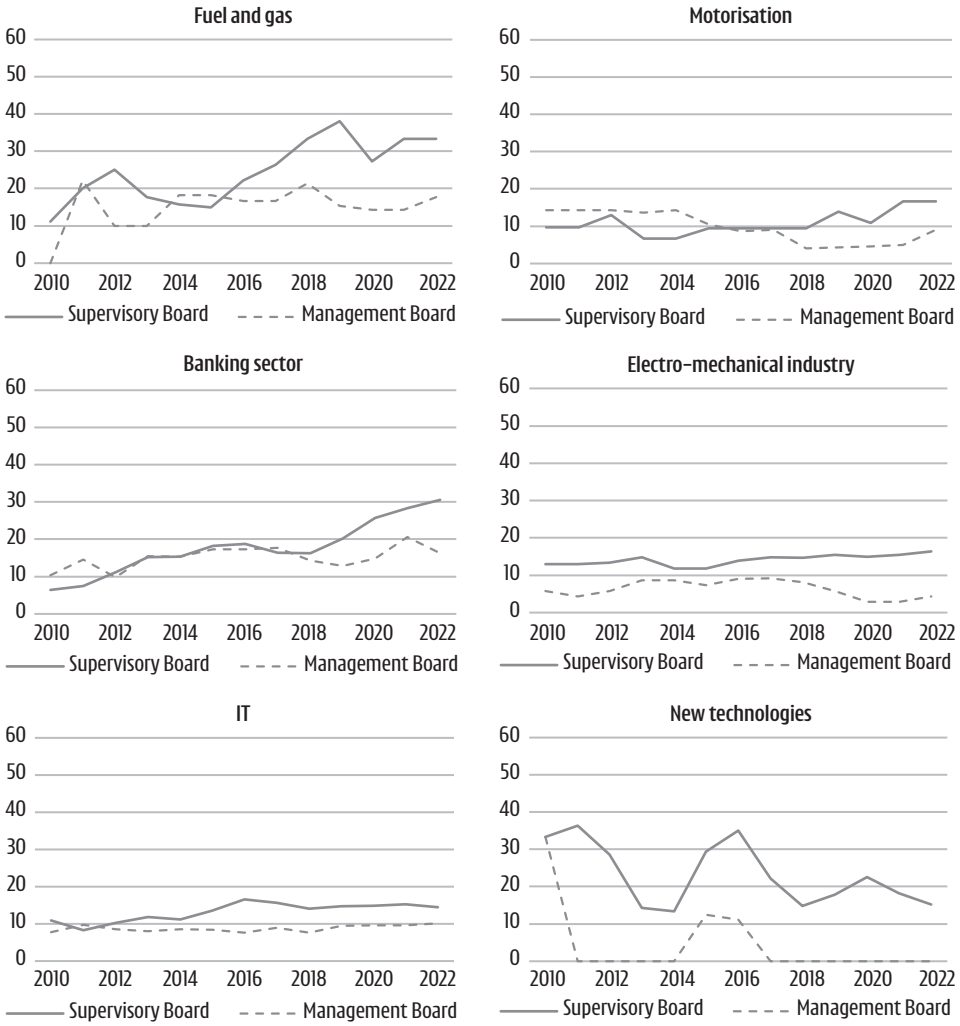
In ten largest sectors by number, the range for the average percentage of women on boards between 2010 and 2022 was from 12.3% to 18.1%, with a parallel range for boards of directors of 4.6% to 18.8%. A total of 20 of the 41 sectors surveyed were concentrated in this defined area.

Feminisation rates in selected sectors

The fuel and gas production sector in terms of revenue was the largest sector surveyed (see Figure 9). The average revenue share of all sectors was 22.5%, and the sector was made up of three companies. The share of women on supervisory boards rose steadily from 11.1% to 33.3% between 2010 and 2022, while on the board of directors was relatively stable. In 2010, it was 0.0%, while in the 2011–2022 period it changed from 22.2% to 17.6%. In the automotive sector (2.1% share, six companies) the share of women in the company management at the beginning of the period under review was higher than on supervisory boards (14.3%, 9.7% respectively) and this structure reversed after 2017. In 2022, the feminisation rate on supervisory boards increased relative to the beginning of the study period to 16.7% and was higher than in management boards, which in turn fell to 9.1%. The banking sector (9%, 11 companies) saw a significant increase in the percentage of women on boards from 6.5% in 2010 to 30.6% in 2022. Significant fluctuations were seen in the management, but also an overall increase from 10.3% to 16.2%. The increase in the feminisation ratio in the banking sector is particularly important given the size of the

sector and its importance to the economy. A similar significant increase could be seen in the real estate sector (1.0%, 21 companies). The rates for supervisory boards rose from 7% in 2010 to 19% in 2022. For the management, it also grew, especially after 2015, reaching 19.5% in 2022.

Figure 9. Women's participation in the boards of listed companies of selected sectors in the period 2010–2022



Source: Authors' own work.

The electrical machinery sector was one of the largest sectors surveyed (1.76%, 27 companies). The share of women on supervisory boards was stable, rising from

13.0% to 16.4%, while the share of women on management boards was very low, falling from 5.8% to 4.3%. In the IT sector, the situation was similar, while in the sector competing at the level of the innovation chain to the previous two: the new technology sector (0.03%, six companies), there was a frequent lack of it.

Results of the correlation analysis of women's shares in the boards and the level of capital intensity and debt structure of the sectors

The analysis was performed at the level of sectors (the two-character classification of the WSE) and examined the correlation between the shares of women in the bodies of listed companies and the capital intensity and debt structure of the sectors. The capital intensity of the sectors was measured by the ratio of total assets / net sales revenue (A/S), while the debt structure was measured by the ratio of liabilities / equity (D/E). The average values of the above ratios for the studied sectors are presented in Table 13. Visual analysis showed that a linear relationship between the percentage of women and the studied variables could be found only in the pair of variables: percentage of women on boards of directors – debt structure. No clear linear relationship was found in the other pairs. For this reason, where there was no clear linear relationship between the variables, an analysis using the Spearman correlation coefficient was applied, and where a linear relationship could occur, the Pearson linear correlation coefficient was used. The correlation analysis carried out showed, first, that there is no significant correlation between the proportion of women in the bodies and the capital intensity of the sectors. Second, there is no statistically significant correlation between the share of women on boards and the level of debt. There is, however, a statistically significant correlation at the 0.05 level between the share of women on boards and the level of sector debt. The value of the correlation coefficient in this case was $r = 0.42$, indicating a moderate positive correlation, with p-value = 0.0062. confidence interval (0.13, 0.64). The analysis is summarised in Table 13.

Table 13. Average levels of capital intensity (A/S) and debt (D/E) ratios of sectors and participation of women in supervisory and management bodies of listed companies in 2010–2022

Sector	Code	D/E	A/S	Mean share Sup. Board (in %)	Mean share Management (in %)
Construction	41	3.22	0.07	12.8	8.7
IT	82	1.09	0.10	13.3	8.8
Real estate	14	1.12	0.38	12.3	12.3

cont. Table 13

Sector	Code	D/E	A/S	Mean share Sup. Board (in %)	Mean share Management (in %)
Electromechanical industry	42	0.92	0.09	14.1	6.3
Games	65	0.26	0.13	14.3	4.6
Clothing and cosmetics	52	1.55	0.07	17.2	12.9
Investment activities	18	1.02	0.20	17.0	6.2
Biotechnology	75	0.58	0.20	12.3	9.5
Media	64	0.72	0.12	16.2	18.8
Energy	22	0.84	0.14	18.1	13.0
Groceries	51	1.00	0.06	16.1	14.3
Banks	11	8.60	1.88	17.8	15.2
Business supplies	44	1.46	0.04	24.6	10.3
Capital market	13	1.00	0.22	3.8	10.6
Chemistry	31	1.10	0.09	15.7	4.9
Metallurgy	33	1.14	0.06	10.8	5.5
Services for business	45	3.93	0.05	9.4	22.4
Other sectors (n = 24)		2.46	0.12	16.2	12.9

Source: Authors' own work.

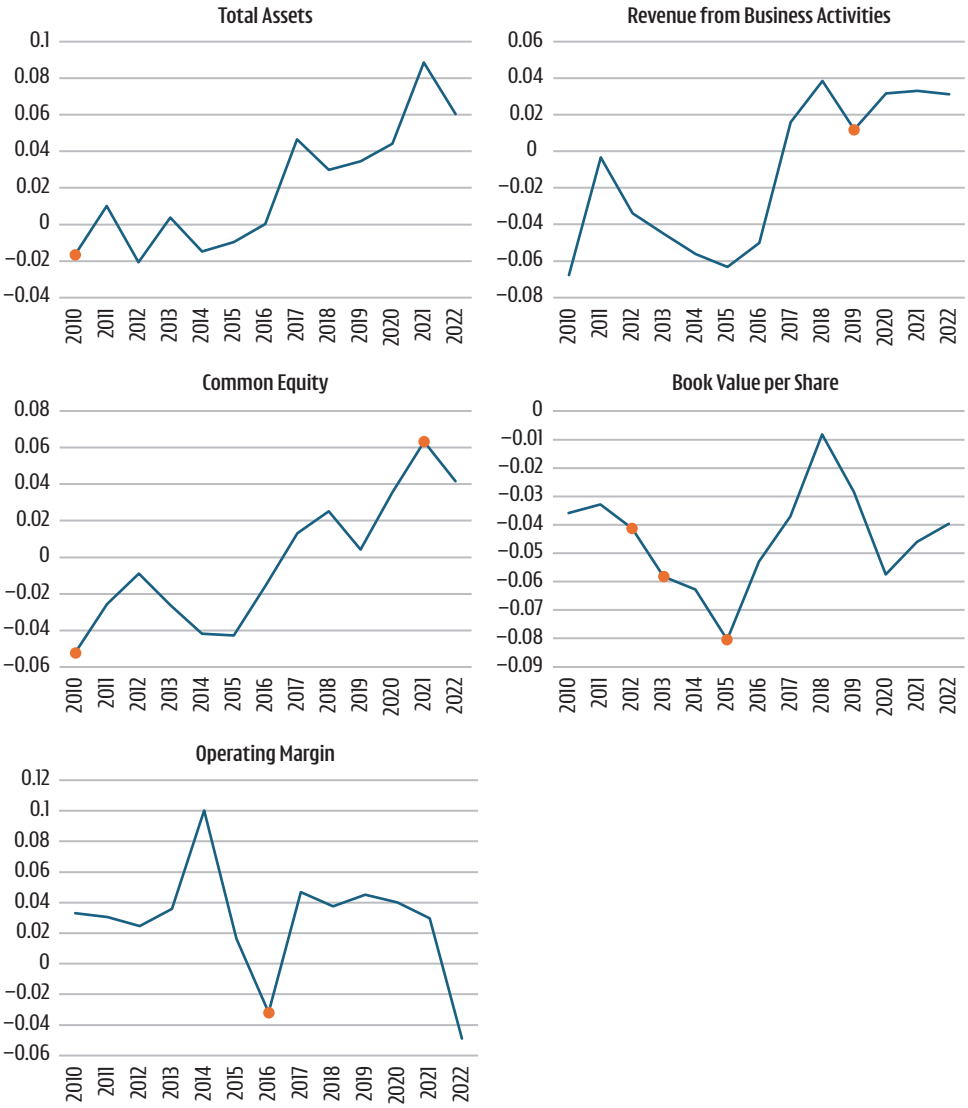
Gender diversity and the financial performance of companies

In further analysis, it was decided to examine how the share of women on the management and supervisory boards of companies listed on the WSE in 2010–2022 correlated with their financial performance. It was decided to analyse the correlation until the end of 2022 due to the lack of availability of financial data in 2023. For this purpose, the annual financial results of the companies in the given years were downloaded, in particular, regarding:

- asset heights,
- sales revenue,
- primary capital volumes,
- book value of shares,
- operating margin.

The above indicators are the basic quantities describing the situation and condition of the company. On the one hand, they inform about its size and scale of operations (the amount of assets, revenue or capital) on the other hand, about its financial quality (share value, operating margin).

Figure 10. Correlation graph between women's participation on corporate boards and financial performance



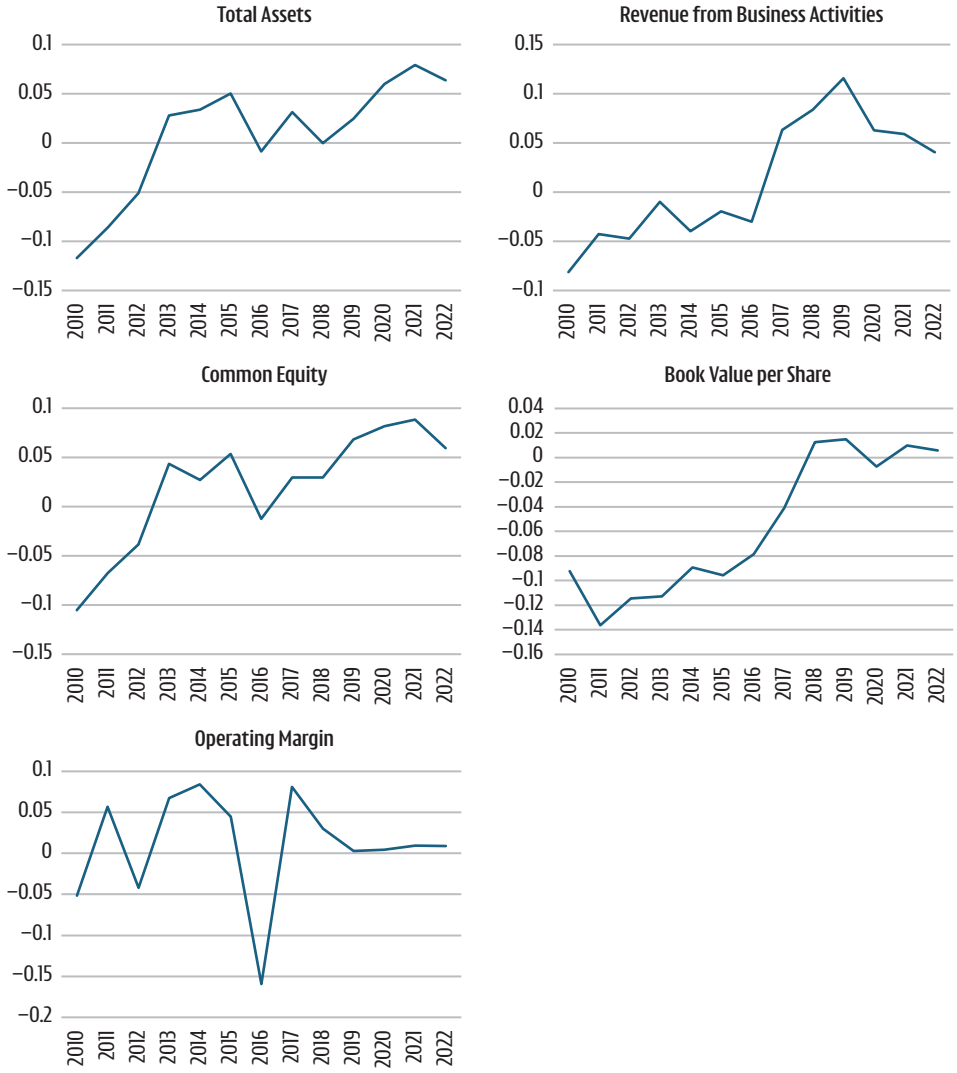
Note: Orange dots indicate statistically significant correlations (for a significance level of 0.05).
Source: Authors' own work.

For these indicators, a correlation coefficient was determined with the share of women on management and supervisory boards separately. Due to highly probable changes in economic values over time, it was decided to determine correlation coefficients for each year separately. As mentioned earlier, the study included all companies

listed on the WSE in a given year. Thus, for each financial indicator, we obtain 14 correlation values with the share of women, separately for each year of analysis.

The results of the correlation analysis are presented graphically in the charts below. The graphs show the value of the correlation index, varying over time, along with highlighting statistically significant correlation values.

Figure 11. Correlation graph between the share of women on the supervisory boards of companies and financial performanc



Note: Orange dots indicate statistically significant correlations (for a significance level of 0.05).
Source: Authors' own work.

Based on the above results, we can observe very little quantitative relationship between the phenomena studied. In the case of boards of directors, no significant correlation was observed between the share of women on the company board and its financial performance. In the case of supervisory boards, there are historical negative correlations between book value and asset size which could suggest that smaller companies were more likely to appoint women to their boards. In contrast, there are no clear statistical correlations, other than isolated anomalies.

Conclusions

The aim of the study was to expand knowledge of gender diversity in the management and supervisory boards of companies listed on the WSE over recent years. The analysis showed that although gender parity is increasing in company authorities still the share of women is far below 50%. The share is much lower in masculinised industries such as automotive and IT.

The analysis of the relationship between the financial performance of companies and the participation of women in the company governing bodies showed no significant correlation between these variables. This means, on the one hand, the absence of a simple causal relationship in this regard. On the other hand, the analysis gives room for more in-depth research, including the use of more sophisticated methods to study these relationships. It may also be valuable to focus on the analysis of specific companies and the impact of different personnel on changes in their performance and therefore financial results.

REFERENCES

Adams, R.B., Ferreira, D. (2009). Women in the Boardroom and Their Impact on Governance and Performance, *Journal of Financial Economics*, 94(2), pp. 291–309. DOI: 10.1016/j.jfineco.2008.10.007.

Adams, R.B., Funk, P. (2012). Beyond the Glass Ceiling: Does Gender Matter? *Management Science*, 58(2), pp. 219–235. DOI: 10.1287/mnsc.1110.1452.

Ahern, K.R., Dittmar, A.K. (2012). The Changing of the Boards: The Impact on Firm Valuation of Mandated Female Board Representation, *The Quarterly Journal of Economics*, 127(1), pp. 137–197. DOI: 10.1093/qje/qjr049.

Aluchna, M., Krejner-Nowecka, A., Tomczyk, E. (2017). Własność SP a obecność kobiet w radach nadzorczych: Badanie spółek giełdowych notowanych na GPW, *Organization and Management*, 175(1), pp. 103–118.

Amin, A., Ali, R., Rehman, R. ur, Naseem, M.A., Ahmad, M.I. (2021). Female Presence in Corporate Governance, Firm Performance and the Moderating Role of Family Ownership, *Research-Ekonomska Istraživanja*, 35(1), pp. 929–948. DOI: 10.1080/1331677X.2021.1952086.

Błaszczyk, A. (2020). Udział kobiet w organach statutowych a wyniki finansowe spółek publicznych w Polsce, *Współczesne Trendy*, 253.

Błaszczyk, A. (2021). Obecność kobiet w organach statutowych spółek publicznych w Polsce, *Zeszyty Naukowe Polskiego Towarzystwa Ekonomicznego w Zielonej Górze*, 8(15), pp. 117–134.

Campbell, K., Mínguez-Vera, A. (2008). Gender Diversity in the Boardroom and Firm Financial Performance, *Journal of Business Ethics*, 83, pp. 435–451. DOI: 10.1007/s10551-007-9630-y.

Dobija, D., Arena, C., Kozłowski, Ł., Krasodomska, J., Godawska, J. (2023). Towards Sustainable Development: The Role of Directors' International Orientation and Their Diversity for Non-Financial Disclosure, *Corporate Social Responsibility and Environmental Management*, 30(1), pp. 66–90. DOI: 10.1002/csr.2339.

Gordini, N., Rancati, E. (2017). Gender Diversity in the Italian Boardroom and Firm Financial Performance, *Management Research Review*, 40(1), pp. 75–94. DOI: 10.1108/MRR-02-2016-0039.

GPW (2024). Objaśnienia nazw sektorów, https://www.gpw.pl/objasnienia-nazw-sektorow (accessed: 22.03.2024).

Liu, Y., Wei, Z., Xie, F. (2014). Do Women Directors Improve Firm Performance in China? *Journal of Corporate Finance*, 28, pp. 169–184. DOI: 10.1016/j.jcorpfin.2013.11.016.

Marciniak, M. (2023). Sukcesy polskich spółek giełdowych pod kierownictwem kobiet, *Zeszyty Naukowe Wyższej Szkoły Bankowej w Poznaniu*, 100(1). DOI: 10.58683/dnswsb.578.

Nielsen, S., Huse, M. (2010). The Contribution of Women on Boards of Directors: Going beyond the Surface, *Corporate Governance: An International Review*, 18(2), pp. 136–148. DOI: 10.1111/j.1467-8683.2010.00784.x

Rose, C. (2007). Does Female Board Representation Influence Firm Performance? The Danish Evidence, *Corporate Governance: An International Review*, 15(2), pp. 404–413. DOI: 10.1111/j.1467-8683.2007.00570.x.

Słomka-Gołębiowska, A. (2018). Polityka zrównoważonego udziału kobiet i mężczyzn w spółkach w Polsce, *Zarządzanie i Finanse*, 16(2), pp. 217–229.

Vafaei, A., Ahmed, K., Mather, P. (2015). Board Diversity and Financial Performance in The Top 500 Australian Firms, *Australian Accounting Review*, 25(4), pp. 413–427. DOI: 10.1111/auar.12068.

IMPACT OF PATENT RIGHTS ON INDUSTRY COMPETITION – AN OVERVIEW

Jacek Prokop
SGH Warsaw School of Economics, Collegium of World Economy
Department of Business Economics
e-mail: jacek.prokop@sgh.waw.pl

ABSTRACT

The objective of this paper is to provide an overview of research on the impact of patents on competition in a duopolistic market structure. The study discusses incentives of firms with essential patent rights to restrict competition in a duopoly. It makes a comparison between the legal patent-protected environment and the situation of no patent protection given by law. The key aim of the analysis was to determine the contribution of patents to cartel formation. Several different types of duopolistic competition with various assumptions about the cost functions were considered to show that the existence of patent rights helps eliminate the prisoner's dilemma and facilitates cartel agreements. The presented models support the hypothesis that patent rights may have a significant impact on curbing industry competition and leading to market cartelisation.

JEL Classification: L13, L41, O34

Keywords: duopolistic competition, industry cartelisation, patent rights

Introduction

Market competition is an important objective of economic policy, and ensuring its implementation is crucial. Governments attempt to protect free market competition by actively fighting corporate collusion, especially in oligopolistic markets, where a small number of firms dominate. These markets present opportunities for companies to form cartels, which can manipulate prices and output, leading

to monopolistic profits and significant losses for consumers and society. As such, preventing cartel formation is of paramount importance for maintaining a competitive market environment.

