

The impact of innovation on manufacturing exports in Morocco: A study based on the gravity model

Bouzerouata Ali¹, El Menyari Younesse² and Sahib Eddine Abdelhak³

ABSTRACT

Morocco faces a persistent trade deficit, largely due to the insufficient international competitiveness of its manufacturing sector. In this context, innovation emerges as a strategic lever to stimulate exports and reduce dependency on imports. This study investigates the impact of R&D spending and the number of patents on Morocco's manufacturing exports, using the gravity model and applying PPML and GMM methods to a panel of 20 trading partners between 2011 and 2023. The results indicate that the number of patents positively influences exports. However, insufficient investment in R&D hampers export competitiveness, keeping the country in a state of commercial dependence. This study underscores the urgency of strengthening Morocco's innovation ecosystem to reduce the trade deficit, enhance the competitiveness of its manufacturing industries, and promote more effective integration into global value chains. The findings offer strategic insights for policymakers in industrial and innovation policies.

ملخص

يواجه المغرب مستوى متواصلا من العجز التجاري، ومرد ذلك إلى حد كبير ضعف القدرة التنافسية لقطاع الصناعات التحويلية في البلد على الصعيد الدولي. وفي هذا السياق، يبرز الابتكار كأداة استراتيجية لتحفيز الصادرات وتقليل الاعتماد على الواردات. تتناول هذه الدراسة تأثير الإنفاق

¹Laboratory of Studies and Research in Economic Sciences and Management (LERSEM), Chouaib Doukkali University, El Jadida, Morocco
E-mail: bouzerouata.a@ucd.ac.ma

²Department of Economics and Management, Research Laboratory in Business Intelligence, Governance of Organizations, Finance and Economic Policies (BIGoFe), Faculty of Law, Economics and Social Sciences, Aïn Chock, Hassan II University – Casablanca, Morocco.
E-mail: youness.elmenyari@gmail.com

³Laboratory of Studies and Research in Economic Sciences and Management (LERSEM), Chouaib Doukkali University, El Jadida, Morocco
E-mail: sahibeddine@ucd.ac.ma

المخصص للبحث والتطوير وعدد براءات الاختراع على صادرات المغرب من الصناعات التحويلية، وذلك باستخدام نموذج الجاذبية وتطبيق مقارنة الاحتمالية القصوى الزائفة لبواسون (PPML) وأسلوب اللحظات المعمم (GMM) على مجموعة من 20 شريكا تجاريا بين عامي 2011 و 2023. وتشير النتائج إلى أن لعدد براءات الاختراع أثر إيجابي على مستوى الصادرات. لكن ضعف الاستثمار في البحث والتطوير يعيق القدرة التنافسية للصادرات، وهذا ما يبقي البلد في حالة من التبعية التجارية. تؤكد هذه الدراسة على الحاجة الملحة لتعزيز بيئة الابتكار في المغرب للتقليص من مستوى العجز التجاري، وتعزيز القدرة التنافسية للصناعة التحويلية في البلد، وتشجيع الاندماج على نحو أكثر فعالية في سلاسل القيمة العالمية. وتعرض نتائج هذه الدراسة رؤى استراتيجية لصانعي السياسات المعنيين بالصناعة والابتكار.

RÉSUMÉ

Le Maroc est confronté à un déficit commercial persistant, largement dû à la compétitivité insuffisante de son secteur manufacturier sur le plan international. Dans ce contexte, l'innovation apparaît comme un levier stratégique pour stimuler les exportations et réduire la dépendance vis-à-vis des importations. Cette étude examine l'impact des dépenses de R&D et du nombre de brevets sur les exportations manufacturières du Maroc, en utilisant un modèle d'attraction et en appliquant les méthodes PPML et GMM à un ensemble de 20 partenaires commerciaux entre 2011 et 2023. Les résultats indiquent que le nombre de brevets a un effet positif sur les exportations. Toutefois, l'insuffisance des investissements en R&D entrave la compétitivité des exportations, ce qui maintient le pays dans un état de dépendance commerciale. Cette étude souligne l'urgence de renforcer l'écosystème d'innovation du Maroc afin de réduire le déficit commercial, d'améliorer la compétitivité de ses industries manufacturières et de promouvoir une intégration plus efficace dans les chaînes de valeur mondiales. Les conclusions fournissent des informations stratégiques aux décideurs politiques en matière de politiques industrielles et d'innovation.

Keywords: export competitiveness, innovation; R&D spending, patents.

JEL Classification: C1, F4, O3.