A key issue in antitrust enforcement is understanding the stability of cartel agreements. Instability arises when firms realise that breaking the cartel agreement could lead to higher individual profits, often due to the classic prisoner's dilemma.[1] While this instability can disrupt collusion, it does not prevent cartels from forming, e.g. European Commission [2021]. Cartels remain a persistent challenge, despite their inherent instability, often due to the lack of legal enforcement mechanisms and the reliance on non-legal factors to maintain stability.

The literature extensively discusses factors that influence cartel stability [Levenstein, Suslow, 2011; Paha, 2017; Lipczynski, Wilson, Goddard, 2017, pp. 222–233]. However, certain mechanisms, such as the role of patents, remain underexplored. Patents, as exclusive rights to produce certain products, can significantly influence the behaviour of firms within a cartel. This chapter investigates the impact of patents on the stability of cartel agreements, particularly in a duopolistic market where each firm holds a patent essential for supplying the final product.

In highly innovative industries, technologies are protected by many different patents, and no company has a full set of technologies needed to create the final product. Companies are forced to use a competitor's patent rights to bring their product to market.

One example is the smartphone industry where companies like Apple and Samsung (and other manufacturers) operate. There are many key patents in this industry, such as communications (3G, 4G, 5G), displays and processors. Apple is forced to use patents belonging to Qualcomm, Ericsson, and Samsung, especially in mobile technology (e.g. 5G chips). Samsung, in turn, must use Apple's patents related to, for example, the user interface (UI) or design elements. In such a situation, both companies can sign cross-licensing agreements allowing each party to use the competitor's patent rights.

Another example is the electric car industry where Tesla and other manufacturers (e.g. Ford, GM, Toyota) function. Tesla holds many key patents related to battery technology, charging technology, and vehicle management software. Other car manufacturers, like Ford, General Motors, or Toyota, may need to use these patents

[1] Levenstein and Suslow [2006] and Harrington and Wei [2017] noticed that the average longevity of undisruptive cartel functioning is usually not very long exactly because of instability caused by the prisoner's dilemma.

to offer their electric cars. Tesla, in turn, may need to use patents from competitors, such as hydrogen technology from Toyota or advanced hybrid systems.

In the pharmaceutical industry, companies often hold patents for various steps in the drug production process. For example, Pfizer/BioNTech and Moderna are competitors offering mRNA vaccines (COVID-19), but both companies use key patents related to mRNA technology owned by different entities. There is a dispute between Moderna and Pfizer/BioNTech regarding technology ownership; however, they also utilise each other's technology through indirect licences.

The presentation in his chapter is mainly based on the works by Prokop [2021, 2023, 2024]. However, we supplement previous research by considering the case of quadratic cost functions for Cournot and Stackelberg duopoly models.

The chapter is structured as follows. We begin with a review of literature on the factors affecting cartel stability, emphasising the role of patents. Then, we present the basic market setup and discuss the duopolistic competition in the Cournot and Stackelberg models with linear and quadratic cost functions. Each of these models is compared to the case of a cartelised industry with a patent pool and without it. Next, we conduct a similar comparison of competition vs. collusion for a duopoly model characterised by price leadership. Finally, the results of this comparison are discussed, followed by conclusions and suggestions for future research in this area.

Literature review

Discussions surrounding the prisoner's dilemma, which explain why cartels lack internal stability, were traditionally based on a static understanding of how cartel agreements work. However, when oligopolistic competition is analysed from a dynamic perspective, it becomes possible to justify the strong cooperation among firms within a cartel [Church, Ware, 2000, pp. 331–340; Tirole, 1997, pp. 245–247]. The arguments supporting cartel stability, as derived from the super game theory, hold true if the actions of firms in the market are observable. In cases where firms lack complete information about each other's pricing strategies, cartels may experience periodic breakdowns, particularly when demand fluctuations in the market are difficult to immediately identify. Green and Porter [1984] introduced a model to describe such a scenario, where cartel members are unsure if a drop in profits is due to a demand decline or the secret price reduction of one member, which weakens the collusive behaviour [Tirole, 1997, pp. 251–253 and pp. 262–265].

The effects of demand fluctuations on cartel stability were also explored by Rotemberg and Saloner [1986], and Harrington and Skrzypacz [2007]. Their studies revealed that a rise in demand strengthens cooperation between cartel members, while a decrease, or even fluctuating demand, tends to lead to the collapse of cartel agreements.

The number of firms in an industry and their production capacities are significant factors in determining cartel durability. Fewer firms in a market make cartel formation easier and contribute to its sustainability [Pepall et al., 2014, pp. 375–376]. According to Compte et al. [2002] and Vasconelos [2005], companies with larger production capacities are more likely to break cartels, as smaller firms struggle to retaliate. Symmetry in production capacities helps maintain cartel stability, although Prokop [1999] observed that even identical firms can find it challenging to establish stable cartels.

Research on the influence of antitrust policies on cartelisation has mainly focused on government leniency programmes. The studies by Aubert, Kovacic and Rey [2006], Harrington [2008] and Spagnolo [2008] confirmed that such programmes can destabilise cartel arrangements. Harrington [2017] discusses the optimal competition policies in this context.

The debate on how patents impact cartel stability began with Wu [2019], who argued that creating patent pools could help stabilise cartels among final goods producers, with vertical licensing agreements aiding in monitoring compliance. In contrast, Karbowski [2020] introduced a formal model of the relationship between patents and market collusion, suggesting that patents could actually destabilise cartels by allowing firms to avoid retaliation if they leave the cartel.

Market setup

We consider an industry comprised of two firms, denoted *1* and *2*. The firms are assumed to supply a homogenous product to the market characterised by the following inverse demand function of a linear form:

$$p = a - q_1 - q_2, \tag{3}$$

where p denotes the market price, q_i is the level of production supplied by firm i, a is the demand parameter.

It is assumed that the manufacturing of the final product requires the technology composed of two indispensable elements, denoted A and B. These elements are

patented. Firm *1* holds the patent rights to element A, and firm *2* is the owner of patent rights to element B.

The total costs of supplying the product to the market by firm i (C_i) is the sum of manufacturing costs (C_i^m) and the amount of payment for the patent rights held by the other company (C_i^p).

The manufacturing costs of firm i depends on its production level (q_i) and on the parameter of efficiency (c):

$$C_i^m(q_i; c). \tag{4}$$

It is assumed that $c < a$ and no entry to this industry is possible.

In our analysis, we will consider two forms of manufacturing cost functions: a linear one and a quadratic one. The manufacturing cost function of the linear type will be assumed to take the form of:

$$C_i^m(q_i; c) = cq_i. \tag{4a}$$

The quadratic function will be given by the following expression:

$$C_i^m(q_i; c) = \frac{cq_i^2}{2}. \tag{4b}$$

The costs of the patent rights purchased by firm i from firm j are assumed to have a linear form:

$$C_i^p(q_i, w_j) = w_j q_i, \tag{5}$$

where w_j is the unit cost for firm i for the patents owned by firm w_j ($j \neq i$).

We consider a game composed of two phases. In the first phase, both firms trade the patent rights, and in the second phase, they compete in the final product market.

Four possible forms of competition among duopolists will be analysed. In the case of noncooperative decisions of companies, we will review the quantity competition of the Cournot- and Stackelberg-type, as well as the price-leadership scheme. Finally, in the case of cooperative decision-making of firms, we will analyse the feasibility of creating a stable cartel, i.e. the situation in which the companies make joint decisions to maximise their total profit. Each of the noncooperative settings will be compared with the performance of companies in the cartelised industry to assess the stability of cooperative behaviour.

Cournot duopolists with essential patents

In the case of Cournot-type behaviour, the firms compete in the final product market by choosing their level of output in a simultaneous and independent way. Following Prokop [2021], when the manufacturing costs take the linear form given by (4a), the optimal prices charged by each firm for its patent rights are:

$$w_i^* = \frac{5(a-c)}{11}, \tag{6}$$

and the equilibrium market price of the final product offered by the competing firms equals:

$$p^* = \frac{7a+4c}{11}. \tag{7}$$

The profit-maximising supply of firm *i* was found to be:

$$q_i^* = \frac{2(a-c)}{11}, \tag{8}$$

and their equilibrium levels of profit:

$$\pi_i^* = \frac{14}{121}(a-c)^2. \tag{9}$$

When the firms form a cartel, they create a patent pool which enables them to obtain the patent rights from the partner firm free of charge for a production level not exceeding $\frac{a-c}{4}$, and as long as the sales of each firm is nonzero. Otherwise, the firm must pay for the patent rights that belong to the other company at the unit price given by (6).

At the equilibrium each cartel member supplies:

$$\bar{q}_i = \frac{a-c}{4} \tag{10}$$

of the final product at the market price equal to:

$$\bar{p} = \frac{a+c}{2}. \tag{11}$$

Each cartel firm *i* earns profit of

$$\bar{\pi}_i = \frac{(a-c)^2}{8}. \tag{12}$$

From (9) and (12), we see that:

$$\pi_i^* < \bar{\pi}_i,$$

i.e. the profit of a company in the fully cartelised industry is higher than the non-cooperative profit under Cournot competition. Thus, it pays for both firms to form a cartel in the final product market.

Prokop [2021] shows that this cartel is stable as long as the patent rights are fully enforced. However, when the patent rights cannot be guaranteed, the cartel agreement is not stable, i.e. the firms would have significant incentives to deviate from a collusive agreement.

Now, consider the case when the manufacturing costs of Cournot duopolists take the form of a quadratic function given by (4b). Then, each firm would charge a price of:

$$w_i^* = \frac{5+5c+c^2}{11+10c+2c^2}a \tag{13}$$

for its patent rights. The equilibrium market price of the final product offered by the Cournot duopolists equals:

$$p^* = \frac{7+8c+2c^2}{11+10c+2c^2}a. \tag{14}$$

The equilibrium output of company *i* is obtained to be:

$$q_i^* = \frac{2+c}{11+10c+2c^2}a, \tag{15}$$

and its equilibrium profit level:

$$\pi_i^* = \frac{(2+c)(14+14c+3c^2)}{2(11+10c+2c^2)^2}a^2. \tag{16}$$

When firms with the manufacturing costs described by the quadratic function (4b) form a cartel, they create a patent pool which entitles them to freely use the patent rights of the partner company to produce up to $\frac{a-c}{4}$, as long as each firm sells a positive amount. Otherwise, the firm is obliged to pay for the patent rights that belong to the other company at the rate given by (13).

At the equilibrium, each cartel member supplies:

$$\bar{q}_i = \frac{a}{4+c} \tag{17}$$

of the final product at the market price equal to:

$$\bar{p} = \frac{2+c}{4+c}a. \tag{18}$$

Each cartel firm i earns a profit of:

$$\bar{\pi}_i = \frac{a^2}{2(4+c)}. \tag{19}$$

From (16) and (19), we can easily check that:

$$\pi_i^* < \bar{\pi}_i,$$

i.e. the profit of each firm in a cartel is higher than the profit of a Cournot duopolist. Thus, both firms would be interested to form a cartel also in the case of quadratic cost functions in manufacturing.

When there is no patent protection and firm i believes that firm j will stick to the cartel quota by producing $\bar{q}_i = \frac{a}{4+c}$, then the profit function of firm i equals:

$$\pi_i = \left(a - q_i - \bar{q}_j - \frac{cq_i}{2}\right)q_i = \left(a - \frac{a}{4+c} - \frac{2+c}{2}q_i\right)q_i. \tag{20}$$

For firm i, it is optimal to produce:

$$q_i = \frac{3+c}{(2+c)(4+c)}a. \tag{21}$$

It is easy to check that:

$$q_i = \frac{3+c}{(2+c)(4+c)}a > \bar{q}_i = \frac{a}{4+c} \tag{22}$$

and the profit of firm i equals:

$$\pi_i = \frac{(3+c)^2}{2(2+c)(4+c)^2}a^2. \tag{23}$$

Comparing (23) to (19), it is easily seen that:

$$\pi_i > \bar{\pi}_i$$

for all positive values of a and c.

This result proves that in the case of a quadratic cost function, the cartel will not be stable, if patent rights are neglected.

When patent laws are fully enforced, company i by increasing production above the cartel quota will be required to cover the cost of patent for each unit above the quota. Thus, the profit of firm i will be given by:

$$\pi_i = \left(a - q_i - \bar{q}_j - \frac{cq_i}{2}\right)q_i - w_j\left(q_i - \frac{a}{4+c}\right) = \left(a - q_i - \frac{a}{4+c} - \frac{cq_i}{2}\right)q_i - \\ - \frac{5+5c+c^2}{11+10c+2c^2}a\left(q_i - \frac{a}{4+c}\right). \tag{24}$$

The derivative of (24) with respect to q_i is obtained to be:

$$\frac{\partial \pi_i}{\partial q_i} = \frac{a(13+16c+7c^2+c^3)}{(4+c)(11+10c+2c^2)} - (2+c)q_i. \tag{25}$$

It can be seen that for $q_i = \frac{a}{4+c}$, the derivative in (25) is negative for all positive values of a and c. Thus any increase in q_i above $\frac{a}{4+c}$ causes the profit of firm i to decline, and it does not pay for firm $i$to supply more than the cartel quota.

So, also in the case of quadratic cost function and full enforcement of patent rights, we showed that it doesn't pay for the firms to deviate from the collusive agreement.

Stackelberg duopoly with patent rights

Another type of quantity competition among duopolists in the final product market is Stackelberg behaviour, i.e. one of the firms, say firm *1* takes the role of the leader, and firm *2* assumes the role of the follower. The Stackelberg leader is the first to decide about the level of supply, and the follower, after learning that decision, chooses its own output level.

Prokop [2023] demonstrated that under the manufacturing costs taking the linear form given by (4a), the optimal prices charged by each firm for its patent rights are:

$$w_1^* = \frac{a-c}{2}, \tag{26a}$$

$$w_2^* = \frac{a-c}{3}, \tag{26b}$$

and the equilibrium market price of the final product offered by the duopolists equals:

$$p^* = \frac{(2a+c)}{3}. \tag{27}$$

The supply of each firm is:

$$q_1^* = q_2^* = \frac{a-c}{6}, \tag{28}$$

and their profits can be calculated as:

$$\pi_1^* = \frac{5}{36}(a-c)^2, \tag{29a}$$

$$\pi_2^* = \frac{1}{12}(a-c)^2. \tag{29b}$$

Should a cartel be formed in this industry, the situation will be identical to the one described in the previous section for the case of linear costs, i.e. the equilibrium supply of each cartel member, the price of the final product, and the profit of each cartel firm will be given by (10), (11), and (12), respectively.

The comparison of profits under Stackelberg competition given by (29a) and (29b) versus cartel profits of each firm given by (12) shows that:

$$\pi_1^* > \bar{\pi}_1,$$
$$\pi_2^* < \bar{\pi}_2.$$

It means that, on the one hand, the Stackelberg leader prefers the competition rather than the cartel formation, but on the other hand, the Stackelberg follower is better off as a cartel member.

However, once a cartel is formed, Prokop [2023] shows that it would be stable under the enforcement of patent rights. In the case of no patent protection, the stability of cartel agreement cannot be achieved.

Under the manufacturing costs taking the form of a quadratic function given by (4b), the optimal prices charged by each firm for its patent rights are:

$$w_1^* = \frac{a}{2}, \tag{30a}$$

$$w_2^* = \frac{4 + c(2+c)(7+2c)}{2(2+c)(3+2c(4+c))}a, \tag{30b}$$

and the equilibrium market price of the final product offered by the duopolists equals:

$$p^* = \frac{8 + 27c + 20c^2 + 4c^3}{2(2+c)(3+8c+2c^2)}a. \tag{31}$$

The supply of each firm is:

$$q_1^* = \frac{1+2c}{2(3+8c+2c^2)}a, \tag{32a}$$

$$q_2^* = \frac{1+3c+c^2}{(2+c)(3+8c+2c^2)}a, \tag{32b}$$

and their profits can be calculated as:

$$\pi_1^* = \frac{(20+108c+177c^2+84c^3+12c^4)}{8(2+c)(3+8c+2c^2)^2}a^2, \tag{33a}$$

$$\pi_2^* = \frac{2+6c+3c^2}{4(2+c)(3+8c+2c^2)}a^2. \tag{33b}$$

Should a cartel be formed in this industry, the situation will be identical to the one described in the previous section for the case of quadratic cost function, i.e. the equilibrium supply of each cartel member, the price of the final product, and the profit of each cartel firm will be given by (17), (18), and (19), respectively.

The comparison of profits under Stackelberg competition given by (33a) and (33b) versus cartel profit of each firm given by (19) shows that:

$$\pi_1^* > \bar{\pi}_1 \text{ for } 0 < c \leq 0.862, \text{ and } \pi_1^* < \bar{\pi}_1 \text{ for } c \geq 0.8621$$
$$\pi_2^* < \bar{\pi}_2 \text{ for all } c > 0.$$

It means that, in the case of quadratic cost function, the Stackelberg leader prefers the competition rather than the cartel formation, for $c \leq 0.862$, and is better off as a cartel member for $c \geq 0.8621$.[2] The Stackelberg follower always prefers cartel membership to quantity competition. Thus, both firms would be interested to form a cartel in the case of quadratic cost functions in manufacturing for $c \geq 0.8621$.

We showed in the previous section that in the case of no patent protection, it pays for the firms to break the cartel agreement also for the quadratic cost function.

Now, we consider the stability of a collusive agreement in the case of enforceable patent rights. By increasing production above the cartel quota, firm *1* is responsible for incurring patent royalties for each unit supplied above the quota. Thus, the profit of company *1* is calculated as:

$$\begin{gathered}\pi_1 = \left(a - q_1 - \bar{q}_2 - \frac{cq_1}{2}\right)q_1 - w_2\left(q_1 - \frac{a}{4+c}\right) = \\ \left(a - q_1 - \frac{a}{4+c} - \frac{cq_1}{2}\right)q_1 - \frac{4 + c(2+c)(7+2c)}{2(2+c)(3+2c(4+c))}a\left(q_1 - \frac{a}{4+c}\right).\end{gathered} \tag{34}$$

The derivative of (34) with respect to q_1 is obtained to be:

$$\frac{\partial \pi_1}{\partial q_1} = \frac{20 + c(66 + c(52 + c(17 + 2c)))}{2(2+c)(4+c)(3+2c(4+c))}a - (2+c)q_1. \tag{35}$$

For $q_1 = \frac{a}{4+c}$, the derivative in (35) equals:

$$\left.\frac{\partial \pi_1}{\partial q_1}\right|_{q_1 = \frac{a}{4+c}} = -\frac{(2 + c(4+c))(2 + c(7+2c))}{2(2+c)(4+c)(3+2c(4+c))}a,$$

which is negative for all positive values of a and c. Thus, increasing q_1 above $\frac{a}{4+c}$ reduces the profit of firm *1*, which means that it does not pay for firm *1* to supply more than the cartel quota.

[2] More precisely, the pivotal value of c is numerically evaluated to be 0.862047869648708.

Similarly, firm *2*, by increasing supply above the cartel quota, has to cover the costs of patent rights owned by company *1*. Thus, the profit of firm *2* amounts to:

$$\begin{aligned}\pi_2 &= \left(a - q_2 - \bar{q}_1 - \frac{cq_2}{2}\right)q_2 - w_1\left(q_2 - \frac{a}{4+c}\right) = \\ &= \left(a - q_2 - \frac{a}{4+c} - \frac{cq_2}{2}\right)q_2 - \frac{a}{2}\left(q_2 - \frac{a}{4+c}\right)\end{aligned} \tag{36}$$

The derivative of (36) with respect to q_2 is obtained to be:

$$\frac{\partial \pi_2}{\partial q_2} = \frac{(2+c)(a-2(4+c)q_2)}{2(4+c)}. \tag{37}$$

For $q_2 = \frac{a}{4+c}$, the derivative in (37) equals:

$$\left.\frac{\partial \pi_2}{\partial q_2}\right|_{q_2=\frac{a}{4+c}} = -\frac{a(2+c)}{2(4+c)},$$

which is negative for all positive values of a and c. Thus, also for firm *2*, it is not optimal to supply above the cartel quota.

It should also be noticed that neither of the firms is interested in producing below the cartel quota. Thus, also in the case of quadratic cost function and full enforcement of patent rights, we showed that it does not pay for the firms to deviate from the collusive agreement.

Price leadership under the existence of patent rights

Now, let us consider the price leadership behaviour in the final product market [compare, e.g. Diamantoudi, 2005]. Assume that firm *1* takes the role of the leader and firm *2* is the follower, i.e. firm *1* chooses the price level first, and then firm *2* decides on the size of its production at this price.

When the manufacturing costs take the form of a quadratic function given by (4b), the equilibrium prices of patent rights charged by each firm are:

$$w_1^* = \frac{(3+c)(3+2c)}{27+28c+6c^2}a, \tag{38a}$$

$$w_2^* = \frac{(3+c)(3+2c)+c}{27+28c+6c^2}a, \tag{38b}$$

and the production levels of each firm at the equilibrium point are:

$$q_1^* = \frac{2(3+2c)}{27+28c+6c^2}a, \tag{39a}$$

$$q_2^* = \frac{3+2c}{27+28c+6c^2}a. \tag{39b}$$

The profits of the firms are calculated to be:

$$\pi_1^* = \frac{3(3+c)(3+2c)^2}{(27+28c+6c^2)^2}a^2, \tag{40a}$$

$$\pi_2^* = \frac{162+297c+168c^2+28c^3}{2(27+28c+6c^2)^2}a^2. \tag{40b}$$

The equilibrium price set by firm *1* at which both firms will be selling the final product is:

$$p^* = \frac{2(9+11c+3c^2)}{27+28c+6c^2}a. \tag{41}$$

When the firms decide to enter a cartel agreement, they form a patent pool which entitles them to free patent rights from the cartel partner for a production level not exceeding $\frac{a}{4+c}$ as long as the sales of each firm are positive. Otherwise, the firm must pay the royalties at the unit price of w_j^* given by (38a) and (38b).

Should the firm pursue a collusive agreement within this industry, the equilibrium output for each cartel member will equal:

$$\bar{q}_1 = \bar{q}_2 = \frac{a}{4+c}, \tag{42}$$

and the equilibrium price of the final good will be:

$$\bar{p} = \frac{2+c}{4+c}a. \tag{43}$$

The profit achieved by each cartel participant will be:

$$\bar{\pi}_1 = \bar{\pi}_2 = \frac{a^2}{2(4+c)}. \tag{44}$$

From (40a), (40b) and (44), it can be shown that for any positive parameter c:

$$\pi_1^* < \bar{\pi}_1, \tag{45a}$$

$$\pi_2^* < \bar{\pi}_2, \tag{45b}$$

i.e. both firms will earn a higher profit by being in a cartel rather than competing according to the price-leadership model.

Let us consider the stability of a cartel in the absence of patent rights. Any firm i believing that its competitor sticks to the cartel agreement by producing:

$$\bar{q}_j = \frac{a}{4+c} \tag{46}$$

will maximise the following profit function:

$$\pi_i = \left(a - q_i - \bar{q}_j\right)q_i - \frac{cq_i^2}{2} = \left(a - q_i - \frac{a}{4+c}\right)q_i - \frac{cq_i^2}{2} = \left(\frac{3+c}{4+c}a - \frac{c+2}{2}q_i\right)q_i. \quad (47)$$

From the first-order conditions, we obtain the optimal supply of company *i* to be:

$$q_i = \frac{3+c}{(2+c)(4+c)}a, \quad (48)$$

which is greater than the output of this firm in the cartel given by (42). By substituting (48) into (47), we obtain the profit of firm *i*:

$$\pi_i = \frac{(3+c)^2}{2(2+c)(4+c)^2}a^2, \quad (49)$$

which is larger than this firm's cartel profit given by (44). Thus, firm *i* would prefer to cheat on the cartel agreement.

Now, let us consider a situation where patent rights are present. Rather than sticking to the cartel price, firm *1* may try to undercut by offering a price slightly lower, i.e.:

$$\tilde{p}_1 = \bar{p} - \varepsilon = \frac{2+c}{4+c}a - \varepsilon, \quad (50)$$

where ϵ is a small positive number. In that case, firm *1* takes over the entire demand, i.e.:

$$\tilde{q}_1 \approx \frac{2}{4+c}a, \quad (51)$$

and the demand for the output of firm *2* drops to $\tilde{q}_2 = 0$.

The net profit of firm *1*, after paying the royalties to firm *2*, equals:

$$\begin{aligned}\tilde{\pi}_1 &= (p - w_2^*)\tilde{q}_1 - \frac{c\tilde{q}_1^2}{2} \approx \left(\frac{2+c}{4+c}a - \frac{(3+c)(3+2c)+c}{27+28c+6c^2}a\right)\frac{2}{4+c}a - \frac{4c}{2(4+c)^2}a^2 \\ &= \frac{2(18+7c-6c^2-2c^3)}{(4+c)^2(27+28c+6c^2)}a^2,\end{aligned} \quad (52)$$

which for positive values of *c* is always lower than the cartel profit of firm *1* given by (24). Thus firm *1* will have no interest in leaving the cartel.

In a parallel way, we can show that firm *2* will earn net profit of:

$$\begin{aligned}\tilde{\pi}_2 &= (p - w_1^*)\tilde{q}_2 - \frac{c\tilde{q}_2^2}{2} \approx \left(\frac{2+c}{4+c}a - \frac{(3+c)(3+2c)}{27+28c+6c^2}a\right)\frac{2a}{4+c}a - \frac{4c}{2(4+c)^2}a^2 \\ &= \frac{2(18+11c-5c^2-2c^3)}{(4+c)^2(27+28c+6c^2)}a^2,\end{aligned} \quad (53)$$

which for positive values of *c* is also lower than the cartel profit of that firm given by (44).

Thus, no cartel member would be interested in breaking the cartel agreement when patent rights are in place. However, cartel stability will not be achieved in the absence of patent rights.

Results

The presented analysis provides important insights into the behaviour of firms in a duopoly, especially when patent rights are enforced.

When firms in a Cournot duopoly with linear or quadratic cost functions form a cartel, they experience a higher level of profits compared to noncooperative competition. However, if patent rights are not enforceable, the cartel becomes unstable. This instability arises because firms, in the absence of patent protection, have strong incentives to deviate from the collusive agreement. With patent enforcement, firms have an incentive to stick to the cartel agreement since deviation would result in lower profits due to the added patent costs.

In a Stackelberg competition with linear cost function, when one firm (the leader) decides its output first, and the other firm (the follower) reacts accordingly, the results indicate that the leader prefers the competitive market rather than a cartel. For quadratic cost functions, the Stackelberg leader prefers the cartel when the cost parameter exceeds a certain threshold (approximately 0.862). However, the follower benefits from cartel membership for the linear as well as for the quadratic cost function, as its profit always increases under cooperative behaviour. Nevertheless, the analysis indicates that in the absence of patent enforcement, firms in Stackelberg settings similarly to the Cournot model would have incentives to break the cartel and engage in competitive behaviour.

When patent rights are fully enforced, the cartel remains stable under both the Stackelberg and Cournot duopoly models. Firms are discouraged from deviating from cartel agreements because any increase in production beyond the cartel's prescribed quota incurs additional patent costs, diminishing the incentive to break the agreement.

In a duopoly with price leadership, it is generally beneficial for all firms to join a cartel. The stability of such a cartel is highly contingent upon the presence of patent rights. The analysis points to a critical difference in the operating conditions of firms, where patent rights act as a stabilising force that not only ensures the profitability of cartel membership but also minimises the likelihood of breaking the collusive agreement.

Conclusions

This chapter demonstrates that patent rights can significantly impact market competition, specifically by facilitating the formation and stability of cartels in duopolistic markets. Patent rights create conditions that reduce the incentives for firms to deviate from cartel agreements, increasing their profits through cooperative behaviour. However, the stability of these cartels is contingent on the enforceability of patent rights, as their absence leads to competition and a breakdown of collusive agreements. Thus, patent rights can contribute to industry cartelisation, curbing competition and affecting market outcomes. This insight is particularly valuable for understanding the role of intellectual property in oligopolistic markets and its impact on market structure and competition.

Our analysis suggests that the antitrust authorities should pay specific attention to industries characterised by a set of patents owned by firms manufacturing the final product, because such markets are particularly prone to cartelisation. Moreover, the cartel-stabilising role of patent rights gives another argument against the existence of patent protection laws.[3]

The conclusions obtained in this chapter are obtained within basic models of duopolistic competition with homogenous goods. Clearly, further research is necessary to give the final assessment of the role of patents in cartel stability. The analysis could be extended to more general oligopoly models with heterogenous final products. Among other directions for further considerations, we could focus on various types of licensing agreements between the patent holders for the components of the final good.

REFERENCES

Aubert, C., Kovacic, W., Rey, P. (2006). The Impact of Leniency and Whistle-Blowing Programs on Cartels, *International Journal of Industrial Organization*, 24(6), pp. 1241–1266. DOI: 10.1016/j.ijindorg.2006.04.002.

Church, J., Ware, R. (2000). *Industrial Organization: A Strategic Approach*. Boston: McGraw-Hill.

Compte, O., Jenny, F., Rey, P. (2002). Capacity Constraints, Mergers and Collusion, *European Economic Review*, 46. DOI: 10.1016/S0014-2921(01)00099-X.

[3] For a review of the debate on the economic justification of patent protection see, for example, Karbowski and Prokop [2013].

Diamantoudi, E. (2005). Stable Cartels Revisited, *Economic Theory*, 26(4), pp. 907–921. DOI: 10.1007/s00199-004-0550-0.

European Commission (2021). *Cartels: Cases*, https://ec.europa.eu/competition/cartels/cases/cases.html (accessed: 17.10.2020).

Green, E.J., Porter R.H. (1984). Noncooperative Collusion under Imperfect Price Information, *Econometrica*, 52(1), pp. 87–100. DOI: 10.2307/1911462.

Harrington, J.E., Jr. (2008). Optimal Corporate Leniency Programs, *The Journal of Industrial Economics*, 56(2), pp. 215–246. DOI: 10.1111/j.1467-6451.2008.00339.x.

Harrington, J.E., Jr. (2017). *The Theory of Collusion and Competition Policy*. Cambridge, MA: The MIT Press.

Harrington, J.E., Skrzypacz, A. (2007). Collusion Under Monitoring of Sales, *RAND Journal of Economics*, 38(2), pp. 314–331. DOI: 10.1111/j.1756-2171.2007.tb00070.x.

Harrington, J.E., Jr., Wei, Y. (2017). What Can the Duration of Discovered Cartels Tell Us about the Duration of All Cartels? *The Economic Journal*, 127(604), pp. 1977–2005. DOI: 10.1111/ecoj.12359.

Karbowski, A. (2020). A Note on Patents and Leniency, *Gospodarka Narodowa. The Polish Journal of Economics*, 301(1), pp. 97–107. DOI: 10.33119/GN/116615.

Karbowski, A., Prokop, J. (2013). Controversy over the Economic Justification for Patent Protection, *Procedia Economics and Finance,* 5, pp. 393–402. DOI: 10.1016/S2212–5671(13) 00047–6.

Levenstein, M.C., Suslow, V.Y. (2006). What Determines Cartel Success? *Journal of Economic Literature*, 44(1), pp. 43–95. DOI: 10.1257/002205106776162681.

Levenstein, M.C., Suslow, V.Y. (2011). Breaking Up Is Hard to Do: Determinants of Cartel Duration, *Journal of Law and Economics*, 54(2), pp. 455–492. DOI: 10.1086/657660.

Lipczynski, J., Wilson J.O.S., Goddard, J. (2017). *Industrial Organization: Competition, Strategy and Policy*. Harlow, England; New York: Pearson.

Paha, J. (2017). The Value of Collusion With Endogenous Capacity and Demand Uncertainty, *Journal of Industrial Economics*, 65(3), pp. 623–653. DOI: 10.1111/joie.12143.

Pepall, L., Richards, D.J., Norman G. (2014). *Industrial Organization: Contemporary Theory and Empirical Applications*. Wiley: John Wiley & Sons, Inc.

Prokop, J. (1999). Process of Dominant-Cartel Formation, *International Journal of Industrial Organization*, 17(2), pp. 241–257. DOI: 10.1016/S0167-7187(97)00040-4.

Prokop, J. (2021). The Impact of Patents on Cartel Stability, *Ekonomia i Prawo. Economics and Law*, 20(2), 2021, pp. 401–412, DOI: 10.12775/EiP.2021.024.

Prokop, J. (2023). Wpływ patentów na stabilność kartelu. In: *Współczesne problemy gospodarowania*, D. Kopycińska, J. Korpysa (Eds.). Szczecin: Scientific Publishing House, Centre of Sociological Research.

Prokop, J. (2025). Patent Rights in a Duopoly with Price Leadership. Manuscript to be published in *International Journal of Management and Economics*.

Rotemberg, J.T., Saloner, G. (1986). A Supergame-Theoretic Model of Price Wars during Booms, *The American Economic Review*, 76(3), pp. 390–407. https://www.jstor.org/stable/1813358

Spagnolo, G. (2008). Leniency and Whistleblowers in Antitrust. In: *Handbook of Antitrust Economics* (pp. 259–304), P. Buccirossi (Ed.). Cambridge, MA: The MIT Press.

Tirole, J. (1997). *The Theory of Industrial Organization*. Cambridge, MA: The MIT Press.

Vasconelos, H. (2005). Tacit Collusion, Cost Asymmetries, and Mergers, *RAND Journal of Economics*, 36(1), pp. 39–62.

Wu, W. (2019). Managing Cartels Through Patent Pools, *The Antitrust Bulletin*, 64(3), pp. 457–473. DOI: 10.1177/0003603X19863592.

MARKETS AND COMPETITION DYNAMICS WITH IMPERFECT PATENT PROTECTION

Marek Dietl
SGH Warsaw School of Economics
Collegium of World Economy
Department of Business Economics
e-mail: mdietl@sgh.waw.pl

ABSTRACT

This paper conducts a critical literature review on the economic role of patents, focusing on market and competition dynamics under imperfect patent protection, such as overlapping rights or "patent thickets." Challenging the assumption that patents grant uncontested monopoly rights, we analyse their heterogeneous impacts on innovation, growth and welfare across countries, industries and firm sizes. Empirical evidence from Fagerberg, Srholec and Verspagen [2010] and Bloom, Schankerman and Reenen [2013] shows positive links to GDP, productivity and FDI via R&D incentives and spillovers, but drawbacks include rivalry intensification and barriers like thickets. Innovativeness measures [Gallini, 2017; Park, Leahey, Funk, 2023] reveal no universal correlation, with historical non-patent regimes [Moser, 2013] and the "inverted U" relationship [Qian, 2007] underscoring context-dependence. Patent quality flaws, such as invalid grants [Frakes, Wasserman, 2017] and litigation costs [Mezzanotti, 2021], are critiqued, alongside models: Dietl's [2025] hotelling duopolies; Mallios' [2024] licensing-secrecy trade-offs; Capuano and Grassi's [2020] welfare losses from exclusive licensing; and Takalo's [1998] short, broad patents optimising spillovers.

The findings indicate that imperfect protection often enhances welfare by fostering competition and resolving monopolies, contrary to strong patent paradigms. In pharmaceuticals and biotechnology, weak enforcement promotes networks but risks disputes. Policy calls for tailored reforms: moderate quality for diffusion in technology sectors, robust for high R&D fields, with reviews to curb invalidity.

JEL Classification: D43, L13, O31, O34

Keywords: patent rights, patent thickets, spatial monopolistic competition

Introduction

Patent, in economic terms, is an administrative decision which grants the patent assignee monopoly rights over benefits from an intellectual achievement/discovery or an innovation. It is a reward for coming up with a novelty. Typically, patents share the following common features:

1. Legal Protection: a patent is a legal right granted by a government to an inventor, giving them exclusive rights to make, use and sell their invention for a certain period, typically 20 years.
2. Intellectual Property: a patent is a form of intellectual property that protects new inventions, including processes, machines and compositions of matter, by preventing others from using or copying the invention without permission.
3. Innovation Incentive: a patent is a government-issued document that provides inventors with exclusive rights to their innovations, encouraging investment in research and development by ensuring potential financial returns.
4. Exclusive Rights: a patent is an exclusive right granted for an invention, which is a product or a process that provides a new way of doing something or offers a new technical solution to a problem.

The economic research on patents usually assumes that patents give uncontested rights to innovation. It is a fair assumption for most cases, but there is a growing scientific curiosity in the economic implications of imperfect patent protection. An imperfect patent protection occurs when, for instance, the rights from the patent overlap. In this paper, we conduct critical literature review of market and competition dynamics when rights from the patents could be contested.

Patents and economic performance

There was a lively discussion among the economists around the benefits and drawbacks of patents and patent system as whole, summarised by Fagerberg, Srholec and Verspagen [2010]. Their chapter reviews empirical studies showing a positive correlation between the number of patents filed and various economic indicators such as GDP growth, productivity and employment rates. This evidence supports the view that a robust patent system is a significant driver of economic prosperity.

There is also a link between patents and well-being or quality of life. Innovations protected by patents can lead to new products and services that improve quality of life, such as medical advancements and consumer goods. On top of that, the

diffusion of patented technologies can enhance overall societal well-being by making advanced technologies accessible to a broader population. Patents, compared to trade secrets, better facilitate the dissemination of new technologies by providing detailed information about inventions, which others can build upon. This process helps spread technological benefits across different sectors and regions, contributing to economic well-being [Fagerberg et al., 2010]. The authors also indicate the benefits on a country level. Strong patent protection can attract foreign direct investment (FDI) by providing a secure environment for investors. This influx of capital can stimulate economic activity, create jobs and further enhance economic growth and societal well-being.

Interesting markets and competitive dynamics in research and development were analysed by Bloom, Schankerman and Reenen [2013]. Their paper explores the impact of R&D activities on firm performance, focusing on the dual effects of technology spillovers and product market rivalry. The authors investigate how R&D affects firm performance through two main channels: positive technology spillovers and negative business-stealing effects from product market rivals. They develop a framework to distinguish between these effects and use the US firm data from 1981–2001 to analyse the impact.

Their model considers a two-stage game where firms decide on R&D spending and then compete in the product market. Technology spillovers increase productivity, while product market rivalry can reduce a firm's market value due to competition. The authors use measures of a firm's position in technology space (based on patent data) and product market space (based on sales data). They construct spillover pools to quantify the impact of R&D by other firms in the same technology or product market space. They distinguish technology spillovers which are significant and positive, indicating that R&D implemented by one firm can enhance the productivity of other firms in related technology fields and product market rivalry, which has a negative impact on a firm's market value, as R&D implemented by competitors can erode market share and profits. Using this framework, they make statements on the role of patents. They believe that patents incentivise R&D as they provide legal protection, ensuring that inventors can reap the benefits of their innovations, which encourages investment in R&D. Patents support technology spillovers by dissemination of new technologies, as they require detailed disclosure of the invention, which can be used by others to further innovate, and they also support economic growth.

Those obvious benefits should be weighed against the drawbacks. Patents can intensify product market rivalry, leading to negative effects on firms' market values as competitors' innovations can capture market share. Patent system could be used

for over-protection. Excessive patenting can lead to "patent thickets," where overlapping patents create barriers to innovation and increase litigation costs. This might lead to inequality in benefits: smaller firms may generate lower social returns from their R&D due to operating in technological niches, suggesting that patents might disproportionately benefit larger firms.

This paper provides a more nuanced view of the role of patents in encouraging innovation. While patents are essential for incentivising R&D and facilitating technology spillovers, they also have drawbacks related to increased competition and potential over-protection. The generic line of thinking, according to which more patents translate into more innovations, which improves economic growth and well-being is somehow challenged. Academics and policymakers should broaden their analyses in order to understand the factors the benefits of patents for economic growth and innovation. We will take a deeper dive in this issue in the subsequent section. We start with checking if patents really translate into innovations. Then, we attempt to understand the issues related to the quality of patents. Finally, we review literature around imperfect patent protection. The last section concludes with key findings on the impact of imperfect patent protection on markets and competition dynamics.

Do patents really increase innovativeness?

Bronwyn H. Hall and Nathan Rosenberg in their introduction to the *Handbook of Innovation Economics* [Hall, Rosenberg, 2010] claim that patents play a vital role in promoting innovation, which drives economic growth and enhances well-being. By providing legal protection and encouraging investment in R&D, patents help countries develop technological capabilities, attract investment and improve the quality of life of their citizens. There is evidence that a well-operating patent system is a key component of economic development strategies, but patents are one of many tools to encourage innovation. In this section, we investigate the correlation between patents and innovation.

Nancy Gallini in her 2017 paper [Gallini, 2017] offers an overview of innovativeness measures. There is no single and widely accepted parameter. One can advocate for the R&D level of research and development spending. Higher R&D expenditures suggest greater investment in innovation which should foster innovativeness. The number of patents granted and applications filed could be another measure. It can indicate the level of inventive activity, although this measure can be affected by changes in the patent policy and propensity to patent. One can also look at the num-

ber of citations a patent receives used as a proxy for its impact on follow-on innovation. Increased citations indicate that the patented invention is being created by subsequent research. The measure could also be the ratio of forward to backward citations. Park et. al. [2023] claim that of the ratio value above 1 indicates that the patent resulted in a disruptive innovation and ratio below 1 is a sign that the patent (only) consolidated the existing knowledge (C–D model). This very limited overview of innovativeness measures shows that, in many instances, patents related measures are proxies for evaluation of innovativeness. Finding if the correlation really exists requires a bottom-up approach. On the aggregate level, it is considered self-evident.

The paper *Patents and Innovation: Evidence from Economic History* by Petra Moser [Moser, 2013] examines the historical role of patents in encouraging innovation and the implications of patent strength. The author took a historic perspective starting from early patent systems, such as those in Venice and Britain, aimed to attract skilled artisans and promote economic development. She argues that the US Constitution established a modern patent system.

The paper offers a discussion about the extent to which the patent system was decisive for the technological development during the Industrial Revolution. To answer this question the exhibits from 19th-century world fairs were analysed. Several findings contradict the belief in the crucial role of patents. For example, some countries without patent laws, most notably Switzerland and the Netherlands, produced high-quality innovations. Overall, only a small share of innovations were patented, and high-quality innovations were slightly more likely to be patented, but many inventors relied on trade secrecy and other mechanisms to protect their inventions. Those findings suggest that patents were not the primary driver of innovation during this period.

The paper points to the heterogeneity across countries and industries and time. For example, initially trade secrecy was effective in protecting chemical innovations. Countries with and without patent laws had similar innovativeness in this and other industries where trade secrecy could effectively protect intellectual property. With more and more scientific breakthroughs in this industry, the effectiveness of trade secrecy decreased, and the role of patenting increased. Those developments led to a reduction in the geographic concentration of inventive activity, suggesting that patents can promote the geographic spread of innovations.

Historical data indicate that patents are not always necessary or sufficient for innovation. Many high-quality innovations occurred outside the patent system, and inventors often relied on alternative mechanisms like trade secrecy. The effectiveness of patents varies across industries. In some sectors, like chemicals and

pharmaceuticals, patents are crucial for protecting intellectual property. In others, alternative mechanisms may be more effective. Breakthroughs that reduce the effectiveness of secrecy can increase the reliance on patents, as seen in the chemical industry in the late 19th century. Overall findings could be summarised that patent system is not a prerequisite for technological progress. Its role is different across the countries and industries. Patents encourage disruptive innovations if they are strong enough to reduce the risk of litigation.

The role of patent system was also studied by Yi Qian [2007]. The study analyses data from 26 countries that implemented pharmaceutical patent laws between 1978 and 2002, using matched sampling techniques and country-pair fixed-effects regressions controlled for GDP, GDP per capita, economic freedom, education levels, industry-specific factors, etc. Overall, the paper finds that the implementation of national patent laws alone does not significantly stimulate domestic innovation. This conclusion is based on the analysis of citation-weighted US patent awards, domestic R&D expenditures and pharmaceutical industry exports. However, there are several interesting conditional factors. For example, patent laws are more effective in stimulating innovation in countries with higher levels of economic development. The interaction between patent implementation and GDP per capita shows a positive relationship with innovation. Also, higher levels of education and economic freedom enhance the positive impact of patent laws on innovation. There appears to be an optimal level of intellectual property rights (IPR) regulation. Beyond this optimal level, further strengthening of IPR can actually reduce innovative activities, suggesting an "inverted U" relationship between IPR strength and innovation.