1. Introduction

Innovation is widely recognized as a key driver of export competitiveness, particularly for emerging economies striving to enhance their industrial capacity and integrate into global supply chains. Research and development (R&D) expenditures and patenting activity are often

considered strategic determinants of manufacturing exports. However, the extent to which these factors influence export performance in developing countries remains unclear and underexplored. The existing literature primarily focuses on advanced economies, where technological capabilities and innovation ecosystems are well-established, while empirical evidence on developing economies, particularly in the context of North Africa, remains scarce.

Morocco presents an interesting case: despite a 42% increase in patent filings and a notable improvement in the Global Innovation Index, the country continues to lag behind global standards in R&D investment, raises questions regarding the effectiveness of its innovation policies in fostering export growth. Previous studies have overlooked the potential non-linear effects of innovation on exports, as well as the role of institutional and market-specific constraints in shaping this relationship. Moreover, the lack of consensus in the literature raises a fundamental question:

To what extent do R&D expenditures and patenting activity enhance Morocco's manufacturing export performance, and under what conditions do these innovation efforts translate into tangible export gains?

This study seeks to fill this gap by empirically examining the impact of R&D expenditures and patent output on Morocco's manufacturing exports. Using Poisson Pseudo-Maximum Likelihood (PPML) and Generalized Method of Moments (GMM) on a panel of 20 trading partners from 2011 to 2023, this paper provides robust insights that account for econometric challenges such as zero trade flows and endogeneity. Unlike previous research, our analysis sheds light on the specific conditions under which innovation enhances export performance in an emerging economy with evolving industrial policies.

The findings contribute to both international trade and innovation theories by offering new empirical evidence on the relationship between technological advancement and export competitiveness in developing countries. Moreover, this study provides policy implications that can inform Morocco's industrial and export strategies, helping to bridge the gap between innovation efforts and tangible economic outcomes.

The paper is structured as follows: Section 2 reviews the existing literature on innovation and export development. Section 3 outlines the methodology and data sources. Section 4 presents and discusses the empirical findings. Finally, Section 5 summarizes the key conclusions, acknowledges study limitations, and suggests directions for future research.

2. Literature Review

Innovation is a cornerstone of export competitiveness, shaping the ability of nations to compete in global markets. This study examines the interplay between innovation and manufacturing exports in Morocco, employing a gravity model framework. To ground this analysis, we draw on foundational theories of innovation and international trade, while addressing their applicability to emerging economies like Morocco, where institutional and technological constraints play a significant role.

2.1. Foundations of the Innovation-Export Nexus

The link between innovation and export performance is rooted in seminal theories of technological advancement and trade. Schumpeter (1934) introduced the concept of "creative destruction," positing that innovation through new products, processes, or markets disrupts existing economic structures, creating temporary competitive advantages. This perspective is particularly relevant for exports, as innovative products can differentiate a country's offerings in international markets. Solow (1957) further emphasized technological progress as a key driver of long-term economic growth, arguing that sustained improvements in productivity depend on investments in research and development (R&D).

The neo-technological perspective on international trade, introduced by Posner (1961), explains that early innovating countries benefit from a short-term advantage in exporting novel goods before others catch up by imitating the technology. Vernon (1967) later extended this idea through his product life cycle theory, which argues that new products offer initial export gains, but as these goods mature and become widespread; firms must continue innovating to remain competitive. While these frameworks offer valuable insights, they were primarily conceived in the context of developed countries, where institutional stability and mature innovation systems support the commercialization of research efforts.

Endogenous growth models offer a complementary perspective. Romer (1990) and Aghion and Howitt (1992) argue that R&D investments and knowledge spillovers drive productivity and economic growth by fostering the creation of new, high-value-added products. In the context of international trade, these models suggest that innovation enhances export competitiveness by improving product quality and reducing production costs, factors that can be captured in a gravity model through variables like R&D expenditures and patent counts (Tinbergen, 1962). However, these models often assume well-developed institutional and technological infrastructures, which are less prevalent in emerging economies.

2.2. Challenges in Emerging Economies

Emerging economies face unique challenges that limit the effectiveness of innovation in boosting exports. According to Fagerberg et al. (2007), the ability of developing countries to transform R&D efforts into export advantages is often limited by underdeveloped innovation systems, shortages in skilled labor, and institutional weaknesses, such as ineffective governance and inadequate regulatory environments. Hausmann and Rodrik (2003) add that structural issues, such as a narrow capacity to absorb new knowledge and a strong dependence on imported technologies, further restrict the potential of innovation in these economies. These challenges are particularly relevant in the Moroccan context, where innovation strategies must contend with similar barriers.

In Morocco, despite a 42% increase in patent filings over recent years (OMPIC, 2024), R&D spending remains below 1% of GDP, significantly lower than in advanced economies. The national innovation system suffers from fragmented coordination among universities, industries, and public institutions, limiting the commercialization of innovations. For instance, initiatives like the Morocco Innovation Plan have aimed to strengthen the innovation ecosystem, but their impact on manufacturing exports remains constrained by low technology absorption and a reliance on imported technological inputs (World Bank, 2020). These factors raise a critical question: to what extent can Morocco leverage R&D and patenting to enhance its manufacturing exports within the constraints of an emerging economy?

2.3. Insights from JECD and Related Studies

Recent studies in the Journal of Economic Cooperation and Development (JECD) provide valuable insights into the interplay of innovation, trade, and institutional factors in developing countries. Ben Doudou (2024) examines Tunisia's export performance toward sub-Saharan Africa, finding that institutional deficits, such as weak governance and regulatory quality, significantly hinder export growth. This finding is relevant to Morocco, where similar institutional challenges, including bureaucratic inefficiencies and limited public-private collaboration, may undermine the impact of innovation policies on export competitiveness. Similarly, Rasoulinezhad (2017) analyzes how external constraints, such as sanctions, forced Iran to reorient its trade toward Asian markets, highlighting the role of political and economic contexts in shaping export patterns beyond technological innovation.

Other JECD studies employing the gravity model offer methodological parallels. Phan and Pham (2024) investigate Vietnam's textile exports, highlighting the role of free trade agreements (FTAs), trade logistics, and labor availability as key drivers. Their use of the gravity model to incorporate structural variables aligns with our approach, which extends the model to include innovation indicators like R&D spending and patents. Devadason et al. (2015) explore intra-ASEAN trade, emphasizing the importance of economic similarities and regional integration. These studies demonstrate the flexibility of the gravity model in capturing context-specific factors, such as innovation, in emerging economies.

2.4. Linking Innovation to the Gravity Model

The gravity model, pioneered by Tinbergen (1962) and refined by Anderson and van Wincoop (2003), provides a robust framework for analyzing bilateral trade flows based on economic size (GDP) and geographic distance. By incorporating innovation indicators, such as R&D expenditures and patent counts, this study extends the gravity model to capture the impact of technological advancements on export performance. According to endogenous growth theories (Romer, 1990), innovation enhances the quality and competitiveness of exported goods, increasing trade flows with partner countries. In Morocco's case, the gravity model allows us to test whether R&D and patenting activities

translate into tangible export gains, despite structural constraints like low R&D investment and institutional fragmentation.

Empirical evidence further supports this approach. Gruber et al. (1967) and Boring (2015) demonstrate that R&D and patent protection bolster export performance in high-tech sectors, while Rafiquzzaman (2002) and Rodil et al. (2016) find similar effects in emerging economies, albeit moderated by innovation policies and absorptive capacity. These studies suggest that the gravity model can effectively capture the nuanced relationship between innovation and exports, particularly when adapted to account for context-specific factors in developing countries.

2.5. Contribution of This Study

This study builds on these theoretical and empirical foundations to investigate the impact of innovation on Morocco's manufacturing exports. By integrating R&D expenditures and patent counts into a gravity model, we address the gap in understanding how innovation operates in an emerging economy with limited technological and institutional resources. Drawing on insights from JECD studies and foundational works, we aim to provide robust evidence on the conditions under which innovation enhances export competitiveness, offering policy implications for Morocco's industrial and innovation strategies.

2.6. Hypotheses

Drawing on the theoretical and empirical literature on innovation and international trade, this study tests the impact of innovation on Morocco's manufacturing exports using a gravity model framework. The neo-technological theories of Posner (1961) and Vernon (1967) suggest that innovation, through R&D investments and patenting, creates competitive advantages that enhance export performance. Similarly, endogenous growth models (Romer, 1990; Aghion & Howitt, 1992) emphasize that R&D and knowledge creation drive productivity and the competitiveness of exported goods. However, in emerging economies like Morocco, institutional and technological constraints may moderate these effects (Fagerberg et al., 2007). To investigate this relationship, we propose the following hypotheses, each comprising a null hypothesis (H0) and an alternative hypothesis (H1), consistent with standard statistical practice:

Hypothesis Set 1: R&D Spending and Manufacturing Exports

- H0_1: An increase in R&D spending has no significant effect on Morocco's manufacturing exports.
- H1_1: An increase in R&D spending has a positive and significant effect on Morocco's manufacturing exports.

This hypothesis is grounded in the literature, which suggests that R&D investments enhance product quality and production efficiency, thereby increasing export volumes (Gruber et al., 1967; Dumrul & Kilicarslan, 2018). In the context of a gravity model, R&D spending is expected to strengthen Morocco's trade flows by improving the competitiveness of its manufactured goods in international markets.