An interesting perspective is offered by Gallini [Gallini, 2017]. She explores the effectiveness of patents in promoting innovation, particularly in the context of cumulative innovation. The paper emphasises that innovation is a cumulative process where new ideas ae build on previous ones. Patents can either facilitate or hinder this process depending on the context. She differentiated complex and non-complex technologies. In the former, like computers, electronics, and telecommunications, patents can create barriers to follow-on research due to issues like patent thickets (overlapping patents) and the anti-commons problem (fragmented ownership of IP). In the case of non-complex technologies, like pharmaceuticals, chemicals and human genes, patents are less likely to impede follow-on research and can effectively promote innovation. The paper provides a nuanced view of how patents can both promote and hinder innovation, depending on the context and specific technology area. It underscores the importance of complementary policies and institutions in ensuring that the patent system effectively stimulates innovation.

Vertical (industry focused) study published in 2015 by Sampat and Williams [2015] investigates the impact of patents on human genes, subsequent scientific research and product development – another facet of cumulative innovation. The study aims to determine whether patents on human genes hinder or promote follow-on innovation. The authors use administrative data on successful and unsuccessful patent applications submitted to the US Patent and Trademark Office. They link these applications to data measuring follow-on scientific research and commercial investments. Patented genes appear more valuable before being patented compared to non-patented genes. Using two quasi-experimental approaches, the study finds that, on average, gene patents have not had a significant effect on follow-on innovation. Overall, the paper suggests that gene patents do not substantially impede further scientific research and development.

The paper entitled *Sequential Innovation, Patents, and Imitation* by Bessen and Maskin [2009] explores the impact of patents on innovation, particularly in industries where innovation is sequential and complementary. The paper argues that in industries where innovation is sequential (each invention builds on previous ones) and complementary (different firms pursue different research lines), patents may not be as beneficial as traditionally thought. In fact, patents might inhibit innovation in such settings. To illustrate this statement, the authors discuss a natural experiment in the US software industry during the 1980s and 90 s, where patent protection was significantly strengthened. Contrary to the expectations, firms that acquired most software patents reduced their R&D spending relative to sales, suggesting that stronger patents did not spur more innovation.

The paper posits that imitation can actually promote innovation in sequential and complementary industries. Imitation helps imitators develop further inventions, potentially enhancing the overall pace of innovation. This is because imitators may have valuable ideas not available to the original inventor. In a sequential setting, patents might reduce welfare by blocking imitation and subsequent innovation. The paper suggests that society and even inventors might be better off with limited intellectual property protection in such industries. The authors highlight a problem with the argument that patent holders will license their patents to promote follow-on innovation. Information asymmetry between the patent holder and potential licensees can hinder effective licensing, thereby jeopardising subsequent innovation. The paper contrasts a static model (where innovation is a one-time event) with a sequential model. In the static model, patents are shown to encourage innovation by protecting inventors from imitation. However, in the sequential model, the benefits of patents are less clear, and they may even inhibit innovation.

The effectiveness and impact of patents vary significantly across different types of industries. In sequential and complementary industries, patents may not be the best tool for promoting innovation. Instead, limited intellectual property protection and allowing some degree of imitation might be more beneficial. The findings suggest a need for a balanced approach to patent policy, particularly in industries characterised by sequential and complementary innovation. Limiting patent breadth and encouraging competition and imitation could enhance innovation and social welfare in these sectors.

Moser [2005] examines the effects of patent laws on innovation using data from the Crystal Palace World's Fair in 1851 and the Centennial Exhibition in 1876. The study introduces a new dataset of nearly 15,000 innovations exhibited at two major world fairs. This dataset allows for a cross-country comparison of innovations from countries with and without patent laws. The paper argues that patent laws influence not just the quantity but also the direction of innovation. In countries without patent laws, innovation tends to concentrate on industries where alternative mechanisms to protect intellectual property are effective. In contrast, countries with patent laws exhibit a more diversified range of innovations across different industries. The data and analysis confirm that innovation in countries without patent laws concentrates in a smaller set of industries, while countries with patent laws show a broader distribution of innovations. Patent laws help to determine the direction of technological change and industries to become focal points for innovation.

A widely cited paper by Cohen, Nelson and Walsh [2000] offers an insight into the various mechanisms US manufacturing firms use to protect their intellectual property and the reasons behind their patenting decisions. They use a wide range of mechanisms to protect the profits from their inventions, including patents, secrecy, lead time advantages, and complementary marketing and manufacturing capabilities. Patents are often the least emphasised mechanism compared to others like secrecy and lead time. This is consistent across most industries, with a few exceptions where patents are more central to firms' appropriability strategies.

The effectiveness and use of patents vary significantly across different industries. For example, patents are more heavily relied upon in industries like pharmaceuticals and chemicals, where they are crucial for protecting product innovations. In contrast, in industries such as electronics and telecommunications, patents are often used strategically for purposes like blocking rivals and facilitating negotiations rather than solely for protecting direct profits from innovations.

Firms patent for various reasons beyond directly profiting from a patented innovation. These include preventing rivals from patenting related inventions (patent

blocking), using patents in negotiations and preventing infringement suits. The motives for patenting differ between "discrete" product industries (e.g. chemicals) and "complex" product industries (e.g. electronics). In discrete industries, patents are often used to block substitutes, while in complex industries, patents are used to force rivals into negotiations and cross-licensing agreements. The study compares its findings with earlier research and notes that the importance of patents has increased somewhat over time, particularly among larger firms. However, secrecy became a more heavily employed mechanism across most industries compared to previous decades (the paper was published in the year 2000). In summary, this paper underscores the diverse roles and effectiveness of patents in different industrial contexts, illustrating the complexity and strategic nature of patenting decisions in the US manufacturing sector.

We showed that there are some doubts about the role of patenting in fostering innovation. To address this issue quite a few authors attempted to show how the patents system can be beneficial for the economy and society. Michael Kremer [Kremer, 1998] looked at the concept of patent buyouts as a way to stimulate innovation while mitigating some of the negative effects of the current patent system like high prices of patented goods what leads to underconsumption. They also encourage wasteful "me-too" research aimed at inventing around existing patents rather than creating new, original inventions. Patents do not fully capture the social value of inventions, leading to underinvestment in research. The paper begins with discussing the historical example of the French government buying the Daguerreotype patent in 1839 and placing it in the public domain. This move eliminated monopoly pricing and spurred widespread adoption and improvement of the technology. He follows up this example and proposes that governments could buy patents at their estimated private value, determined through an auction, multiplied by a markup reflecting the typical ratio of social to private value. Most patents purchased would be placed in the public domain, but some would be sold to the highest bidder to ensure truthful bidding.

The advantages of patent buyouts could be threefold: elimination of monopoly pricing and increased access to new technologies; reduction in incentives for duplicative research and increased incentives for original research; encouragement to the development of complementary inventions. There are various challenges related to the implementation of that system including determining the appropriate buyout price and preventing collusion among bidders. Kremer's paper proposes a novel approach to encouraging innovation by having governments buy out patents and place them in the public domain. This method aims to eliminate the negative effects of monopoly pricing and increase the social value derived from new inventions.

The proposed auction mechanism and safeguards against collusion are designed to ensure that the buyout prices reflect the true value of patents.

Another benefit offered by the patent system is the possibility to complement it with a renewal system. Scotchmer [1999] devoted her paper to analysing the pros and cons of when patent holders must pay fees to maintain their patents over time. The study addresses the issue of asymmetric information between firms and patent authorities. Firms have better information about the costs and benefits of their R&D investments, which makes the patent system a useful tool for delegating R&D decisions to firms. The paper argues that the patent system can be optimal in certain environments, particularly when only one firm has the idea for an innovation. In such cases, the patent system can efficiently incentivise investment in R&D. Renewal mechanisms are shown to be equivalent to direct mechanisms in their ability to elicit information about the value of innovations. This makes the patent renewal system an effective tool for ensuring that only valuable innovations are protected.

When something goes wrong with a patent...

Until now, we have (tacitly) assumed that the patents are correctly assigned and of the same quality. In reality there are widespread concerns about the quality of patents. Poor quality patents can lead to increased litigation, hinder innovation and impose costs on the economy. Several studies have explored how the incentives and constraints faced by patent examiners affect the quality of their work. They highlight that examiners are under significant time pressure, which can lead to less thorough examinations. We picked up two papers to illustrate the concerns around the quality of papers.

The paper by Frakes and Wasserman [2017] examines the quality of patent review processes at the U.S. Patent and Trademark Office (USPTO). It investigates whether the time allocated to patent examiners for reviewing applications affects the likelihood of granting invalid patents. The authors use microlevel data (over 1 million patent applications disposed between 2002 and 2012, merged with examiner roster data) to analyse examiner behaviour over time, particularly focusing on how promotions, which reduce examination time, influence granting tendencies. The study employs examiner fixed-effects specifications to isolate the impact of time constraints from other factors.

The study finds that as examiners are promoted and given less time to review applications, they are more likely to grant patents. This is attributed to reduced

scrutiny and less thorough searches for prior art. The additional patents granted due to time constraints are generally of lower quality. This is evidenced by a higher likelihood of these patents being rejected by the European Patent Office (EPO) and the Japan Patent Office (JPO), which have similar patentability standards but allocate more resources per application. Examiners make fewer obvious rejections, which are time-intensive, as their allocated examination time decreases. This leads to an increase in the grant rate. On top, they also found out that the share of prior art citations originating from examiners (as opposed to applicants) decreases with reduced examination time, indicating less thorough searches.

The findings suggest that more time allocated to examiners could improve the quality of issued patents by allowing for more thorough examinations. However, this would need to be balanced against the potential for increased backlog and delays in patent processing. The study provides evidence that time constraints on patent examiners lead to higher grant rates and lower quality patents. It underscores the importance of adequate examination time to ensure the issuance of valid patents and suggests that policy adjustments could help mitigate the problem of invalid patents.

The paper by Schankerman and Schuett [2022] examines the effectiveness of patent screening processes and their impact on innovation and welfare. The paper addresses a concern that patent screening is ineffective, leading to the granting of low quality patents that impose unnecessary social costs. The authors developed an integrated framework to study patent screening both theoretically and quantitatively. The framework incorporates four key policy instruments: the intensity of patent office examination, pre-grant (application) fees, post-grant (renewal) fees and the review of patents by courts when challenged by competitors. This comprehensive approach allows for a detailed analysis of how these factors interact to influence the patent quality.

The study highlights that the endogeneity of patent validity challenges implies that courts, even if perfect, cannot fully solve the screening problem. This is because the decision to challenge a patent is affected by the perceived quality of the patent and the costs involved in litigation. Simulations calibrated on US data indicate that the current patent screening process is highly imperfect. Nearly half of all patents are issued for inventions that do not require the patent incentive, suggesting that many low quality patents are granted. Despite these imperfections, the current patent system generates a positive social value. However, the authors find that intensifying the examination process could yield significant welfare gains. The paper suggests that increasing the intensity of patent examinations would improve the quality of

patents issued. This could involve allocating more time and resources to the examination process to better identify low-quality patents.

The quality of patent review is crucial for ensuring that the patent system effectively promotes innovation without imposing excessive social costs of imperfect patent protection. The study by Schankerman and Schuett demonstrates that while the current system has its benefits, there is substantial room for improvement. By intensifying patent examinations and implementing complementary policies, the quality of patents can be significantly enhanced, leading to greater overall welfare.

Imperfect patent protection often results in patent litigation which lowers the returns from R&D by increasing costs and risks, which can deter firms from investing in innovative projects. Litigation exacerbates financial constraints by diverting resources away from productive investments towards legal defenses and settlements. Filippo Mezzanotti [2021] offered a systematic treatment of those issues. He was particularly interested in the question of how patent litigation affects corporate research and development after the Supreme Court decision in "eBay v. MercExchange" [2006], which increased court flexibility in patent cases and reduced the potential costs of patent litigation for defendants? The decision led to a general increase in innovation, particularly for firms that were more exposed to patent litigation. The ruling reduced the share of defensive patents, indicating a shift towards more genuine innovation efforts. There was no significant decline in the quality of patents, and firms were more likely to develop breakthrough innovations.

A difference-in-differences model is employed to compare innovative activities across firms with varying exposure to patent litigation before and after the ruling. The analysis uses data on patent litigation and corporate R&D activities.

The benefits were not equally distributed. Smaller firms and those without strong financial health (e.g. no credit rating, no dividend payments) benefited more from the reduced litigation costs, as they are more sensitive to financial constraints. Firms more likely to be defendants in patent cases saw greater increases in R&D investment compared to those more likely to be plaintiffs. Similarly, firms in highly litigious industries benefited significantly from the ruling, as it reduced the costs and risks associated with patent litigation. The paper concludes that reducing the costs and risks associated with patent litigation can have a substantial positive impact on corporate innovation. By alleviating financial constraints and improving the returns on R&D, such legal changes can promote more genuine and high quality innovation, particularly benefiting smaller and financially constrained firms.

Galasso and Schankerman [2015] investigate the impact of patent rights on subsequent innovation by patent holders, focusing on the heterogeneity of this impact

across different types of firms and competitive environments. The study examines the causal impact of patent invalidation by the U.S. Court of Appeals for the Federal Circuit on the subsequent innovation activities of the patent holder. The analysis uses the random allocation of judges to control the endogeneity of judicial decisions. On average, patent invalidation leads to a 50% decrease in patenting by the patent holder over the following five years. However, this average effect masks significant heterogeneity based on the firm size and competitive environment.

The negative impact of patent invalidation is entirely driven by small innovative firms, particularly in technology fields where they face many large incumbents. For these small firms, losing a core patent significantly reduces their innovation incentives. Invalidation of patents held by large firms does not significantly affect their overall level of innovation. Instead, it shifts the technological direction of their subsequent patenting activities. The impact of losing a patent is more pronounced for core patents, which are central to the firm's research focus and facilitate the development of subsequent innovations. Peripheral patents, which do not directly contribute to follow-on innovation, have a lesser impact when invalidated.

The study explores several mechanisms through which patent rights affect innovation. Small firms are more adversely affected by patent invalidation in fields with many large firms, suggesting that patents help small firms compete and negotiate with larger incumbents. The impact of invalidation is not significantly larger in fields with fragmented patent ownership, suggesting that access to external patented inputs is not the main channel. For large firms, patent invalidation leads to a redirection of innovation efforts rather than a reduction in the overall level of innovation. Large firms tend to increase their patenting in related technology areas when a non-core patent is invalidated.

The effectiveness of patents as an innovation incentive varies significantly across different types of firms and competitive environments. Patents are crucial for small firms, especially in competitive fields with large incumbents, while large firms are more flexible in redirecting their innovation efforts when patents are invalidated. The findings suggest that policies aimed at strengthening patent rights should consider the heterogeneous impact on different types of firms. Support for small innovative firms may be more effective in stimulating overall innovation compared to broad-based patent protection policies.

Analysing markets with imperfect patent protection

Imperfect patent protection is a significant area of study in intellectual property rights, particularly in its implications for innovation, competition and market dynamics. The literature explores various dimensions of this issue, including the effects on various industries, licensing strategies and the relationship between patent strength and research and development investment. We kick-off this section with a paper linking economic growth and imperfect patent protection written by Horii and Tatsuro [2007]. The paper explores the impact of intellectual property rights (IPR) protection on economic growth using a quality-ladder model of endogenous growth. It argues that while a stronger IPR protection increases rewards for innovation, it can also reduce the number of competitive sectors, potentially hindering growth. The authors suggest that an imperfect IPR protection may maximise growth.

Their model includes households with labour and consumption, and production sectors using intermediate goods of varying quality. The probability of successful innovation differs between competitive and monopolistic sectors. The number of monopolistic sectors changes over time due to leapfrogging (innovation by outsiders) and imitation. Researchers enter R&D based on expected returns affected by wages and value of innovation, which depends on the probability of imitation and successful leapfrogging. There is an extreme case when leapfrogging is prohibitively difficult, the model shows that both very weak and very strong IPR protection can lead to zero growth. An intermediate level of IPR protection maximises growth. A more general case is when the model is extended to include both imitation and leapfrogging. The relationship between IPR protection and growth is complex and depends on the difficulty of leapfrogging. Simulations show that when leapfrogging is difficult, intermediate IPR protection maximises growth. When leapfrogging is easier, stronger IPR protection is more beneficial. The paper concludes that the optimal level of IPR protection depends on the difficulty of leapfrogging. Imperfect IPR protection can maximise growth by balancing the incentives for innovation with the need to maintain competitive sectors. The findings emphasise the importance of considering both positive and negative effects of IPR protection on economic growth and welfare.

Imperfect patent protection refers to situations where multiple patents may cover a single product, leading to uncertainty in enforcement and scope. This complexity results in an indeterminate period of monopoly protection for innovators. For instance, in the pharmaceutical sector, about 70% of novel drugs are covered by multiple intellectual property rights, which can delay generic entry into the mar-

ket due to later patent expirations and increased uncertainty regarding remaining patents [Gupta, 2023].

Interesting insights (based on the case of biotechnology) into the market dynamics with imperfect patent protection was offered by Barnett [2000]. He challenged traditional incentive theories of patent protection as they do not fully explain private investment in high risk, high spillover innovations. In the paper, he discusses the impact of imperfect patent protection on innovation, particularly in the biotechnology sector. The paper argues that incomplete patent rights can foster innovation networks that enhance both productivity and accessibility to genetic resources. Imperfect patent rights reduce transaction costs and commitment issues in forming innovation networks, encouraging collaborative ventures that spread the risks and costs of biopharmaceutical development. These networks involve small biotech firms focusing on early-stage research and large pharmaceutical companies handling clinical testing and distribution, efficiently distributing market and technical uncertainties. The paper concludes that imperfect patent protection, coupled with antitrust measures, can effectively stimulate innovation in the biotechnology sector. By encouraging the formation of innovation networks and preventing patent consolidation, these policies help maintain a balance between productivity and accessibility in the genetic commons.

Research indicates that stronger patent protection does not always correlate with increased R&D investment. In fact, enhancing protection can sometimes reduce incentives for innovation by creating barriers that discourage firms from investing in new technologies. A model presented in the literature suggests that firms may be worse off under stronger protections due to reduced imitation incentives, which can lead to a decline in overall innovation activity [Krasteva, 2014].

Imperfect patent protection significantly influences licensing strategies among firms. When the scope of patents is uncertain, firms may be less willing to pay for innovations or engage in licensing agreements. This uncertainty can lead to suboptimal licensing outcomes, affecting overall market dynamics and innovation diffusion [Capuano, Grassi, 2020]. The same paper argues that weak patent protection could enhance social welfare by facilitating greater access to innovations and reducing costs for consumers. This perspective posits that while strong protections may benefit innovators in the short term, they could ultimately hinder broader societal benefits by restricting access to new technologies. Those claims are based on a model which is covered in greater detail in the next section.

The presence of imperfect patent rights can lead to increased competition among firms as they navigate overlapping patents. This situation may foster innovation as

firms seek to differentiate their products or find alternative paths to market entry despite existing patents. However, it can also result in strategic behaviours such as pre-emptive patenting or litigation aimed at stifling competition. Those and other market dynamics were covered by Takalo [1998]. The paper examines how the spillover of R&D is influenced by rational investment in imitation and the innovator's choice between patenting and secrecy. It explores the effects of patent length and breadth on innovation and imitation and discusses the social optimality of patent policies. His model is presented in greater detail in the subsequent section.

Modelling competition dynamics with imperfect patent protection

In this section, we present four models capturing the competition dynamics of markets with imperfect patent protection. We kick-off with the model presented by Takalo [1998]. Tuomas Takalo develops a theoretical model to analyse the interplay between innovation, imitation and imperfect patent protection. The paper is based on a duopoly model with the innovator and the imitator. The innovator must decide first if she wants to work on innovation. If she decides "yes" and she is successful, a new dilemma arises. The innovator decide whether to patent an innovation or keep it secret. Patents provide protection for a fixed period (L years) but do not prevent imitation entirely. The cost of imitation depends on whether the innovation is patented or kept secret. Patent breadth w affects these costs, with broader patents increasing imitation costs. The probability of successful imitation β is influenced by the cost of imitation. For patented innovations, this probability increases with patent length L and decreases with patent breadth w. The innovator will choose to patent if the value of patenting V_p exceeds the value of secrecy V_s. This decision is influenced by the expected spillover rate β.

Tuomas Takalo's findings could be summarised as follows: an increase in patent breadth always encourages patenting, while an increase in patent length encourages patenting only when spillovers are small. For large spillovers, longer patents may discourage patenting and innovation. The optimal patent policy maximises social welfare while ensuring sufficient incentives for innovation. Short patents are generally optimal, especially when spillovers are large. Patent breadth and length are substitutes for small spillovers but complements for large spillovers. The optimal policy involves maximum breadth and minimum length for small spillovers, and both reduced breadth and length for large spillovers. The paper concludes that the design of patent systems must consider these trade-offs, particularly how patent

breadth and life influence innovation incentives and the extent of R&D spillovers through imitation.

Takalo's framework can be applied to a case of imperfect patent protection. Let us reinterpret and generalise the patent breadth w and length L as the general measures of the patent quality. The model setup is similar. There are two players (the innovator and the imitator) in a duopoly. The innovator's choice is the same: she decides whether to patent it or keep it secret. If patented, the patent has quality:

$$Q \in [0, 1), \tag{54}$$

where Q is the probability that an imitation attempt is detected and blocked (e.g. through legal enforcement). Low Q indicates imperfect patent protection. The monopoly profit is, π_m and duopoly profit is π_d, with:

$$\pi_m > 2 * \pi_d > 0. \tag{55}$$

The imitator invests in imitation D (sunk cost). The probability of successful imitation is β. He aims to maximise return on investment:

$$\max \pi_s = (\beta * \pi_d)/D. \tag{56}$$

Conversely, the innovator's initial investment is given as R. If the innovator can deter the imitator's entry, she enjoys monopoly profits and return on investment:

$$(\alpha * \pi_m)/R \tag{57}$$

or

$$(\alpha * \pi_d)/R \tag{58}$$

if the market has to be shared with imitator, where α measures probability of innovation effort success.

If the innovator is indeed successful with innovation, she decides on IP rights protection: Patent (p) or Trade Secret (s). The decision depends on the ratio between "patent quality" and "trade secrecy efficiency": θ. To keep our focus on patent quality we assume no fixed costs related to patenting.