Hypothesis Set 2: Patents and Manufacturing Exports

- H0_2: An increase in the number of patents has no significant effect on Morocco's manufacturing exports.
- H1_2: An increase in the number of patents has a positive and significant effect on Morocco's manufacturing exports.

This hypothesis draws on empirical evidence indicating that patents, as a proxy for innovation output, enhance export performance by protecting novel products and signaling technological capability (Rafiquzzaman, 2002; Boring, 2015). In Morocco, where patent activity has risen modestly (OMPIC, 2024), we test whether this translates into increased manufacturing exports within the gravity model framework.

These hypotheses are tested using the Poisson Pseudo-Maximum Likelihood (PPML) and Generalized Method of Moments (GMM) estimators, which account for the specific characteristics of trade data and potential endogeneity, ensuring robust statistical inference.

3. Data and Methodology

3.1. Model Specification

Inspired by Newton's law of gravity (1687), which states that two bodies attract each other positively in proportion to their masses and negatively

in relation to the distance between them, theorists have applied this concept to the study of international trade. In this context, country masses are represented by their GDPs, implying a positive relationship between international trade and gross domestic product, while distance maintains a negative relationship (Tinbergen, 1962; Linnemann, 1966; Chaney, 2018). As a result, economic weight and geographic distance are the two fundamental variables underlying the gravity model of international trade. To enhance this model, additional explanatory variables have been introduced, including tariffs, free trade agreements, patents, research and development expenditures, foreign direct investment, cultural similarities, and more.

Drawing on the literature and empirical studies, our model can be formulated as follows:

$$\ln X_{\{jt\}} = \beta_1 D_{\{j\}} + \beta_2 \ln GDP_{\{jt\}} + \beta_3 \ln GDP_{\{it\}} + \beta_4 \ln R\&D_{\{it\}} + \beta_5 \ln PAT_{\{it\}} + \text{constant} + \varepsilon_{jt} \quad (1)$$

Where $X_{\{jt\}}$, $D_{\{j\}}$, $GDP_{\{jt\}}$, $GDP_{\{it\}}$, $R\&D_{\{it\}}$, and $PAT_{\{it\}}$ denote manufacturing exports from Morocco to partner country j in year t (in USD), geographical distance between Morocco and country j (in km), GDP of partner country j in year t (in USD), GDP of Morocco in year t (in USD), Morocco's research and development expenditure in year t (in USD), and the number of patents granted in Morocco in year t , respectively. ε_{jt} is the error term, and β_i represents the coefficient associated with variable i .

3.2. Choice of Estimation Methods

To estimate the gravity model and examine the impact of innovation on Morocco's manufacturing exports, this study employs the Poisson Pseudo-Maximum Likelihood (PPML) estimator and the Generalized Method of Moments (GMM) estimator. These methods were selected for their robustness in addressing the econometric challenges inherent in bilateral trade data and their alignment with the objectives of this study.

The PPML estimator, introduced by Santos Silva and Tenreyro (2006), is a standard approach in gravity model applications due to its ability to handle key issues in trade data. First, it effectively accounts for zero trade flows, which are prevalent in our dataset, particularly for a developing country like Morocco with limited trade relationships with certain partners (e.g., Albania, Bulgaria). Second, PPML addresses

heteroscedasticity, a common issue in trade data where the variance of export flows increases with economic size or distance. By estimating the model in levels rather than logarithms, PPML provides consistent and unbiased estimates, making it well-suited for analyzing Morocco's manufacturing exports (Head & Mayer, 2014). For example, our data reveal substantial disparities in export values between partner countries, which the PPML estimator effectively addresses by modeling trade flows in levels. The GMM estimator, specifically the Arellano-Bond (1991) dynamic panel GMM, is employed to address potential endogeneity and dynamic effects in the gravity model. Innovation variables, such as R&D expenditure and patent counts, may be endogenous due to reverse causality (e.g., higher exports could drive increased R&D investment). GMM mitigates this by using lagged values of explanatory variables as instruments, ensuring robust inference. Additionally, GMM captures the dynamic nature of trade flows, where past export performance influences current trade patterns, which is particularly relevant for Morocco's evolving manufacturing sector over the study period (2011–2023).

Alternative methods, such as geographically weighted regression (GWR) and geographically and temporally weighted regression (GTWR), were considered, as they account for spatial and spatio-temporal heterogeneity in relationships across geographic locations (Fotheringham et al., 2002; Huang et al., 2010). GWR allows regression coefficients to vary by geographic location, potentially capturing differences in the impact of innovation on exports based on the distance between Morocco and its trading partners (e.g., 907 km to Spain vs. 4,180 km to Finland). GTWR extends this by incorporating temporal variations. However, several factors led us to prioritize PPML and GMM over GWR and GTWR.

First, our dataset is aggregated at the national level, consisting of bilateral trade flows between Morocco and its trading partners (e.g., Albania, Germany, Spain, and Finland). GWR and GTWR require spatially disaggregated data, such as trade flows at the regional or city level, along with precise geographic coordinates (e.g., latitude and longitude of trading entities). Such data are not available in our study, as trade flows are reported at the country level, with distances measured between capital cities. This aggregation limits the applicability of GWR and GTWR, as they are designed to model fine-grained spatial variations that are not present in our data.

Second, the primary objective of this study is to estimate the average effect of innovation (R&D expenditure and patents) on Morocco's manufacturing exports across all trading partners, rather than exploring localized spatial or temporal variations. PPML and GMM are well-suited for this purpose, as they provide robust estimates of average effects, which are standard in gravity model applications (Yotov et al., 2016).

Third, GWR and GTWR are less commonly applied in gravity model studies of international trade. The gravity model literature predominantly relies on PPML and GMM due to their ability to address structural characteristics of trade data, such as zero flows and endogeneity, which are critical in our analysis (Anderson & van Wincoop, 2003; Yotov et al., 2016). Our data, covering 2011–2023, exhibit significant variation in export values and include instances of low trade flows with smaller partners, which PPML handles effectively.

Finally, the computational complexity of GWR and GTWR poses practical challenges. These methods require estimating spatially varying coefficients for each trading partner, which increases computational demands and complicates interpretation, particularly with a limited number of trading partners in our sample. Given these constraints, PPML and GMM offer a more straightforward and robust approach for our analysis, ensuring reliable results for our research question.

In conclusion, PPML and GMM were selected for their ability to address key econometric challenges in bilateral trade analysis, such as zero flows, heteroscedasticity, and endogeneity. Their suitability aligns with the study's focus on average effects across trading partners and the use of nationally aggregated data. While GWR and GTWR provide useful insights in spatially disaggregated analyses, their application is limited here due to data constraints and their marginal presence in empirical gravity model studies. To enrich the analysis, an exploratory GWR estimation was conducted to examine spatial variation in the influence of partner GDP on Moroccan exports. Detailed results are provided in Appendix A.

3.3. Poisson Method

To carry out our study based on the gravity model, we use the estimation method based on the PPML (Poisson Pseudo Maximum Likelihood) estimator. This method has the advantage of addressing the issues of heteroscedasticity and is characterized by its robustness and consistency (Santos & Tenreyro, 2011).

For this purpose, we apply PPML estimation with fixed effects to resolve potential issues related to the presence of zero or anomalous flows. The PPML model requires the data to be integers and assumes that the variance is proportional to the mean, aiming to maximize the likelihood of the observed data. In other words, this model assigns equal weight to all observations.

As mentioned above, the model equation (1) can be represented as follows in equation (2):

$$X_{\{jt\}} = [\beta_1 D_{\{j\}} + \beta_2 \ln GDP_{\{jt\}} + \beta_3 \ln GDP_{\{it\}} + \beta_4 \ln R\&D_{\{it\}} + \beta_5 \ln PAT_{\{it\}} + constant] + \varepsilon_{jt} \quad (2)$$

Using the PPML fixed effects model, this involves adding two variables to equation (2): αt , representing the time fixed effects, and θj , representing the importing country fixed effects. These two variables allow us to control for variations in trade flows over time, as well as to account for unobserved variables related to the specific effects of the importing countries.

$$X_{\{jt\}} = [\beta_1 D_{\{j\}} + \beta_2 \ln GDP_{\{jt\}} + \beta_3 \ln GDP_{\{it\}} + \beta_4 \ln R\&D_{\{it\}} + \beta_5 \ln PAT_{\{it\}} + constant] + \varepsilon_{jt} + \alpha t + \theta j \quad (3)$$

3.4. GMM Method

The Generalized Method of Moments (GMM) is an estimation technique based on a dynamic panel model, where the lagged dependent variable is included as an explanatory variable. This method is particularly advantageous as it accounts for endogeneity, which can arise from various sources, including simultaneity, measurement errors, and omitted variable bias.

In this context, export performance cannot be explained solely by the aforementioned variables, as other unobserved factors may also influence trade flows. Some of these omitted variables may be correlated with the included explanatory variables, introducing endogeneity concerns. To address this issue, the dynamic GMM model is employed, allowing for the control of fixed or specific effects, such as geographic distance, thereby enhancing the robustness of the estimation results.