The stage is set and one can proceed in reverse order towards optimal decisions for each player. The imitator responds to the innovator's decision. In case the innovator opts for trade secrecy the imitator weights out expected duopoly profits ($\beta * \pi_d$) against the expected cost of imitation. This case is irrelevant to our patent quality investigation.

If the innovator decides to patent the innovation, she discloses details on the innovation in the patent filling what potentially might be easing imitation cost, but the higher the patent quality (Q_p) the more it discourages imitation. The probability of success (entering the market and gaining duopoly profits) is inversely related to patent quality. Formally, the imitator decides to enter the market, if:

$$(1 - Q_p) * \beta_p * \pi_d > R, \tag{59}$$

where:

$$\beta_p > \beta \tag{60}$$

with the probability of successful imitation is higher due to the patent disclosures by innovator, and patents are never perfect:

$$Q_p < 1 \tag{61}$$

with perfect patent prohibiting the imitator entry.

The imitator responses have been outlined. Knowing them, the innovator decides if she wants to patent or rather keep the innovation secret. There are three different scenarios:

1. Monopoly profits are lower than cost of innovation:

$$\alpha * \pi_m < R. \tag{62}$$

   Investment in innovation would never pay back. The innovator should abstain from the project.

2. Both monopoly and duopoly profits offer higher returns than initial outlays:

$$\alpha * \pi_m > \alpha * \pi_d > R. \tag{63}$$

   In any case, the innovator will strive to innovate and later she has to decide on the optimal IP strategy.

3. Only monopoly profits might secure a positive yield on innovation:

$$\alpha * \pi_m > R > \beta * \pi_d. \tag{64}$$

   The innovator invests only if she can deter the entry.

The first case is not relevant to us. The last scenario is interesting only if the imitation yields positive return for imitator under duopoly:

$$(1 - Q_p) * \beta_p * \pi_d / R > 1 \tag{65}$$

in case the innovation is patented, and:

$$\beta * \pi_d / R > 1 \tag{66}$$

in case the innovation is kept as a trade secret. If neither of the conditions is met, the innovator is indifferent in its choice of IP-strategy. There will not be an entry. Conversely, if both conditions are satisfied the imitator will be challenging the incumbent. It can happen if $R > D$. The sunk cost for imitator is much lower than for innovator. The entry would make the return on innovation negative.

If:

$$(1 - Q_p) * \beta_p * \pi_d > \beta * \pi_d \tag{67}$$

secrecy might be a better deterrence strategy. If the opposite is true patenting might be a better option for innovators. The key decision factors are patent quality $(1 - Q_p)$ and relative easing of imitation due to patent disclosures: β_p / β. I discuss this interrelation in paragraph on scenario 2 below.

Under scenario 2, innovator is pursuing innovation independently of potential reactions from imitator. He will abstain from entering the market if:

$$(1 - Q_p) * \beta_p * \pi_d < D \tag{68}$$

and:

$$\beta * \pi_d < D. \tag{69}$$

If:

$$(1 - Q_p) * \beta_p * \pi_d > D \tag{70}$$

and:

$$\beta * \pi_d > D, \tag{71}$$

the imitator will invest in getting around the patent or reverse engineering to workout imitation. The innovator's IP-strategy should set the bar as high as possible for the imitator and increase chance of entry deterrence.

The innovator dilemma could be summarised as a ratio of imitator's profits:

$$\theta = [(1 - Q_p) * \beta_p * \pi_d] / (\beta * \pi_d). \tag{72}$$

If the ratio exceeds one, trade secrecy could deter entry better. If the ratio is below one the opposite is true. The ratio equal to one makes both IP-strategies equally efficient as entry deterrent.

$$\theta > 1 \Leftrightarrow [(1 - Q_p) * \beta_p * \pi_d] > \Leftrightarrow (1 - Q_p) * \beta_p > \beta \Leftrightarrow (1 - Q_p) * (\beta_p / \beta) > 1, \tag{74}$$

$$\theta = 1 \Leftrightarrow [(1 - Q_p) * \beta_p * \pi_d] > (\beta * \pi_d) \Leftrightarrow (1 - Q_p) * \beta_p = \beta \Leftrightarrow (1 - Q_p) * (\beta_p / \beta) = 1, \tag{75}$$

Ratio (β_p/β) could be interpreted as an increase in probability of successful imitation when the patent filling is publicly available. There were several attempts to quantify this relation. The estimates are based on various assumptions, which make the picture rather blurred. Based on my limited professional experience, the patent disclosures increase the probability of successful imitation by 20–40%, which translates into ratio 1.2–1.4. For this range the patent quality needs to be very low (below 0.25 on our scale) to make trade secrecy the preferred option for innovators.

We have a clear picture of competition dynamics with imperfect patent protection. The first finding is that low sunk cost related to imitation (relative to initial outlays related to innovation) discourage innovativeness. The second finding is that innovators would rather turn to patents unless the patent system is really broken and quality of IP-rights protection is inferior.

The last question is if this dynamic is beneficial from the social welfare perspective. Social welfare (SW) is the sum of profits and consumer surplus (*CM*). Investments (sunk cost) reduce the SW. The consumer surplus is higher within competitive markets compared to monopoly so we can assume that:

$$CM_d > CM_m. \tag{76}$$

We can express the social welfare as:

$$SW_m = CM_m + \pi_m - R \tag{77}$$

in case there is no entry:

$$SW_d = CM_d + 2 * \pi_d - R - D \tag{78}$$

in case the imitator enters the market:

$$SW_d < SW_m \Leftrightarrow CM_d + 2 * \pi_d - D < CM_m + \pi_m \tag{79}$$

It was assumed that:

$$D < \pi_d \tag{80}$$

taking highest possible value for *D* we get:

$$CM_d - CM_m < \pi_m - \pi_d. \tag{81}$$

The only case when monopoly is socially optimal is when difference between monopoly and duopoly profits is greater than between duopolistic and monopolistic consumer surplus. It could happen under scenario 3 (above), when imitation costs are very low compared to innovating, but this deters innovation in the first

place as the duopoly profits would not compensate for the innovation effort in the first place. It seems that it is highly unlikely that monopoly is socially more beneficial than duopoly.

The relevant scenario is number two:

$$\alpha * \pi_m > \alpha * \pi_d > R. \tag{82}$$

Innovators enter the market independently of ultimate market set-up. If the duopoly is more desirable the higher chance of market entry are *ceteris paribus* in case when patent quality is low $(1 - Q_p)$, i.e. it is relatively easy to work around the patent and mandatory disclosures in the patent ease the imitation. However, it is true until:

$$(1 - Q_p) * \beta_p = \beta. \tag{83}$$

If the quality of patents is low and mandatory disclosures extensive, the innovator might turn to trade secrecy to secure its monopolistic position. The entry would occur when duopoly profits offer positive return on investment. We can re-write the condition for duopoly as:

$$\alpha * \pi_d = \beta * \pi_d = (1 - Q_p) * \beta_p * \pi_d > D \Leftrightarrow \alpha = \beta = (1 - Q_p) * \beta_p > D/\pi_d. \tag{84}$$

The social planner should strive to equalise the probability of innovation and imitation success $(\alpha = \beta)$ and equal the product of patent quality and benefits of patent disclosures. Those values should be greater than the share of sunk costs in duopoly profits for market challenger. For example, if the ROI for imitator is 400% and patent quality is 60%, then the probability of success in imitation after patent disclosure should be 62.5%. The probability of success with innovation and imitation (without disclosures) would be 37.5%.

From the social welfare perspective, it is optimal if the ratio of returns on investments (ROI on innovation / ROI on imitation) secures competitiveness of the market. We are aware that public policy has a limited influence on the returns on investments. They are mainly driven by the business decisions, internal strengths and external opportunities. Keep the ROI exogenous, we can clearly see that the lower the patent quality the better for the society.

Our model shows that low patent quality, for example, due to overlapping rights, increases welfare through competition. This finding is in line with Takalo. He demonstrated that all measures increasing competition, e.g. short patent life are socially beneficial.

Let us look again at the paper of Capuano and Grassi [2020]. It offers a deep dive into the market dynamics with imperfect patent protection. Their model considers

a market for homogeneous goods with an incumbent firm and a potential entrant. The innovation allows production at zero marginal cost. The level of patent protection is imperfect, meaning patents can be litigated and potentially invalidated. The probability of successful imitation and the probability of winning a patent infringement trial are key factors.

The incumbent can either refuse to license the innovation or offer a sole licence to the entrant. If no licensing agreement is made, the entrant may attempt to imitate the innovation. The profitability of imitation depends on the level of patent protection. The optimal licensing strategy involves a per-unit royalty. The level of patent protection influences the value of the licence.

The entrant can enter the market, offer a sole licence, or offer an exclusive licence to the incumbent. The entrant's decision to enter the market or stay out and license the innovation depends on the level of patent protection and the threat of imitation by the incumbent. The optimal licensing strategy for the entrant involves a fixed fee. Higher patent protection increases the value of the licence.

The willingness-to-pay (WTP) for the innovation is compared between the incumbent and the potential entrant. The entrant's WTP is higher when patent protection is strong. The level of patent protection affects market structure and social welfare. Low patent protection leads to duopoly and higher welfare, while high patent protection can lead to monopoly and lower welfare.

The paper concludes that imperfect patent protection has a significant impact on market performance. Low patent protection encourages competition and increases social welfare, while high patent protection can lead to monopolistic structures and reduce welfare. The potential entrant may be more willing to pay for the innovation when patent protection is strong, leading to exclusive licensing and non-practicing entity behaviour.

This study highlights how licensing, a key strategic response, varies with patent quality. It shows trade-offs between licensing, R&D and competition. When patent protection is high the entrant is willing to pay more for the innovation compared to the incumbent. In this case, the entrant licenses the innovation exclusively and acts as a non-practicing entity, meaning it does not produce the innovation itself but licenses it to others for profit. When patent protection is low, the threat of imitation discourages licensing agreements. This leads the incumbent to invest more in R&D to protect its market position and maintain a competitive advantage.

Capuano and Grassi [2020] show with relatively simple measures that imperfect intellectual property protection influences firms' choices between patenting, secrecy and licensing, affecting market competition. It seems likely that when imi-

tation is inefficient, firms prefer licensing, while efficient imitation leads to more competition through imitation. The evidence leans toward patenting becoming more attractive when secrecy risks, like leakage, increase, especially with more firms involved. Controversy exists around whether strong patents or weaker protection better balance innovation and competition, depending on industry and technological context.

A recent paper modelling competition dynamics under imperfect patent protection was written by Mallios [2024], who explores how firms strategise under imperfect intellectual property (IP) protection, deciding between patenting or secrecy, and whether competitors license or imitate innovations.

The study shows firms choose between patenting, offering legal protection, or secrecy, relying on confidentiality. When imitation is tough, licensing is preferred, facilitating technology sharing. But if imitation is easy, firms imitate, increasing competition.

The Mallios set-up is assumes that a technology holder (innovator) must decide whether to file for a patent, which provides legal protection, or rely on secrecy, which depends on maintaining confidentiality. A competing firm can enter the market either through technology transfer (licensing, where the innovator grants rights to use the innovation) or by imitating the innovation without permission. The study acknowledges that IP protection is not absolute and that imitation is often uncertain, imperfect and time-consuming, taking into account the technological and market context.

Licensing is more likely to occur when the technological efficiency of imitation is low (i.e. imitation is difficult, costly, or time-consuming). In such cases, a competing firm finds it more cost-effective to license the innovation rather than attempt to imitate it, regardless of whether the innovator chooses to patent or keep the technology secret.

Conversely, when imitation is highly efficient (i.e. easy and cost-effective, such as in industries with reverse-engineering capabilities), the competing firm is more likely to imitate rather than license, as imitation becomes a more attractive option. This can lead to increased competition but may reduce collaboration and technology sharing.

The risk of a trade secret leaking to the public can make patenting more attractive than secrecy. This is because a leaked trade secret loses its economic value, as competitors can freely use the innovation, whereas a patent provides legal protection even if the innovation becomes known. Additionally, the probability of leakage may increase with the number of firms practicing the secret. For example, if multiple firms within an industry use the same secret, the risk of accidental disclosure rises,

further reducing the appeal of secrecy and making the patent system more attractive as a reliable protection mechanism.

The paper concludes that while licensing can be a welfare-enhancing strategy under certain conditions, the threat of efficient imitation and the risk of secrecy leakage underscore the importance of considering the technological context and market structure when designing IP policies. It finds licensing is favoured when imitation is hard, but easy imitation leads to more competition via imitation. The risk of secrets leaking makes patenting more appealing, especially as more firms use the secret.

The fourth model was prepared by the SGH Warsaw School of Economics scholars [Dietl, Skrok, Wiśnicki, 2025]. It is not a market entry game. The model is rather rooted in patent race literature. Two players intend to secure rights to their intellectual property or IP. However, they are aware that patenting system is far from being perfect. There can be, for instance, overlapping patent rights (e.g. patent thickets). The IP serves as a mean to achieve horizontal product differentiation under the Hotelling framework [1929], where firms compete over product "flavours" on a spectrum. It is important as in this market there is only one single buyer (or a dominant buyer like the government).

There are basically three scenarios. First, the companies' products are fairly separated by uncontested IP rights. Second, there is a major overlap between IP rights what might foster litigation. Third, the IP rights are not privately held (e.g. patents are not granted) and all innovations remain in the public domain.

A single buyer is positioned at the midpoint of the spectrum and prefers the flavour closest to its location. The "transportation" cost, representing a mismatch between the offered flavour and the buyer's preference, is quadratic amplifying the impact of distance. Each firm can choose only one flavour due to tendering rules or time constraints, selecting from their exclusive range, the shared IP space or the public domain (if applicable). The decision hinges on expected profits and litigation risks, resulting in chosen positions or abstention if costs outweigh benefits.

After selecting flavours, firms simultaneously set prices in a one-shot price competition. They aim to maximise profits, knowing each other's positions and the buyer's preference. Prices can reflect the threat of litigation in later steps, especially in shared IP areas, where firms might charge more to offset potential losses. The outcome is a pair of prices that define the offers presented to the buyer. The single buyer (e.g. a government entity in a tender) selects between the offers based on net value. Finally, a non-selling firm may sue the seller if it believes its patent rights were infringed.

Compared to the previously analysed papers, Dietl, Skrok and Wiśnicki [2025] show that both a strong patent system and forcing innovations into public domain

yield same equilibrium – monopoly. This finding brings public tendering policies favouring open-source products into question. A strong patent system indeed gives strong incentives towards innovation. The innovator which is closer to the buyer's expectations can extract the whole willingness-to-pay. However, this outcome is not desired by those who call the tender. It might be an inferior result from social welfare perspective (depending on the exact parameters).

The results are in line with "patent race" models: "The winner takes it all." The player which has secured exclusivity over the IP rights close to client's expectations grabs all profits and consumer surplus. If we do not account for research costs incurred by both players, the social welfare is higher than in the "patent thickets" case.

After reviewing four different models, we do not have a clear view on how imperfect patent protection influences competition and market dynamics. Could the differences be reconciled? The "patent race" framework could be expanded by allowing for licensing in the shared IP space similarly to Capuano and Grassi [2020] or Mallios [2024]. This could be the other venue for resolving disputes.

The reworked Takalo model as presented above and Dietl, Skrok and Wiśnicki's [2025] paper show that imperfect patent protection can increase welfare through competition. Capuano and Grassi highlight that high protection can reduce welfare due to exclusive licensing. On the other hand, Mallios [2024] advocates that licensing is welfare enhancing and provides valuable insights into how firms strategise under imperfect IP protection, focusing on the interplay between protection choices (patenting vs secrecy) and entry strategies (licensing vs. imitation).

There is a diversity of ways to model markets and competition dynamics with imperfect patent protection. Human curiosity will most likely yield with further theoretical and empirical contributions to this field. Nevertheless, we could draw some conclusions from the existing body of knowledge.

Conclusions

The conventional reasoning goes along the following lines: companies and individuals take risk and effort to innovate because they can obtain monopoly profits when the invention gets patented. Therefore, patents foster innovativeness, support economic growth and create diverse socioeconomic benefits. The policy should be supportive to the patents system so the patents can be granted effectively and efficiently. Imperfect or weak patents are rare and preferably they are to be eliminated.

The research does not support this simplistic view. The impact of patents on the innovation capabilities differs across countries (e.g. due to the stage of development), industries (e.g. trade secrets vs patents) and strategic behaviour of actors (e.g. pre-emptive patenting). There is not a level playing field for large and small companies. Patents are also far from being perfect. Some studies suggest that that up to 70% of them have some overlapping rights.

At the end, it might not be such a serious issue. The literature on imperfect patent protection reveals a complex interplay between innovation incentives, market competition and social welfare. While traditional models often assume a straightforward relationship between patent strength and R&D investment, empirical evidence suggests that this relationship is nuanced and context dependent. As industries evolve and face unique challenges related to technology and competition, understanding these dynamics becomes increasingly critical for policymakers aiming to balance the interests of innovators with those of consumers and society.

Imperfect patent protection, exemplified by overlapping rights or "patent thickets", emerges as a double-edged sword in market dynamics. Models by Takalo [1998], and Capuano and Grassi [2020] illustrate that moderate enforcement levels can enhance social welfare by balancing innovation incentives with competitive pressures, as broader but shorter patents discourage secrecy while permitting rational imitation. In oligopolistic settings, such as those modeled by Dietl, Skrok, Wiśnicki [2025] using a Hotelling framework, imperfect protection resolves monopolistic equilibria, yielding duopolistic outcomes that mitigate the "winner-takes-all" pitfalls of strong patents or public domains. Empirical insights from industries like pharmaceuticals [Gupta, 2023] and biotechnology [Barnett, 2000] corroborate this, showing that weak protection facilitates licensing and collaborative networks, though it risks elevated litigation costs [Schankerman, Schuett, 2022]. Mallios [2024] adds nuance, noting that efficient imitation under imperfect IP favours competition over licensing, potentially amplifying welfare in dynamic sectors but exacerbating leakage risks in others.

In summary, literature converges on a paradigm where patents are neither panacea nor impediment but instruments whose value lies in adaptability. Imperfect systems often outperform the perfect ones by injecting competition, as our synthesis of models shows, yielding higher welfare through balanced innovation and access.

REFERENCES

Barnett, J.M. (2000). Cultivating the Genetic Commons: Imperfect Patent Protection and the Network Model of Innovation, *San Diego Law Review*, 37(987).

Bessen, J., Maskin, E. (2009). Sequential Innovation, Patents, and Imitation, *The RAND Journal of Economics*, 40(4), pp. 611–635. DOI: 10.1111/j.1756-2171.2009.00081.x.

Bloom, N., Schankerman, M., Van Reenen, J. (2013). Identifying Technology Spillovers and Product Market Rivalry, *Econometrica*, 81(4), pp. 1347–1393. DOI: 10.3982/ECTA9466.

Capuano, C., Grassi, I. (2019). Imperfect Patent Protection, Licensing, and Social Welfare, *Economics Bulletin*, 39(4), pp. 2639–2649.

Capuano, C., Grassi, I. (2020). Imperfect Patent Protection, Licensing, and Willingness to Pay for the Innovation, *Journal of Industrial and Business Economics*, 47, pp. 333–359. DOI: 10.1007/s40812-019-00142-w.

Cohen, W.M., Nelson, R.R., Walsh, J.P. (2000). Protecting Their Intellectual Assets: Appropriability Conditions and Why US Manufacturing Firms Patent (or not), *NBER Working Papers*, 7552, https://ideas.repec.org/p/nbr/nberwo/7552.html. (accessed: 10.01.2025).

Dietl, M., Skrok, Ł., Wiśnicki B. (2025). Innovation and Competition with Imperfect Patent Protection, *SGH KAE Working Papers Series*, 2025/112, https://cor.sgh.waw.pl/bitstream/handle/20.500.12182/1380/WPKAE_2025_112.pdf?sequence=2&isAllowed=y (accessed: 15.08.2025).

Fagerberg, J., Srholec, M., Verspagen, B. (2010). Innovation and Economic Development. In: *Handbook of the Economics of Innovation* (vol. 2, pp. 833–872), B.H. Hall, N. Rosenberg (Eds.), Amsterdam: North Holland. DOI: 10.1016/S0169-7218(10)02004-6.

Frakes, M.D., Wasserman, M.F. (2017). Is the Time Allocated to Review Patent Applications Inducing Examiners to Grant Invalid Patents? Evidence from Microlevel Application Data, *Review of Economics and Statistics*, 99(3), pp. 550–563. https://www.jstor.org/stable/26616139.

Galasso, A., Schankerman, M. (2015). Patent Rights and Innovation by Small and Large Firms, *NBER Working Paper*, 7552, https://www.nber.org/system/files/working_papers/w21769/revisions/w21769.rev0.pdf (accessed: 10.01.2025).

Gallini, N. (2017). Do Patents Work? Thickets, Trolls and Antibiotic Resistance, *Canadian Journal of Economics / Revue Canadienne d'Économique*, 50, pp. 893–926. DOI: 10.1111/caje.12312.

Gupta, C. (2023). One Product, Many Patents: Imperfect Intellectual Property Rights in the Pharmaceutical Industry, *Working Paper*, June 22. DOI: 10.2139/ssrn.3748158.

Hall, B.H., Rosenberg, N. (2010). Introduction to the Handbook. In: Handbook of the Economics of Innovation (vol. 1, pp. 3–9). B.H. Hall, N. Rosenberg (Eds.). Amsterdam: North Holland. DOI: 10.1016/S0169-7218(10)01001-4.

Horii, R., Iwaisako, T. (2007). Economic Growth with Imperfect Protection of Intellectual Property Rights, *Journal of Economics*, 90, pp. 45–85. DOI: 10.1007/s00712-006-0222-6.

Hotelling, H. (1929). Stability in Competition, *The Economic Journal*, 39(153), pp. 41–57. DOI: 10.2307/2224214.

Krasteva, S. (2014). Imperfect Patent Protection and Innovation, *The Journal of Industrial Economics*, 62(4), pp. 682–708. DOI: 10.1111/joie.12060.

Kremer, M.R. (1998). Patent Buyouts: A Mechanism for Encouraging Innovation, *Quarterly Journal of Economics*, 113(4), pp. 1137–1167. DOI: 10.1162/003355398555865.