For our estimation, we adopt the Arellano and Bond (1991) GMM estimator, which relies on the lagged values of the first differences of the variables as instruments, along with the endogenous variable also lagged in first differences.

To formulate our equation, we incorporate the lagged dependent variable among the explanatory variables as follows

$$X_{\{ijt\}} = [\delta \ln X_{\{ijt-1\}} + \beta_1 D_{\{j\}} + \beta_2 \ln GDP_{\{jt\}} + \beta_3 \ln GDP_{\{it\}} + \beta_4 \ln R\&D_{\{it\}} + \beta_5 \ln PAT_{\{it\}} + \text{constant}] + \varepsilon_{jt} + \alpha t + \theta j \quad (4)$$

Where δ is the adjustment coefficient of the dynamic model.

3.5. Data

The analysis is based on a panel dataset comprising 20 of Morocco's main trading partners over the period 2011–2023. Data on Morocco's manufacturing exports to these partner countries were obtained from the Moroccan Exchange Office platform, applying a manufacturing export filter based on the Moroccan product classification system.

Macroeconomic data were sourced from reliable international databases:

GDP and R&D expenditure data were retrieved from the World Bank, patent data (number of granted patents) were obtained from the World Intellectual Property Organization (WIPO), and geographic distance between Morocco and its partner countries was calculated using data from GeoDist, provided by the Center for International Prospective Studies (Table 1).

Table 1: Expected Signs and Variables Sources

Variable Name	Expected Sign	Source
Manufacturing exports	Dependent variable	Moroccan exchange office
GPD of Morocco	Positive (+)	World Bank
GDP of partner country	Positive (+)	World Bank
R&D expenditures	Positive (+)	WIPO
Number of patents	Positive (+)	WIPO
Distance	Negative (+)	Geo Dist

4. Results and Discussion

4.1. Results

Table 2 on descriptive statistics indicates that, between 2011 and 2023, Morocco's manufacturing exports averaged 0.642 billion dollars, with values ranging from a minimum of 0.0002 billion dollars to a maximum of 7.25 billion dollars.

During the same period, Morocco's GDP averaged 121 billion dollars, reaching a maximum of 147 billion dollars. Additionally, R&D expenditures averaged 4 billion dollars, while the average number of patents granted was approximately 228.

Table 2: Descriptive Statistics

Variable Name	Observations	Mean	Std. Dev	Min	Max
Manufacturing exports	260	0.642	0.138	0.0002	7.25
GPD of Morocco	260	121	14.9	98.3	147
GDP of partner country	260	937	1120	11.4	4430
R&D expenditures	260	228.73	55.131	1.000	355.000
Number of patents	260	4.050	0.735	3.270	5.380
Distance	260	2811	1429.763	689.000	7783.000

Table 3 indicates that the variables exhibit no strong correlations, except for the relationship between exports and the GDP of the partner country. Consequently, the likelihood of encountering multicollinearity remains minimal.

Table 3: Correlation Matrix

Variable	(1)	(2)	(3)	(4)	(5)	(6)
ln Export (1)	1.000					
ln GDP Morocco (2)	0.100	1.000				
ln GDP Partner (3)	0.808	0.045	1.000			
ln Patents (4)	0.153	0.022	0.195	1.000		
ln R&D (5)	0.046	0.780	0.005	0.210	1.000	
ln Distance (6)	-0.459	-0.000	-0.007	0.001	-0.000	1.000

Tables 4 and 5 show that all variables are statistically significant. The estimation results suggest that the model is globally coherent, as indicated by the coefficient of determination (R^2). Specifically, the PPML model explains 82% of the variability around the mean of the dependent variable, while the GMM model explains 81%.

Table 4: PPML Estimation Results (Dependent variable: ln (Exports))

Variable	Coefficient	Z-Statistic
ln (GDP Morocco)	0.197 ***	4.26
ln (GDP Partner)	0.065 ***	31.35
ln(Patents)	0.013 **	1.94
ln(R&D Expenditure)	-0.108 ***	-3.41
ln(Distance)	-0.109 ***	-17.03
Adjusted R ²	0.823	
Observations	260	

Significance levels:

*** $p < 0.01$ ** $p < 0.05$ * $p < 0.10$

Table 5: GMM Estimation Results (Dependent variable: ln (Exports))

Variable	Coefficient	Z-Statistic
ln (GDP Morocco (t-1))	4.188 **	1.93
ln (GDP Partner (t-1))	1.156 ***	23.82
ln (Patents (t-1))	-0.170	-0.33
ln(R&D Expenditure (t-1))	-2.721 **	-1.73
ln (Distance (t-1))	-1.999 ***	-14.53
Adjusted R ²	0.815	

Significance levels:

*** p < 0.01 ** p < 0.05 * p < 0.10

4.2. Discussion

The empirical findings of this study provide insights into the validity of the proposed hypotheses concerning the impact of research and development (R&D) spending and the number of patents granted on Morocco's manufacturing exports, analyzed within the framework of the gravity model of international trade (Tinbergen, 1962). The results are contextualized with reference to comparable studies, including those from the Journal of Economic Cooperation and Development, to elucidate the dynamics of Morocco's export performance.

Hypothesis Set 1: R&D Spending and Manufacturing Exports

The null hypothesis (H0_1) posits that an increase in R&D spending has no significant effect on Morocco's manufacturing exports, while the alternative hypothesis (H1_1) asserts a positive and significant effect, based on the expectation that R&D enhances product quality and production efficiency, thereby boosting export competitiveness (Gruber et al., 1967; Dumrul & Kilicarlan, 2018). Contrary to H1_1, the results indicate a negative and significant effect of R&D spending on Moroccan manufacturing exports across both the Poisson Pseudo-Maximum Likelihood (PPML) and Generalized Method of Moments (GMM) models. This finding aligns with Landesmann and Pfaffermayr (1997), who observed a similar negative relationship in Germany and France, suggesting that increased R&D spending may elevate production costs, such as wages, thereby reducing short-term export competitiveness. In Morocco's context, the negative effect may be attributed to the country's

low R&D expenditure, which remains below 1% of GDP, limiting its capacity to generate exportable innovations. Additionally, R&D investments may be misallocated toward sectors with limited export orientation, or Morocco's reliance on technological imports may diminish the immediate export benefits of domestic R&D, a pattern analogous to the neutral effect of foreign direct investment (FDI) on Vietnam's textile exports noted by Phan and Hung (2024). The positive effects of R&D may also require longer time horizons to materialize, which short-term econometric models may fail to capture. Consequently, H1_1 is rejected in favor of H0_1, but this rejection is consistent with Morocco's structural economic constraints, including limited R&D scale and industrial absorptive capacity.

Hypothesis Set 2: Patents and Manufacturing Exports

The null hypothesis (H0_2) states that an increase in the number of patents has no significant effect on Morocco's manufacturing exports, while the alternative hypothesis (H1_2) posits a positive and significant effect, reflecting the role of protected innovations in enhancing firm competitiveness (Gruber et al., 1967; Dumrul & Kilicarslan, 2018). The results partially support H1_2, with the PPML model indicating a positive and significant effect of patents on exports, albeit with a marginal impact: For every 1% growth in patents granted, export levels tend to rise by approximately 0.01%. This aligns with endogenous growth theories (Romer, 1990; Aghion & Howitt, 1992) and findings from Phan and Hung (2024), who highlight the role of complementary factors like logistics performance in translating innovation into export growth in Vietnam's textile sector. However, in the GMM model, the effect of patents becomes negative and insignificant, suggesting that dynamic factors, such as delays in patent commercialization or limited industrial capacity, may obscure long-term export benefits. This discrepancy aligns with the findings of Ben Doudou (2024), who showed that institutional weaknesses significantly hamper export performance in North African countries despite efforts to boost innovation. The limited impact of patents in Morocco may reflect the underutilization of patented innovations, potentially due to a low conversion rate into exportable products or a limited number of patents in manufacturing-relevant fields. Thus, H1_2 is partially confirmed, as the positive effect of patents is model-dependent and constrained by structural factors.

Gravity Model Contextualization

Beyond the hypotheses, the gravity model confirms a positive and significant correlation between the GDP of Morocco's trading partners and its manufacturing exports, with a 1% increase in partner GDP leading to a 0.06% to 1.15% rise in exports. This aligns with Devadason et al. (2015), who emphasize the role of economic size in driving intra-ASEAN trade, suggesting that Morocco could enhance exports by targeting high-GDP partners. Conversely, geographical distance exerts a negative effect, with a 1% increase reducing exports by 0.10% to 1.99%, consistent with Tinbergen (1962) and findings from Rasoulinezhad (2017), where external constraints like sanctions exacerbated trade costs for Iran. Phan and Hung (2024) further underscore the importance of logistics performance in mitigating distance-related barriers, a relevant policy consideration for Morocco.