Mallios, K.A., (2024). Licensing and Secrecy under Imperfect Intellectual Property Protection, *Theory and Decision*, 97, pp. 527–552. DOI: 10.1007/s11238-024-09984-w.

Mezzanotti, F. (2021). Roadblock to Innovation: The Role of Patent Litigation in Corporate R&D, *Management Science*, 67(12), pp. 7362–7390. DOI: 10.1287/mnsc.2020.3816.

Moser, P. (2005). How Do Patent Laws Influence Innovation? Evidence from Nineteenth-Century World's Fairs, *American Economic Review*, 95(4), pp. 1214–1236. https://www.jstor.org/stable/4132712

Moser, P. (2013). Patents and Innovation: Evidence from Economic History, *Journal of Economic Perspectives*, 27(1), pp. 23–44. DOI: 10.1257/jep.27.1.23.

Park, M., Leahey, E., Funk, R.J. (2023). Papers and Patents Are Becoming Less Disruptive over Time, *Nature*, 613, pp. 138–144. DOI: 10.1038/s41586-022-05543-x.

Qian, Y. (2007). Do National Patent Laws Stimulate Domestic Innovation in a Global Patenting Environment? A Cross-Country Analysis of Pharmaceutical Patent Protection, 1978–2002, *The Review of Economics and Statistics*, 89(3), pp. 436–453. https://www.jstor.org/stable/40043040

Sampat, B.N., Williams, H.L. (2015). How Do Patents Affect Follow-On Innovation? Evidence from the Human Genome, *NBER Working Paper,* w21666. https://ssrn.com/abstract=2679705 (accessed: 10.01.2025).

Schankerman, M., Schuett, F. (2022). Patent Screening, Innovation, and Welfare, *The Review of Economic Studies*, 89(4), pp. 2101–2148. DOI: 10.1093/restud/rdab073.

Scotchmer, S. (1999). On the Optimality of the Patent Renewal System, *The RAND Journal of Economics*, 30(2), 181–196. DOI: 10.2307/2556076.

Takalo, T. (1998). Innovation and Imitation under Imperfect Patent Protection, *Journal of Economics Zeitschrift für Nationalökonomie*, 67, pp. 229–241. DOI: 10.1007/BF01234644.

SUBSIDY COMPETITION IN EUROPEAN FOOTBALL: A CASE OF POLAND

Jędrzej Lubasiński
Polish Economic Institute
e-mail: jedrzej.lubasinski@pie.net.pl

Łukasz Skrok
SGH Warsaw School of Economics
Collegium of World Economy
Department of Business Economics
e-mail: lskrok@sgh.waw.pl

ABSTRACT

The article describes results of an empirical analysis of spatial patterns of development of football leagues in Poland, covering four top tiers of men's competitions and two top tiers of women's competition. An important motivation for conducting the research stems from the observation of relative underdevelopment of football in Warsaw and anecdotal explanations related to it. Using spatial econometric modelling techniques, we investigated the relation between external factors and strength of football clubs at the level of powiats (the second level of Polish local government and administration system) at the end of the 2010s. Firstly, our results show that the relationship between the local market potential and strength of women's football is considerably weaker than in the case of the men's football. Secondly, negative spatial effects for the two genders are consistent with the hypothesis about subsidy competition. Thirdly, local government expenditure on sports is positively related to the level of men's teams, but not the women's teams, further emphasising a lower level of commercialisation of the latter.

JEL Classification: C21, H76, L83, R51, Z21

Keywords:, football, market potential, spatial autocorrelation, spatial econometrics, public funding of professional sports, sports economics

Acknowledgement

The authors would like to thank Andrzej Torój for his crucial advice and to the participants of the 12th ESEA Conference on Sport Economics for their invaluable suggestions.

Introduction

A motivation for the analysis described in this article was our work on a so-far unpublished report commissioned by a Warsaw-based club, describing the state of football in the city from the economic point of view [Lubasiński, Skrok, 2021]. Its aim was to investigate the reasons behind a low number of Warsaw-based clubs at the top level of Polish football. The anecdotal evidence and opinions collected in the project suggest a crucial role of local governments, occurrence of intense spatial competition and disadvantage on the part of the biggest cities. The scope for econometric analysis was limited by the purpose and nature of the report. We kept it in mind employing spatial econometric modelling techniques. The research aim was to assess the impact of local government's expenditure on football clubs state of development, measured by sports strength.

An important, more general phenomenon investigated within the analysis has been the "subsidy competition", a process studied within international economics [e.g. Borck, Koh, Pflüger, 2012; Kondo 2013] within which countries or regions compete for companies or investment by effectively subsidising them. A similar process is often suggested in the case of American leagues [e.g. Coates, 2019], where, due to a closed form of competition cities effectively compete for teams in the major leagues (NBA, NFL, MLB, NHL) by offering subsidies or tax reliefs, usually with respect to arenas or stadiums. Ross and Szymanski [2010] suggested that under the open league systems the possibilities for clubs to extract subsidies from local governments would be lower than under the closed league systems. Humphreys and Zhou [2015] develop a circular city monopolistic competition model that is adjusted for specificity of a sports arena to explain motivation for subsidies in the American context.

On the other hand, as our aforementioned investigation indicates, the European multi-level league structure with regionalised system in lower tiers creates another way in which subsidies form local government units (Local Administrative Units, LAU) harm competition – between football clubs – by restricting possibilities to be

promoted to higher leagues, with greater revenue potential. The reason for this is the availability of external funds that can be transferred to clubs and increase their budgets. This allows for higher renumerations paid to the best players. Besides, since most clubs usually do not own sport facilities but only rent them, usually for LAUs, a lower number of competing clubs might lead to an easier access to matchday and training infrastructure, also a more modern one, which can be used irrespective of the weather conditions. As a result, greater subsidies increase strength of teams, which, in a longer perspective, creates opportunity to win promotion to higher-tier leagues. This enables access to considerably higher revenues, including TV broadcasts, and, eventually, financial stability necessary for long-term investment in both team development and infrastructure [Lubasiński, Skrok, 2021].

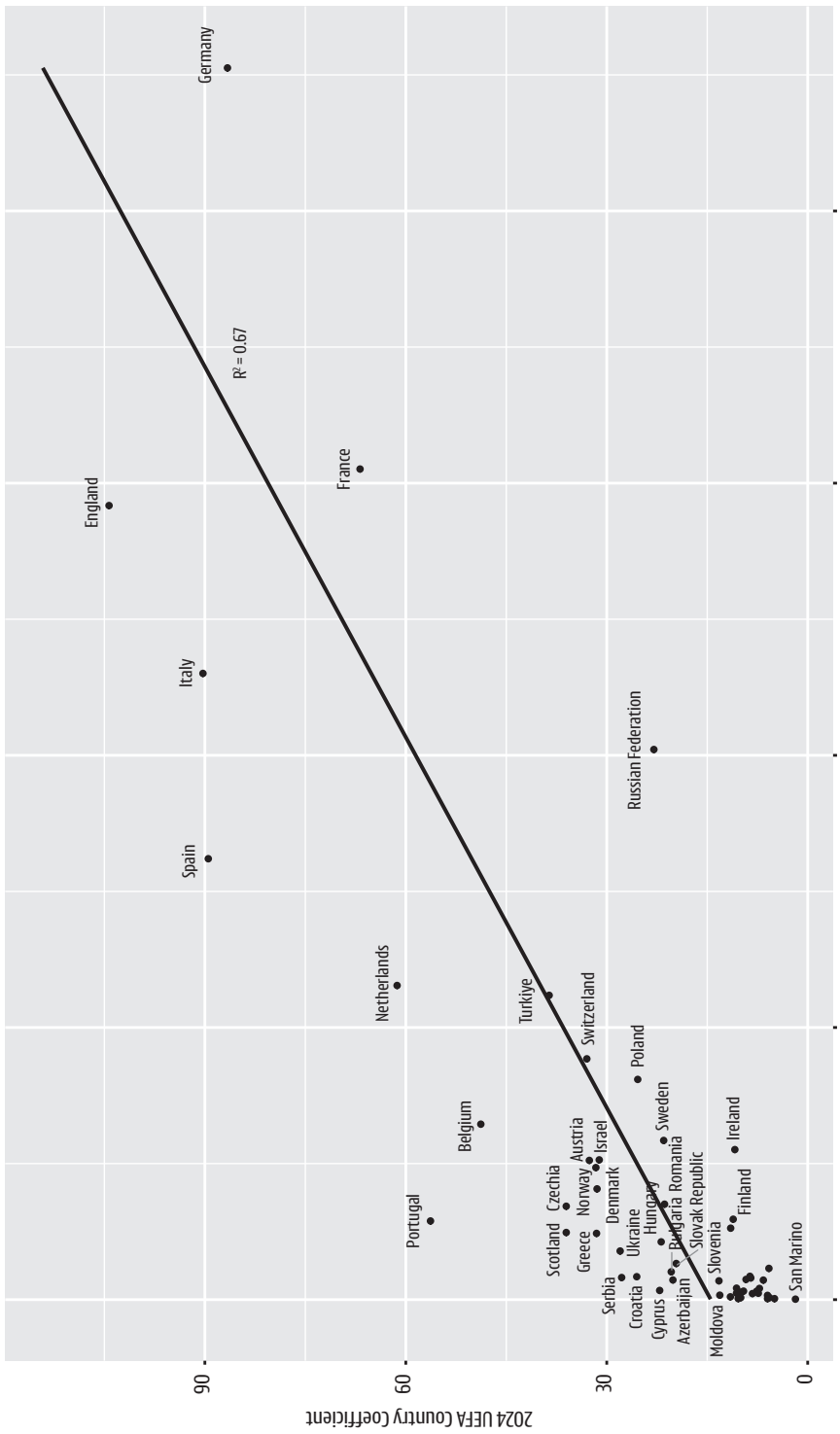
When considering subsidy competition, it is especially important to consider less affluent leagues and clubs, in particular, those in lower tiers. As Andreeff and Staudohar [2000] argue and financial data show [e.g. UEFA, 2020], over the last decades of the twentieth century, the financing model at the top level of football was transformed from the one relying on local resources like fans, entrepreneurs and local governments to the one of greater scope relying on broadcasting rights, corporate partnerships and international exposure. In particular, as Wyszyński [2015] showed, the reliance of clubs on public funds increases significantly with each lower tier of the league system in Poland.

Unsurprisingly, spatial modelling of economic aspect of sports has mostly concerned infrastructural or land aspects. Feng and Humphreys [2008] have estimated a model with spatial lags to analyse, positive, but within a limited area, impact of two sport facilities on residential real estate values in Columbus. Ahlfeldt and Maennig [2010] find in general analogous results for two stadiums in Berlin, Keeler, Stephens and Humphreys [2021] for Staples Center and Los Angeles and Propheter [2023] for Chase Center in San Francisco. Torres, Torres, Arbeláez, and Ceballos [2015] found opposite effects for Medellin (Colombia) and Hyun [2022] for Gwangju (South Korea). Ahlfeldt and Feddersen [2010] empirically analysed the issue of provision of sport facilities in particular areas of a city using a dataset on Hamburg.

The context

As Figure 12 illustrates, at the end of the second decade of the 21st century, Polish men's club football achievements remained below the country's economic and demographic potential.

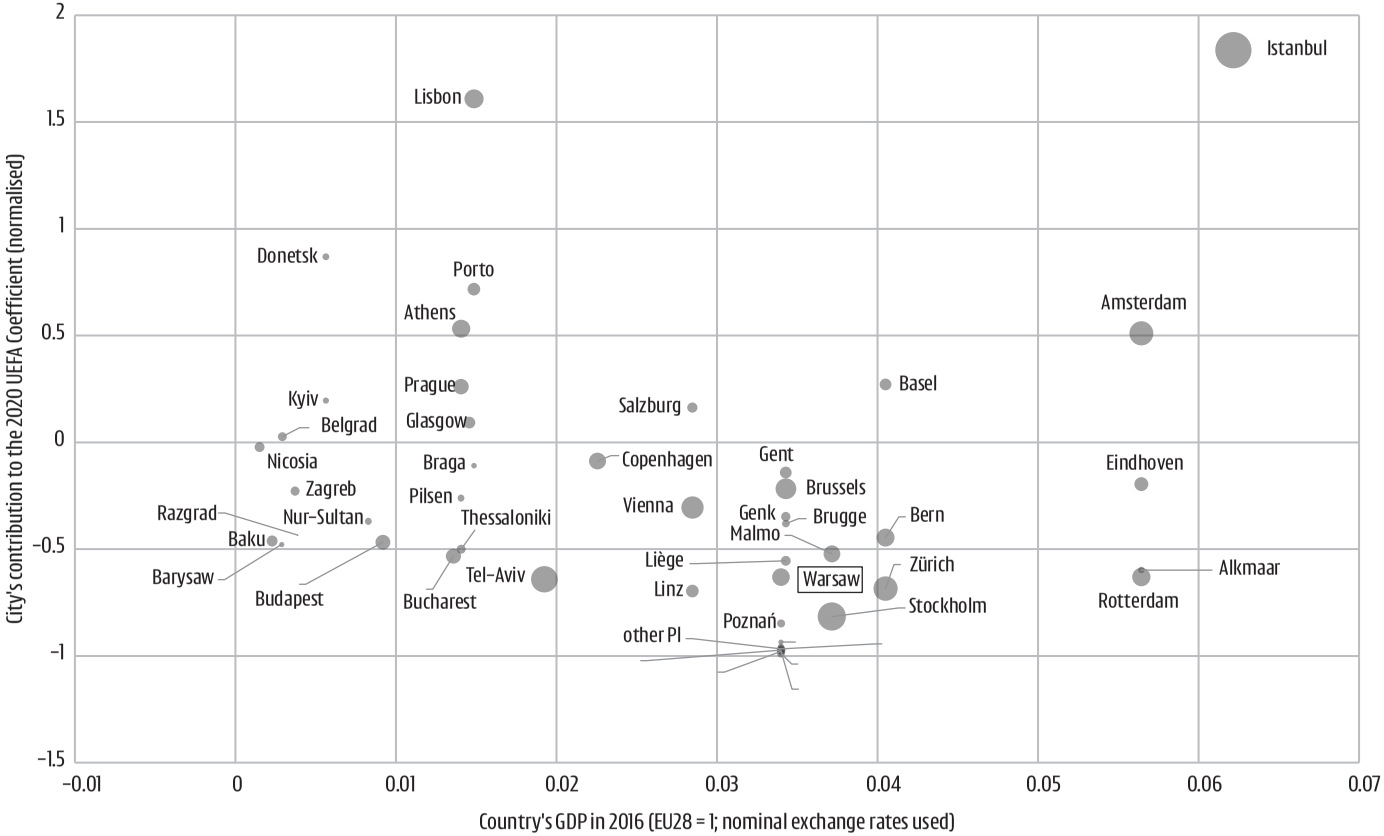
Figure 12. GDP and UEFA Club Coefficient for UEFA leagues



Note: For Liechtenstein and San Marino data on GDP from 2022 were used, for England, Northern Ireland, Scotland and Wales 2022 proportions and value of GDP for UK from 2023 were used.

Source: Authors' own compilation based on the World Bank, UEFA and ONS data.

Figure 13. Countries and cities economic size and UEFA Club Coefficient for UEFA leagues – Polish football against top European leagues form countries of comparable GDP



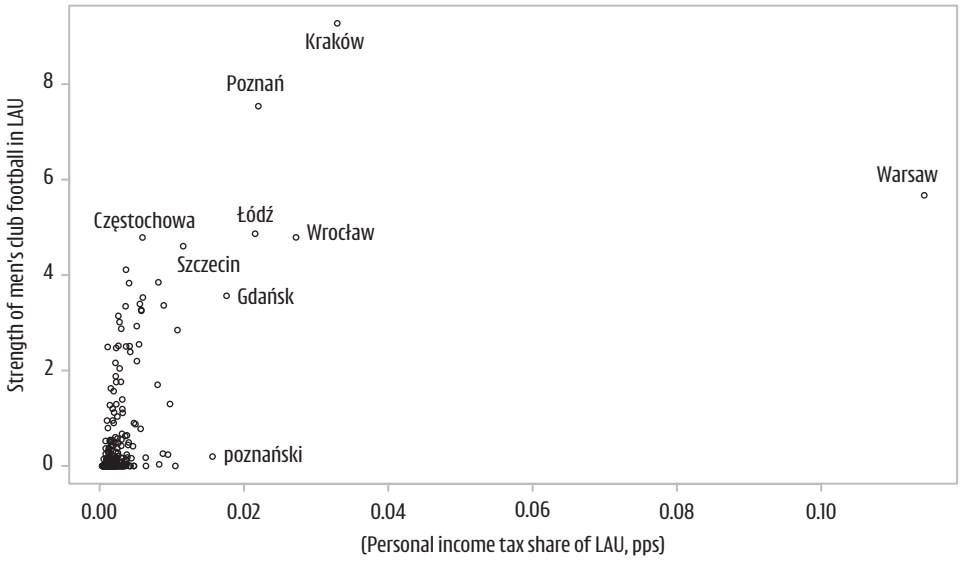
Note: For greater clarity, the graph is censored with respect to economic size of the country (measure by its GDP). In particular, Spain, Italy, England and Wales, Germany have GDP over the threshold (0.07 of EU28) and, therefore, are not included in the graph. Bubble size reflects city's/urban area's contribution to GDP in 2016 (with nominal exchange rates used). The city's contribution to the UEFA Coefficient is normalised with respect to 32nd team in the 2020 ranking – Schalke 04 Gelsenkirchen (its score has been set at 0).

Source: Authors's own compilation based on Lubasiński, Skrok [2021] and the World Bank, Eurostat and UEFA data.

Figure 13 shows that, at the city level, Warsaw, the capital and biggest city of Poland, was the main contributor to Poland's UEFA Club Coefficient. The outcomes, however, were considerably weaker than for economically comparable cities from other European countries. Unlike Switzerland, where Zurich has been recently superseded by Basel as the top city in terms of men's football, or Austria, where Vienna clubs had less success than RB Salzburg in recent years, no other Polish city hosts a football club to have successfully competed in European competition in the last ten years.

However, as Figure 14 illustrates, in terms of domestic competition of men's teams Warsaw's contribution is lower than expected considering the relative economic size of the capital city. This is even more pronounced in the case of the women's football (see Figure 15). As a matter of fact, no Warsaw-based club competed in either of the two top leagues between seasons 2021/2022 and 2023/2024, when Legia Warsaw took over a club from another region of Poland that played in the second-tier league [90 Minut.pl, 2024].

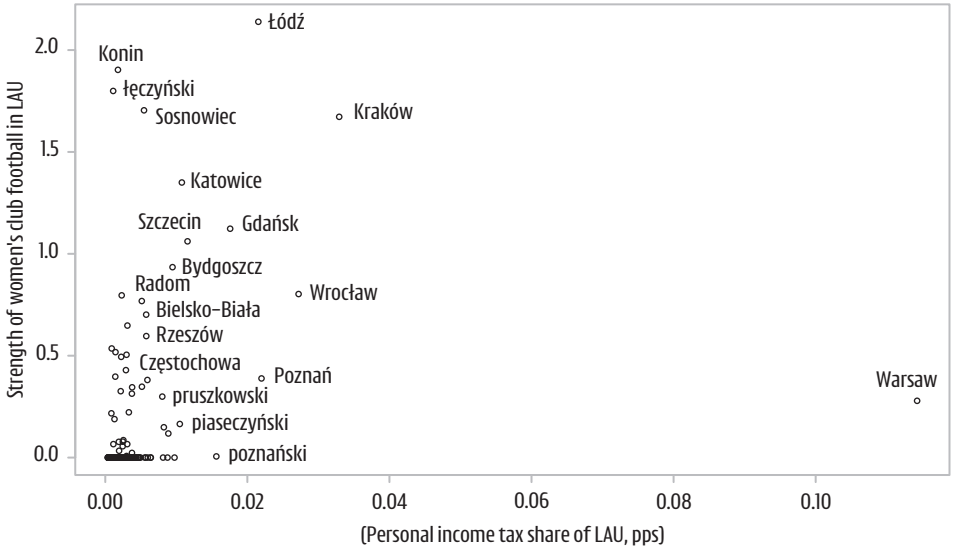
Figure 14. Share of the Personal Income Tax in Poland (average for 2016–2023) and the level of men's football (2016/2017–2023/2024) in powiats



Note: The strength index was based on four top tiers of men's competition. It was based on a number of clubs located in a given regional unit, weighted by the tier at which these clubs competed (i.e. clubs competing in the top league received 3 points, on the second level 2 points etc.) and their win ratios, and averaged over eight seasons.

Source: Authors' own compilation based on Lubasiński, Skrok [2021] and footystats.org and Statistics Poland data.

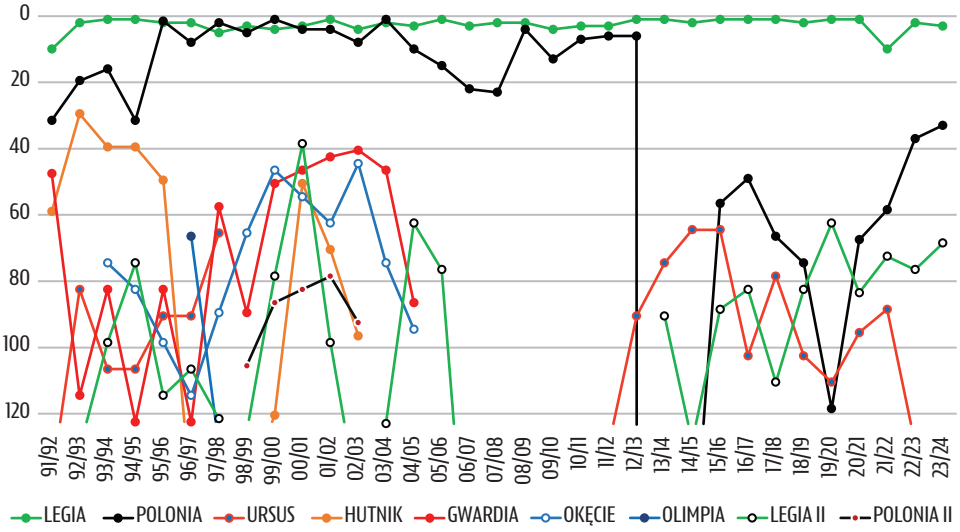
Figure 15. Share of the Personal Income Tax in Poland (average for 2016–2023) and the level of women's football (2016/2017–2023/2024) in powiats



Note: The strength index was based on two top tiers of women's competition. It was based on a number of clubs located in a given regional unit, weighted by the tier at which these clubs competed (i.e., clubs competing in the top league received 1 point, on the second level no points) and their win ratios, and averaged over three seasons.

Source: Authors' own compilation based on footystats.org and Statistics Poland data.

Figure 16. Warsaw's clubs rank in men's football in Poland (1991–2024)



Source: Authors' own compilation based on Lubasiński, Skrok [2021] and mogiel.net [Mogielnicki, 2006] and 90minut.pl data.

Figure 16 further illustrates the lack of competitive balance within Warsaw's football. In particular, over the last 10 years, Warsaw's contribution to the domestic men's football at the top level can be attributed to one club only (Legia). Others have competed below the third tier league over that period, except for Polonia which in season 2022/2023 managed to get promoted to the second tier competition. Obviously, also at the European level, Warsaw's contribution came from Legia only and its inconsistent participation in the UEFA competitions.

The qualitative analyses based on interviews with club representatives [Lubasiński, Skrok, 2021] led to the conclusions that the balanced development of football in Warsaw might have been hampered by the dominance of Legia, which limited the market potential of other entities due to attracting fans' attention, but also reduced the willingness of the local authorities to support the discipline, by difficult market conditions, for example expensive access to sports infrastructure, and also by competition of clubs from neighboring powiats which were able to build stronger teams due to more beneficial financial conditions, partially resulting from local public financing. The importance and broad scope of channels to support football clubs by the local administrative units (LAUs) has been discussed by Gawrecki [2024]. Importantly, this would suggest a spatial relation opposite to the positive agglomeration effects identified for English football by Doran and Jordan [2018].

The motivation to write this article was to empirically examine spatial effects in Polish football as well as impact of financial support from the LAUs. Cross-sectional spatial econometric methods were used to meet this goal.

Data and Methods

Unfortunately, no complete and precise data on use of public funds in football have been collected yet. Therefore, to investigate the relation between the use of public funds and strength of football clubs, Statistics Poland data on LAUs expenditure in 380 'NUTS 4' territorial units on physical activity (current expenditures, subsidies, investments) in 2011–2016. It should be borne in mind that expenditure data concerns all sports – no discipline, including football has been singled out. A set of demographic and economic variables (Statistics Poland) as well as results of parliamentary election results in 2023 (National Electoral Commission) were used as control variables (Table 1). The latter was motivated by the supposed congruence of support for development of football and political polarisation in Poland [Lubasiński, Skrok, 2021].

In order to focus on the long-term differences between strength of football and economic factors, a set cross-sectional models based on values averaged over time were examined. In particular, based on results of LM test and information criteria (Table 2), we chose to present spatial autoregressive (SAR), spatial Durbin error model (SDEM) and spatial Durbin model (SDM). For comparison, specification with spatially lagged matrix of independent variables (SLX) is also presented in the main results. Other specifications (OLS and spatial error model, SEM) are presented in the Appendices. The analysis was conducted separately for women's and men's football. As the dependent variable, in each model, a specifically constructed index of strength was used, which was based on the number of clubs from a given powiat, the tiers at which they competed and their win ratios. To reduce the impact of one-season fluctuations in form, an average for eight last seasons (2016/2017–2023/2024) was calculated. Previous changes in the competition format (and withdrawals during the seasons), especially at the lower tiers, prevented the use of earlier seasons and inclusion of further lower tiers in the analysis.

$$women's\ strength_i = \frac{1}{3}\sum_t \sum_{wKi,t} (w_{k,t} + (2 - L_{k,t})),$$

$$men's\ strength_i = \frac{1}{3}\sum_t \sum_{mKi,t} (w_{k,t} + (4 - L_{k,t})),$$

where $w_{k,t}$ – win ratio of club k in season t, $L_{k,t}$ – tier of the league system in which club k competed in season t, $w_{Ki,t}$ – set of clubs from LAU i competing in two top tiers of women's competition in season t, $m_{Ki,t}$ – set of clubs from LAU i competing in four top tiers of women's competition in season t.

In line with the literature, the general formula for spatial models might be described as:

$$\boldsymbol{y} = \lambda \mathbf{W}\boldsymbol{y} + \mathbf{X}\beta + \mathbf{W}\mathbf{X}\theta + \boldsymbol{\epsilon}, \tag{85}$$

$$\boldsymbol{\epsilon} = \rho \mathbf{W}\boldsymbol{\epsilon} + \boldsymbol{u}. \tag{86}$$

In particular, for the SEM and SDEM the spatial autocorrelation coefficient:

$$\lambda = 0, \tag{87}$$

and for SAR and SDM, the errors spatial correlation coefficient:

$$\rho = 0, \tag{88}$$

for OLS, SEM and SAR coefficients for dependent variables matrix:

$$\theta = 0, \tag{89}$$

and for OLS and SLX [Elhorst, 2014]:

$$\lambda = \rho = 0. \tag{90}$$

All analyses used R Statistical Software [v4.3.1; R Core Team, 2023]. For estimation, we used packages: spatialreg [Bivand, Pebesma, Gomez-Rubio, 2013; Bivand, Millo, Piras, 2021; Bivand, Piras, 2015; Pebesma, Bivand, 2023], spdep [Bivand, 2022; Pebesma, Bivand, 2023] and sphet [Bivand et al., 2021; Piras, 2010; Bivand, Piras, 2015; Piras, Postiglione, 2022]. The assumed distance matrix was the inverse distance matrix based on centroids of LAU areas, normalised by rows. The matrices were calculated based on maps provided by CODGiK for powiats and Eurostat [2019] for voivodeships – provinces], further adapted and made available by Torój [2019]. For the auxiliary tests, estimations and visualisations, we used packages: calibrate [Graffelman, van Eeuwijk, 2005], lmtest [Zeileis, Hothorn, 2002], sandwich [Zeileis, 2004; Zeileis, Köll, Graham, 2020] and stargazer [Hlavac, 2022].

Table 14. Descriptive statistics

	Mean	Std. dev.	Min	Median	Max
Men's strength	0.43	1.11	0.00	0.00	9.28
Women's strength	0.07	0.26	0.00	0.00	2.14
Area (in 1000 km)	0.82	0.52	0.01	0.77	2.98
Population density (in 100/km)	0.36	0.64	0.02	0.09	3.61
Average salary (Poland = 1)	0.86	0.10	0.68	0.83	1.65
Feminisation rate	1.05	0.04	0.96	1.04	1.19
LAU current expenditure on sports	0.16	0.21	0.001	0.09	2.05
LAU investment in sports	0.20	0.35	0.01	0.12	3.69
LAU subsidies for sports	0.08	0.16	0.0003	0.05	2.45
Votes for minor opposition parties	0.11	0.02	0.06	0.11	0.24

Source: Authors' own work.

Results

Table 15 presents results of Moran I test and Lagrange Multiplier tests. The main results of the analysis are presented in Tables 16–17, showing estimates for the baseline specifications (SLX, SAR, SDM and SDEM), and Table 18, presenting indirect impact analysis for the SDM specification. Supplementary tables present results for alternative specifications (OLS and SEM) and estimators.

For both genders the LM test suggest that SAR specification should be preferred to SEM, but either SDM or SDEM could be used as well, while SLX is insufficient, though for women spatial correlation is weak.

Table 15. Moran I and LM tests

	Women's league OLS	Men's league OLS	Women's league SLX	Men's league SLX
Moran I	−1.436*	−2.061*	−1.647**	−2.896***
LMerr	2.762*	4.617	4.395**	8.644***
LMLag	4.376*	13.829****	4.774**	8.356***
RLMerr	0.088	0.144	0.062	0.341
RLMlag	1.702	9.356***	0.401	0.054
SARMA	4.465*	13.972****	4.780*	8.698**

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; **** $p < 0.001$.
Source: Authors' own work.

For women's football, the SAR specification seems to best fitting as suggested by the information criterion. Indeed, most of the estimated coefficients of spatially lagged independent variables are not significantly different from zero, especially in the SLX specification. Two of the variables which might be considered as negatively influencing the development of women football teams in surrounding powiats are the ones that positively affect development locally. These are population density (an increase by one standard deviation of the density meant increase by over 5.7 pps of the win ratio index, though no significant effect is found for the SAR specification) and average salary level (an increase by one standard deviation of the average salary meant increase by 2.7–3.3 pps in the win ratio index), both contributing significantly to a market potential of a given area. Consistently, a significantly negative spatial correlation was found for SAR, SDEM and SDM specification (Table 16). This suggests spatial competition, even though the initial Moran I test was far from conclusive, as shown in Table 15. In particular, impact analysis (Table 18) for SDM suggests that increase in the two variables describing market potential by their standard deviations in all the other powiats means, on average, a worsened win ratio index by 13.6 (population density) or 21 (average salary) pps, emphasising that capacity to host teams in communities close to the biggest, wealthiest cities is severely limited – it should be borne in mind that the inverted distance matrix was used.

Furthermore, we found a positive effect of LAU current on physical activity – an increase by one standard deviation of the expenditure meant an increase by 6–7.5 pps in the win ratio index and investment expenditure – an increase by one

standard deviation of the expenditure meant an increase by 6.4–7.8 pps in the win ratio index. It suggests a positive impact of support for development of organisation and physical framework for sports. On the other hand, subsidies for sports were found to be negatively related to the development of women's football – an increase by one standard deviation of the expenditure meant decrease by 4–5.3 pps in the win ratio index. Perhaps, it indicates competition and focus on other disciplines or men's football in each powiat.

Nevertheless, it should be borne in mind that homoscedasticity assumption is rejected without any doubt. For the SLX robust HC3 estimators included in the sandwich package [Zeileis, 2004; Zeileis et al., 2020] are reported in Table 16. Due to differing estimation methods (SLS instead of ML), default standard errors are reported for the other specifications. However, Table E presents alternative calculations, using spatial two-stage least square estimation methods for robust standard errors implemented either in the spdep package [Bivand, 2022; Pebesma, Bivand, 2023] or the sphet package [Bivand et al., 2021; Piras, 2010; Bivand, Piras, 2015; Piras, Postiglione, 2022]. In general, these results remain, to a significant extent, consistent with the outcomes described above, with greatest doubts concerning spatial effect in general and estimations proving to be relatively noisy.

Table 16. Strength of women teams

	SLX	SAR	SDM	SDEM
Spatial autocorrelation		−0.947** (0.413)	−1.183** (0.469)	
Spatial error autocorrelation				−1.173** (0.482)
Area of LAU	0.033 (0.039)	0.006 (0.029)	0.031 (0.032)	0.033 (0.033)
Population density	0.092* (0.054)	0.042 (0.030)	0.089** (0.038)	0.088** (0.039)
Average salary	0.348 (0.353)	0.266** (0.131)	0.332** (0.136)	0.331** (0.137)
Feminisation rate	−0.006 (0.770)	0.310 (0.502)	0.016 (0.558)	0.014 (0.567)
LAU current expenditure on sports	0.347* (0.195)	0.286**** (0.079)	0.359**** (0.087)	0.347**** (0.085)
LAU investment in sports	0.188 (0.137)	0.224**** (0.042)	0.183**** (0.043)	0.190**** (0.043)
LAU subsidies for sports	−0.325 (0.339)	−0.252*** (0.090)	−0.333**** (0.096)	−0.326**** (0.096)

	SLX	SAR	SDM	SDEM
Votes for minor opposition parties	0.193 (0.693)	0.169 (0.553)	0.156 (0.687)	0.186 (0.683)
Spatial area of LAU	−0.483 (0.344)	−0.530 (0.536)	−0.504* (0.299)	−0.434 (0.268)
Spatial population density	−0.542* (0.326)		−0.552** (0.241)	−0.540** (0.224)
Spatial average salary	−3.963 (2.523)		−4.155* (1.620)	−3.858*** (1.398)
Spatial feminisation rate	5.125 (5.952)		6.491 (5.151)	5.721 (4.713)
Spatial LAU current expenditure on sports	1.110 (1.038)		1.429* (0.784)	1.342* (0.803)
Spatial LAU investment in sports	−0.592 (0.631)		−0.343 (0.578)	−0.679 (0.543)
Spatial LAU subsidies for sports	−0.117 (1.617)		−0.247 (1.124)	−0.087 (1.016)
Spatial votes for minor opposition parties	−2.106 (4.168)		−1.614 (4.073)	−1.991 (3.570)
R^2	0.316			
Adjusted/Nagelkerke R^2	0.286	0.300	0.327	0.327
F Statistic (*df* = 16; 363)	10.482****			
Log likelihood		36.585	44.100	43.900
Sigma^2	0.049	0.048	0.046	0.046
Akaike inf. Crit.	−45.849	−51.170	−50.199	−49.801
Wald Test (*df* = 1)		5.245**	6.350**	5.919**
LR test (*df* = 1)		5.599**	6.351**	5.952**
Residual autocorrelation test		0.044	0.025	
Breusch–Pagan test	45.430****	37.526****	44.911****	44.459***

Note: Standard errors in parentheses; * p < 0.1; ** p < 0.05; *** p < 0.01; **** p < 0.001.
Source: Authors' own work.

For men (Table 17), most of the results are similar to the ones described for women, but the effects are stronger, (even taking into account higher values of the index for men) and clearer. Firstly, a positive relation can be once more observed in the case of population density – an increase by one standard deviation of the density meant increase by between 33 pps in the SAR specification, and 51 pps in the SDEM specification, in the win ratio index, and average salary level – an increase by one standard deviation of the salary meant an increase by 23–25 pps in the win ratio

index. Strong effects are also found for LAU current expenditure on physical activity – an increase by one standard deviation of the expenditure meant an increase by 14–18 pps in the win ratio index and investment – an increase by one standard deviation of the expenditure meant an increase by 37–41 pps in the win ratio index. Unlike in the case of women, there is no negative relation to subsidies, for the SAR specification, the coefficient is even significantly greater than zero. It might suggest that men's football is more often a benefactor of such subsidies than women's. Another difference in comparison to women teams can be seen regarding significant impact can be seen in case of feminisation rate (an increase by one standard deviation of the expenditure meant a decrease by 12–21 pps in the win ratio index). It suggests that while they have the most substantial market potential, the largest, wealthiest Polish cities have been not as good space for development of men's football as population density and salaries would suggest.

In terms of spatial correlation, a negative correlation has been observed as well (Tables 16 and 17). While scale of the distance matrix should be considered (see Table 20 for description of the distances distribution), a direct effect of one club moving one league up would mean between approximately between 2 pps and even over 50 pps lower win ratio in a nearby LAU. This is further reinforced by strong negative, indirect impact of population density (an increase by one standard deviation in all the other powiats meant a decrease by over 91 pps in the win ratio index), average salary (an increase by one standard deviation in all the other powiats meant a decrease by 37 pps in the win ratio index) and positive of feminisation rate (an decrease by one standard deviation in all the other powiats meant a decrease by 54 pps in the win ratio index Table 5).

On a more general note, as for differences between the two genders, it may be concluded that a greater degree of commercialisation of men's competition indeed results in greater impact of market potential and financial support from LAUs on the possibilities to run a successful football team than for women.

As in the case of women's teams, homoskedasticity assumption is rejected, but results based on use of robust estimators do not change outcomes substantially (Table 24), with the most important exception being LAU current expenditure on physical activity, for which coefficient in some specifications is not significantly different from zero.

No clear impact of voting tendencies can be observed for genders or LAU areas. For the first one, however, some specifications (spatial effect in the SDEM for men, both local and spatial for men for some of alternate estimations presented in Table 24) suggest positive relation between support for minor opposition parties (all

except Law and Justice) and the state of development of football. Taking into account the profiles of these parties, to some extent, it suggests confirmation of supposed linked between men's football and right-wing worldview, on the other, opposition to major parties in general. It should be borne in mind, however, that this outcome is far from clear-cut, also due to the lack of robustness to specification.

Table 17. Strength of men teams

	SLX	SAR	SDM	SDEM
Spatial autocorrelation		−1.320**** (0.314)	−1.542**** (0.437)	
Spatial error autocorrelation				−1.915**** (0.445)
Area of LAU	0.056 (0.089)	−0.032 (0.089)	0.066 (0.098)	0.062 (0.099)
Population density	0.741**** (0.204)	0.515**** (0.093)	0.728**** (0.117)	0.790**** (0.117)
Average salary	2.428** (1.056)	2.317**** (0.399)	2.441**** (0.410)	2.506**** (0.412)
Feminisation rate	−4.812* (2.557)	−3.041** (1.533)	−4.986*** (1.685)	−5.228*** (1.716)
LAU current expenditure on sports	0.797 (0.726)	0.665*** (0.246)	0.842*** (0.263)	0.723*** (0.256)
LAU investment in sports	1.059** (0.522)	1.177**** (0.128)	1.060**** (0.129)	1.047**** (0.130)
LAU subsidies for sports	0.446 (1.472)	0.829*** (0.274)	0.434 (0.290)	0.411 (0.291)
Votes for minor opposition parties	1.209 (1.858)	2.334 (1.684)	0.952 (2.077)	−0.052 (2.035)
Spatial area of LAU	0.113 (2.054)		−0.015 (0.903)	0.056 (0.762)
Spatial population density	−2.896** (1.426)		−2.402*** (0.752)	−3.000**** (0.657)
Spatial average salary	−7.526 (10.883)		−5.407 (4.901)	−5.087 (3.894)
Spatial feminisation rate	29.583 (33.541)		25.527 (15.527)	24.023* (13.577)
Spatial LAU current expenditure on sports	6.756 (13.255)		5.781** (2.359)	3.984 (2.494)
Spatial LAU investment in sports	−0.037 (3.279)		2.472 (1.768)	1.805 (1.605)

cont. Table 17

	SLX	SAR	SDM	SDEM
Spatial LAU subsidies for sports	−2.838 (7.592)		0.489 (3.463)	−0.617 (2.895)
Spatial votes for minor opposition parties	11.886 (14.446)		19.853 (12.293)	23.749** (10.156)
R^2	0.643			
Adjusted/Nagelkerke R^2	0.627	0.634	0.653	0.656
F Statistic (*df* = 16; 363)	40.791****			
Log likelihood		−386.374	−377.185	−375.719
Sigma^2	0.460	0.442	0.420	0.413
Akaike inf. Crit.	801.763	794.749	792.371	789.437
Wald Test (*df* = 1)		17.709****	12.428****	18.529****
LR test (*df* = 1)		18.855****	11.392****	14.326****
Residual autocorrelation test		0.389	0.150	
Breusch–Pagan test	124.68****	137.39****	120.36****	126.74***

Note: Standard errors in parentheses; * p < 0.1; ** p < 0.05; *** p < 0.01; **** p < 0.001.

Source: Authors' own work.

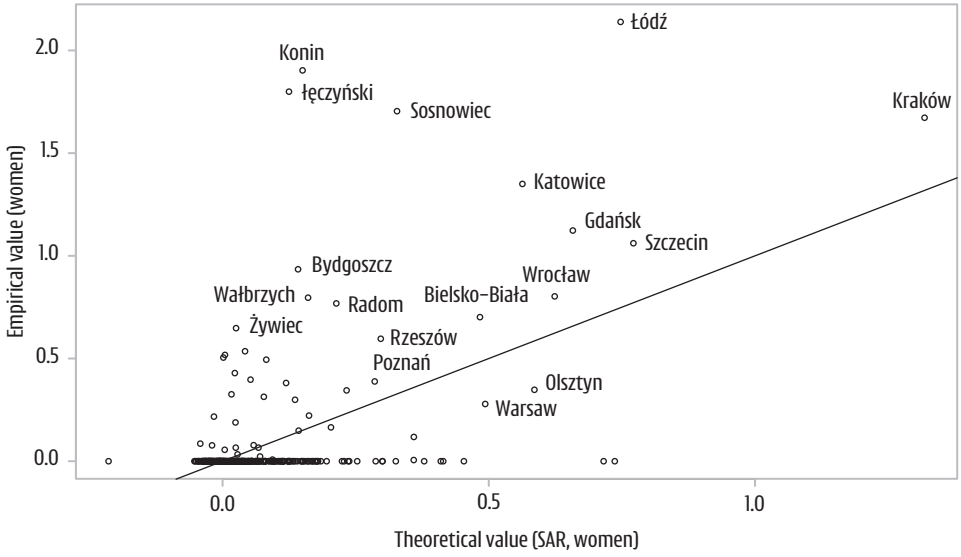
Table 18. Indirect and total estimated impact for SDM specifications

	Indirect for men	Total for men	Indirect for women	Total for women
Area of LAU	−0.047 (0.408)	0.020 (0.366)	−0.252 (0.165)	−0.217 (0.153)
Population density	−1.420**** (0.408)	−0.658* (0.344)	−0.306** (0.149)	−0.212* (0.129)
Average salary	−3.696* (2.165)	−1.167 (2.033)	−2.118** (0.956)	−1.751* (0.927)
Feminisation rate	13.384* (7.300)	8.080 (6.501)	3.014 (2.844)	2.981 (2.607)
LAU current expenditure on sports	1.806 (1.111)	2.605** (1.145)	0.467 (0.436)	0.819* (0.453)
LAU investment in sports	0.338 (0.723)	1.389* (0.710)	−0.260 (0.302)	−0.073 (0.300)
LAU subsidies for sports	−0.073 (1.459)	0.363 (1.411)	0.069 (0.570)	−0.266 (0.557)
Votes for minor opposition parties	7.408 (6.108)	8.184* (4.834)	−0.837 (2.270)	−0.668 (1.859)

Note: Standard errors in parentheses and estimated using 10,000 bootstrap replications; * p < 0.1; ** p < 0.05; *** p < 0.01; **** p < 0.001.

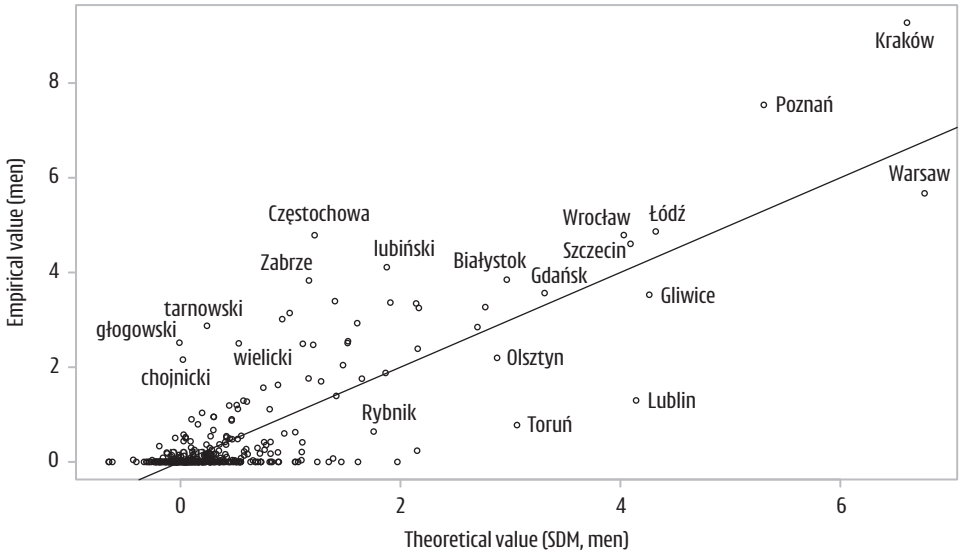
Source: Authors' own work.

Figure 17. Comparison of empirical and theoretical value (calculated using the most accurate model – SAR) for women's football strengths in Polish powiats



Source: Authors' own work.

Figure 18. Comparison of empirical and theoretical value (calculated using the most accurate model – SDM) for men's football strengths in Polish powiats



Source: Authors' own work.

Lastly, Figures 17 and 18 providing comparison of theoretical and empirical value of football strength show that Warsaw is indeed relatively underperforming as a base for development of the discipline, especially Łódz (women), Poznań (men) and Kraków (both genders). This underperformance, when considering used explanatory variables, is relatively limited. In other words, socio-economic characteristic of the city and spatial aspects explain a major portion of the relative underperformance described in the introductory part of the article. One should also bear in mind fundamental characteristics of the analysed distributions – biggest cities, as well as top clubs are essentially outliers. Fitting linear regression models can always underestimate the impact of the decreasing returns to scale.

Conclusions and limitations

The obtained results suggest that the women's football in Poland is operating within grassroots model, less commercialised and reliant on market forces. The difference between the two genders – level of salaries, necessary expenditure on sports facilities etc. might also explain different results in terms of correlation with public expenditure. In general, our results suggest that traditional financing model based in substantial part on local funding and subsidies, even recently, is still relevant for men's football in Poland.

The crucial limitation of the research was a possible endogeneity of the explanatory variables. It may be argued that for the control variables it is less of an issue, since the level of professional clubs as a factor significantly influencing the demographic and economic issues does not usually find confirmation in empirical research [e.g. Coates, 2019]. A more concerning issue is the possible endogeneity of the data on public expenditure. Specifically, a presence of a strong, successful team in a given city or village, with broad local social support or substantial opportunities for exposure at national (or even international) level, could increase motivation for local authorities to support the club to a greater extent. For this reason, time-lagged data on public expenditure was used. This does not resolve the issue completely; however, due to a strong path dependence in professional football, where "success breeds success", e.g. through increasing fan base after winning trophies [e.g. Sass, 2016]. As a result, the analysis should be interpreted with caution. The scope for extending the research in this respect would be to consider quasi-experimental designs or instrumental variables method (e.g. using data on outcomes of local government elections resulting in substantial changes of the structure of the authorities and policies regarding sports).

Furthermore, the used expenditure data concern general expenditure on all sports, without distinction between disciplines, professional status or gender. Our results confirm that it nevertheless signals the stance of LAU towards supporting sport. For example, professional and semi-professional clubs can benefit, in general, from grants aimed at supporting youth teams through shared fixed costs. Furthermore, indirect (e.g. through additional employment opportunities) or financial assistance may also be awarded through city-owned or state-owned companies. In terms of assessment of the spatial competition, it could be captured by spatial correlation in errors. A potential improvement in this respect would be to utilise data on the use public finances in football, which would have to be collected individually on club/LAU level and aggregated.

Furthermore, we have not found strong support for the relation between football development and political stances in the local community. This might still result from an inadequate measure of the latter. Unfortunately, at the powiat level, availability of more direct measures is limited and, at best, incomplete.

Another interesting extension would to be to conduct the analysis for different European countries, especially for the ones in which popularity of women's football has increased substantially in the recent years, with the clubs with most renowned men's teams gradually dominating national and continental competition also within women's competition. To be able to reliably compare the results, it would be necessary to collect consistent datasets for different European countries. Furthermore, it would allow for analysis of cross-border spatial effects, which could enhance the distinction between long-run regional cultural effects, which might transgress borders and affect differing policies and institutional framework resulting from the operation in separate states.

Appendix A. Additional tables

Table 19. Descriptive statistics for spatially lagged variables

	Mean	St. dev.	Min	Median	Max
Men's strength	0.46	0.11	0.30	0.43	1.73
Women's strength	0.07	0.02	0.04	0.07	0.32
Area (in 1000 km)	0.79	0.10	0.47	0.80	1.15
Population density (in 100/km)	0.39	0.12	0.26	0.36	1.03
Average salary (Poland = 1)	0.86	0.01	0.82	0.86	0.91

cont. Table 19

	Mean	St. dev.	Min	Median	Max
Feminisation rate	1.05	0.01	1.03	1.05	1.08
LAU current expenditure on sports	0.17	0.03	0.11	0.16	0.37
LAU investment in sports	0.21	0.03	0.14	0.20	0.46
LAU subsidies for sports	0.09	0.01	0.06	0.09	0.29
Votes for minor opposition parties	0.11	0.004	0.10	0.11	0.13

Source: Authors' own compilation based on footystats.org, Statistics Poland and National Electoral Commission data.

Table 20. Percentiles describing distribution of distance for non-zero elements of the distance matrix

0%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
0.0006	0.0010	0.0011	0.0012	0.0013	0.0014	0.0014	0.0015	0.0016	0.0017	0.0018
55%	60%	65%	70%	75%	80%	85%	90%	95%	100%	
0.0019	0.0021	0.0023	0.0025	0.0028	0.0031	0.0037	0.0047	0.0068	0.2957	

Source: Authors' own work.

Table 21. Strength of women teams – OLS and SEM specifications

	OLS	SEM
Spatial error autocorrelation		−0.946* (0.480)
Area of LAU	0.014 (0.028)	0.009 (0.028)
Population density	0.044 (0.039)	0.029 (0.028)
Average salary	0.269 (0.292)	0.217* (0.128)
Feminisation rate	0.332 (0.689)	0.490 (0.477)
LAU current expenditure on sports	0.264 (0.167)	0.280**** (0.081)
LAU investment in sports	0.228* (0.131)	0.225**** (0.042)
LAU subsidies for sports	−0.241 (0.226)	−0.246*** (0.089)
Votes for minor opposition parties	0.045 (0.607)	0.082 (0.493)
Constant	−0.614 (0.674)	−0.731 (0.508)

	OLS	SEM
R^2	0.290	
Adjusted/Nagelkerke R^2	0.275	0.304
F Statistic (*df* = 8; 371)	18.926****	
Log likelihood		35.681
Sigma^2	0.050	0.048
Akaike inf. Crit.	−47.572	−49.361
Breusch–Pagan test	37.752****	35.317***
Wald Test (*df* = 1)		3.872**
LR test (*df* = 1)		3.790*

Note: * p < 0.1; ** p < 0.05; *** p < 0.01; **** p < 0.001.
Source: Authors' own work.

Table 22. Strength of men teams – OLS and SEM specifications

	OLS	SEM
Spatial error autocorrelation		−1.274** (0.481)
Area of LAU	−0.011 (0.071)	0.017 (0.084)
Population density	0.510*** (0.169)	0.409**** (0.082)
Average salary	2.232** (0.920)	2.031**** (0.390)
Feminisation rate	−2.408 (2.067)	−1.810 (1.442)
LAU current expenditure on sports	0.354 (0.673)	0.490* (0.251)
LAU investment in sports	1.223** (0.521)	1.232**** (0.128)
LAU subsidies for sports	0.961 (1.222)	0.963**** (0.273)
Votes for minor opposition parties	1.221 (1.773)	1.536 (1.463)
Constant	0.340 (2.217)	−0.161 (1.534)
R^2	0.617	
Adjusted/Nagelkerke R^2	0.609	0.624
F Statistic (*df* = 8; 371)	75.788****	
Log likelihood		−392.515

cont. Table 22

	OLS	SEM
Sigma^2	0.482	0.457
Akaike inf. Crit.	811.604	807.031
Breusch–Pagan test	146.64****	139.37***
Wald Test (*df* = 1)		7.017***
LR test (*df* = 1)		6.574**

Note: * p < 0.1; ** p < 0.05; *** p < 0.01; **** p < 0.001.
Source: Authors' own work.

Table 23. Values for SLS estimations for women

	SAR	SAR (sphet)	SEM (sphet)	SDM	SDM (sphet)
Spatial autocorrelation	−0.400 (0.707)	−0.400**** (0.058)		<0.001 (<0.001)	−0.189 (0.452)
Spatial error autocorrelation			−0.513 (0.424)		
Area of LAU	0.011 (0.027)	0.011*** (0.004)	0.012 (0.024)	0.038 (0.042)	0.033**** (0.006)
Population density	0.043 (0.036)	0.043 (NaN)	0.036 (0.034)	0.090 (0.072)	0.091**** (0.015)
Average salary	0.268 (0.267)	0.268	0.243 (0.261)	0.362 (0.321)	0.346**** (0.059)
Feminisation rate	0.323 (0.606)	0.323*** (0.089)	0.412 (0.605)	−0.059 (0.736)	−0.003 (NaN)
LAU current expenditure on sports	0.273* (0.140)	0.273 (NaN)	0.272* (0.147)	0.355** (0.160)	0.349 (NaN)
LAU investment in sports	0.226** (0.108)	0.226**** (0.030)	0.227** (0.108)	0.183 (0.119)	0.187**** (0.029)
LAU subsidies for sports	−0.246* (0.133)	−0.246**** (0.044)	−0.243* (0.132)	−0.325** (0.158)	−0.326**** (0.049)
Votes for minor opposition parties	0.097 (0.600)	0.097 (0.348)	0.062 (0.542)	0.266 (0.724)	0.187 (0.308)
Spatial area of LAU				−0.400 (0.372)	−0.486**** (0.109)
Spatial population density				0.247 (1.316)	−0.544**** (0.100)
Spatial average spatial salary				−4.148 (2.537)	−3.994**** (0.870)
Spatial feminisation rate				6.517 (6.377)	5.343*** (1.855)
Spatial LAU current exp. On sports				1.585 (1.426)	1.161**** (0.213)

	SAR	SAR (sphet)	SEM (sphet)	SDM	SDM (sphet)
Spatial LAU investment in sports				0.750 (1.888)	−0.552*** (0.176)
Spatial LAU subsidies for sports				1.184 (3.498)	−0.137 (0.365)
Spatial votes for minor opposition parties				−3.864 (5.330)	−2.028 (1.772)

Note: * p < 0.1; ** p < 0.05; *** p < 0.01; **** p < 0.001.
Source: Authors' own work.

Table 24. Values for SLS estimations for men

	SAR	SAR (sphet)	SEM (sphet)	SDM	SDM (sphet)
Spatial autocorrelation	−1.212*** (0.422)	−1.212**** (0.222)		< 0.001 (< 0.001)	−1.014** (0.507)
Spatial error autocorrelation			−0.883* (0.535)		
Area of LAU	−0.030 (0.060)	− 0.030 (0.024)	0.004 (0.064)	0.066 (0.093)	0.063 (0.044)
Population density	0.515**** (0.138)	0.515**** (0.080)	0.450**** (0.134)	0.735**** (0.212)	0.732**** (0.084)
Average salary	2.310*** (0.717)	2.310**** (0.285)	2.117*** (0.738)	2.460*** (0.868)	2.437**** (0.328)
Feminisation rate	−2.989* (1.594)	−2.989**** (0.679)	−2.037 (1.568)	−4.910** (2.027)	−4.927**** (0.669)
LAU current expenditure on sports	0.639 (0.536)	0.639**** (0.073)	0.428 (0.492)	0.829. (0.475)	0.826 (NaN)
LAU investment in sports	1.181*** (0.366)	1.181**** (0.054)	1.228**** (0.370)	1.043*** (0.348)	1.060**** (0.079)
LAU subsidies for sports	0.840 (0.719)	0.840**** (0.242)	0.965 (0.660)	0.428 (0.540)	0.438. (0.261)
Votes for minor opposition parties	2.242 (1.594)	2.242**** (0.164)	1.359 (1.458)	1.305 (2.111)	1.040 (NaN)
Spatial area of LAU				0.206 (1.370)	0.029 (0.463)
Spatial population density				−1.578 (3.221)	−2.571**** (0.529)
Spatial average spatial salary				−8.067 (7.241)	−6.133** (2.878)
Spatial feminisation rate				32.569 (21.400)	26.916**** (7.094)
Spatial LAU current exp. On sports				6.932 (5.980)	6.115**** (1.316)

cont. Table 24

	SAR	SAR (sphet)	SEM (sphet)	SDM	SDM (sphet)
Spatial LAU investment in sports				3.856 (8.150)	1.613 (NaN)
Spatial LAU subsidies for sports				6.342 (23.079)	−0.651 (3.037)
Spatial votes for minor opposition parties				9.651 (14.607)	17.124*** (5.211)

Note: * p < 0.1; ** p < 0.05; *** p < 0.01; **** p < 0.001.
Source: Authors' own work.

REFERENCES

Ahlfeldt, G.M. Feddersen, A. (2010) Geography of a Sports Metropolis, *Région et Développement*, 3, https://eprints.lse.ac.uk/29080 (accessed: 15.03.2025).

Ahlfeldt, G.M., Maennig, W. (2010). Impact of Sports Arenas on Land Values: Evidence from Berlin, *The Annals of Regional Science*, 44(2), pp. 205–227. DOI: 10.1007/s00168-008-0249-4.

Andreff, W., Staudohar. P. (2000). The Evolving European Model of Professional Sports Finance, *Journal of Sports Economics*, 1(3), pp. 257–276. DOI: 10.1177/152700250000100304.

Bivand, R.S. (2022). R Packages for Analyzing Spatial Data: A Comparative Case Study with Areal Data, *Geographical Analysis*, 54(3), pp. 488–518. DOI: 10.1111/gean.12319.

Bivand, R.S., Millo G., Piras G. (2021). A Review of Software for Spatial Econometrics in R, *Mathematics*, 9(11), p. 1276. DOI: 10.3390/math9111276.

Bivand, R.S., Pebesma, E., Gomez-Rubio, V. (2013). *Applied Spatial Data Analysis with R* (2nd edition). New York: Springer.

Bivand, R.S., Piras, G. (2015). Comparing Implementations of Estimation Methods for Spatial Econometrics, *Journal of Statistical Software*, 63(18), pp. 1–36. DOI: 10.18637/jss.v063.i18.

Borck, R., Koh, H.J., Pflüger, M. (2012). Inefficient Lock-In and Subsidy Competition, *International Economic Review*, 53, pp. 1179–1204. DOI: 10.1111/j.1468-2354.2012.00716.x.

Coates, D. (2019). Franchise Relocation and Stadium Subsidies. In: *The SAGE Handbook of Sports Economics* (pp. 231–240), P. Downward, B.R. Humphreys, J.E. Ruseski, B.P. Soebbing, B. Frick (Eds.). London: SAGE Publications Ltd.

CODGiK (2018). *PRG Data*, http://www.codgik.gov.pl/index.php/darmowe-dane/prg.html, (accessed: 16.03.2018).

Doran J., Jordan, D. (2018) The Effect of Geographical Proximity and Rivalry on Performance: Evidence from the English Football League, *Regional Studies*, 52(11), pp. 1559–1569. DOI: 10.1080/00343404.2017.1414177.

Elhorst, J.P. (2014). *Spatial Econometrics. From Cross-Sectional Data to Spatial Panels*. Berlin: Springer.

Eurostat (2024). *Gross Domestic Product (GDP) at Current Market Prices by NUTS 2 Region*. DOI: 10.2908/NAMA_10R_2GDP (accessed: 17.11.2024).

Feng, X., Humphreys, B. (2018). Assessing the Economic Impact of Sports Facilities on Residential Property Values: A Spatial Hedonic Approach, *Journal of Sports Economics*, 19(2), pp. 188–210. DOI: 10.1177/1527002515622318.

FootyStats (2024). footystats.org (accessed: 17.11.2024).

Gawrecki, B. (2024). *Pomoc państwa na rzecz podmiotów rynku sportowego – (nie) przejrzystość relacji pomiędzy państwem a beneficjentami*. PhD Dissertation, Adam Mickiewicz University Poznań, Faculty of Law and Administration, https://bip.amu.edu.pl/nadanie-stopnia-doktora2/nauki-prawne/gawrecki-bartlomiej (accessed: 15.03.2025).

Graffelman, J., van Eeuwijk, F. (2005). Calibration of Multivariate Scatter Plots for Exploratory Analysis of Relations within and between Sets of Variables in Genomic Research, *Biometrical Journal*, 47(6), pp. 863–879. DOI: 10.1002/bimj.200510177

Hlavac, M. (2022). *Stargazer: Well-Formatted Regression and Summary Statistics Tables* (R package version 5.2.3), https://CRAN.R-project.org/package=stargazer (accessed: 17.11.2024).

Humphreys, B.R., Zhou, L. (2015). Sports Facilities, Agglomeration, and Public Subsidies. *Regional Science and Urban Economics*, 54, pp. 60–73. DOI: 10.1016/j.regsciurbeco.2015.07.004

Hyun, D. (2022). Proud of, But Too Close: The Negative Externalities of a New Sports Stadium in an Urban Residential Area, *The Annals of Regional Science*, 68(3), pp. 615–633. DOI: 10.1007/s00168-021-01095-6.

Keeler, Z.T., Stephens, H.M., Humphreys, B.R. (2021). The Amenity Value of Sports Facilities: Evidence from the Staples Center in Los Angeles, *Journal of Sports Economics*, 22(7), pp. 799–822. DOI: 10.1177/15270025211018258

Kondo, H. (2013). International R&D Subsidy Competition, Industrial Agglomeration and Growth, *Journal of International Economics*, 89(1), pp. 233–251. DOI: 10.1016/j.jinteco.2012.04.004.

Mogielnicki, P. (2006). mogiel.net (accessed: 15.03.2018).

90 Minut.pl (2024). http://www.90minut.pl/ (accessed: 17.11.2024).

Office for National Statistics (24.04.2024). Regional Economic Activity by Gross Domestic Product, UK: 1998 to 2022, *ONS Website, Statistical Bulletin*, (accessed: 15.05.2025).

Park, M., Leahey, E., Funk, R.J. (2023). Papers and Patents Are Becoming Less Disruptive over Time, *Nature* 613, pp. 138–144.

Pebesma E., Bivand R.S. (2023). *Spatial Data Science with Applications in R*. New York: Chapman & Hall.

Piras, P. (2010). sphet: Spatial Models with Heteroskedastic Innovations in R, *Journal of Statistical Software*, 35(1), pp. 1–21. DOI 10.18637/jss.v035.i01.

Piras, G., Postiglione, P. (2022). A Deeper Look at Impacts in Spatial Durbin Model with {sphet}, *Geographical Analysis*, 54(3), pp. 664–684. DOI: 10.1111/gean.12318.

Propheter, G. (2023). Sports Facilities as a Housing Amenity: Do Prices Follow Facilities? *Journal of Sports Economics*, 24(4), pp. 443–474. DOI: 10.1177/15270025221132221.

R Core Team (2023). *R: A Language and Environment for Statistical Computing*. Vienna: R Foundation for Statistical Computing.

Ross, S.F., Szymanski, S. (2010), Open Competition in League Sports. In: *The Comparative Economics of Sport* (pp. 139–173), S. Szymanski (Ed.) London: Palgrave Macmillan UK.

Sass, M. (2016). Glory Hunters, Sugar Daddies, and Long-Term Competitive Balance under UEFA Financial Fair Play, *Journal of Sports Economics*, 17(2), pp. 148–158.

Statistics Poland (2024). *Local Data Bank*, https://bdl.stat.gov.pl/bdl/start (accessed: 17.11.2024).

Torój, A. (2019). *Spatial Econometrics*, http://web.sgh.waw.pl/~atoroj/ (accessed: 16.03.2018).

Torres, J.E.A., Torres, G.A.A., Arbeláez, L.C.F., Ceballos, L. (2015). The Effect of a Sports Stadium on Housing Rents: An Application of Geographically Weighted Regression, *Ecos de Economía*, 19(40), pp. 66–80. DOI: 10.17230/ECOS.2015.40.4

UEFA (2020). *Club Licensing Benchmarking Report Financial Year 2018*, https://www.uefa.com/insideuefa/protecting-the-game/news/025f-0fe85ed2acf8-db382645ca21-1000--benchmarking-report-highlights-profits-and-polarisation/ (accessed: 17.11.2024).

UEFA (2025). *UEFA Rankings*, https://www.uefa.com/nationalassociations/uefarankings/club/ (accessed: 15.05.2025).

The World Bank (2024). *World Development Indicators*, https://databank.worldbank.org/reports.aspx?source=2&series=NY.GDP.MKTP.CD (accessed: 17.11.2024).

Wyszyński, A. (2015). Wyniki ekonomiczne klubów sportowych o statusie pożytku publicznego w Polsce, *Quality in Sport*, 1(1), pp. 7–20. DOI: 10.12775/QS.2015.001.

Zeileis, A. (2004). Econometric Computing with HC and HAC Covariance Matrix Estimators, *Journal of Statistical Software*, 11(10), pp. 1–17. DOI: 10.18637/jss.v011.i10.

Zeileis, A., Hothorn, T. (2002). *Diagnostic Checking in Regression Relationships. R News*, 2(3), pp. 7–10, https://CRAN.R-project.org/doc/Rnews/ (accessed: 17.11.2024).

Zeileis, A., Köll S., Graham, N. (2020). Various Versatile Variances: An Object-Oriented Implementation of Clustered Covariances in R, *Journal of Statistical Software*, 95(1), pp. 1–36. DOI:10.18637/jss.v095.i01.

LIST OF FIGURES

LIST OF TABLES