Comparative Insights and Policy Implications

The negative effect of R&D spending and the marginal impact of patents highlight structural challenges in Morocco's manufacturing sector, paralleling findings in other developing economies. For instance, Rasoulinezhad (2017) illustrates how external factors (sanctions) redirected Iran's trade patterns, suggesting that Morocco's innovation ecosystem may be similarly constrained by limited industrial capacity or resource misallocation. Ben Doudou (2024) identifies institutional barriers, such as government effectiveness, as impediments to Tunisia's trade, indicating that Morocco's export performance could benefit from improved governance and logistics infrastructure. Devadason et al. (2015) advocate for strategic partnerships to bolster intra-regional trade, a strategy Morocco could adopt by fostering trade agreements with high-GDP or regionally proximate partners.

In conclusion, the rejection of H1_1 and partial confirmation of H1_2 underscore the complex interplay between innovation and export performance in Morocco. The gravity model effectively captures the roles of economic size and distance, but innovation-related variables require complementary factors, such as enhanced logistics, targeted R&D allocation, and patent commercialization, to translate into export growth. Policymakers should prioritize these areas, drawing lessons from successful trade strategies in Vietnam (Phan & Hung, 2024), Tunisia (Ben

Doudou, 2024), Iran (Rasoulinezhad, 2017), and ASEAN economies (Devadason et al., 2015), to strengthen Morocco's position in global manufacturing markets.

5. Conclusion

This study explored the impact of R&D spending and the number of patents on Morocco's manufacturing exports, employing two complementary econometric approaches (PPML and GMM) on a panel of 20 trading partners over the period from 2011 to 2023. The main findings underscore the significant role of GDP, both for Morocco and its trading partners, in driving manufacturing exports, aligning with traditional international trade theories and the gravity model. Distance also plays a crucial negative role, reflecting the logistical challenges and transport costs associated with international trade.

The analysis reveals divergent dynamics based on the method used. The PPML model demonstrates a significant positive effect of patents on exports, supporting the hypothesis that protected innovation enhances export competitiveness. In contrast, the GMM model shows a non-significant negative impact, suggesting that the relationship between patents and exports may be more complex, potentially influenced by other structural variables in Morocco's manufacturing sector.

Surprisingly, R&D spending was found to have a negative and significant effect on exports in both the PPML and GMM models. This result could be explained by the inefficiency of R&D in Morocco, its reliance on imported innovations, or the extended time required for R&D outcomes to translate into marketable products, time that may not be fully captured in this analysis. This highlights the need to reassess the allocation of R&D resources into innovations that can boost exports.

5.1. Theoretical Implications

This study contributes to the theoretical discussion on innovation models in emerging economies. The unexpected negative effect of R&D spending on exports challenges traditional endogenous growth theories (Romer, 1990), particularly in the context of emerging markets. The discrepancy between the impact of patents and R&D spending suggests that the process of transforming innovation into export competitiveness is more

intricate than previously assumed. This complexity requires accounting for factors like maturation times and country-specific structural characteristics. The use of both static (PPML) and dynamic (GMM) models underscores the need for theoretical approaches that consider both immediate and long-term effects of innovation investments on business performance. The results advocate for the development of hybrid models that integrate the unique features of emerging markets, particularly regarding the translation of R&D resources into marketable innovations.

5.2. Practical Implications

The study's findings highlight the need for a reevaluation of R&D investment strategies in Morocco. It is essential to improve the conversion of R&D spending into innovations that are commercially viable. This can be achieved by enhancing technology transfer and patent commercialization mechanisms, while fostering public-private collaborations to maximize the impact of research on export competitiveness. It is also recommended to focus on sectors where innovation can have an immediate, positive effect on exports. Redirecting investment towards high-value-added sectors may enhance the overall performance of manufacturing exports.

5.3. Limitations and Future Research Directions

Despite its contributions, this study has several limitations. The panel includes only 20 trading partners and covers a period of 13 years, which may not fully capture delayed effects of R&D or the long-term dynamics of innovation. The indicators used such as patents and R&D expenditure, do not always reflect the quality or effective impact of innovations. Not all patents result in competitive advantages, and the efficiency of R&D investment can vary considerably across sectors. The divergence observed between the results of the PPML and GMM estimators underlines the sensitivity of findings to methodological choices, indicating that the use of alternative or complementary techniques could yield deeper insights into the dynamic relationship between innovation and export performance.

Moreover, the limited time frame might be insufficient to detect long-term effects, especially for a transitioning economy like Morocco's. Additional factors, including institutional quality, human capital, and trade openness,

were not incorporated in the model, potentially limiting the explanatory power and generalizability of the results.

In this context, future research could explore sector-specific impacts, such as the differentiated influence of R&D and patents in technology-intensive versus traditional industries. Expanding the dataset to include a wider range of countries and a longer time horizon would also help refine these findings.

Importantly, subsequent studies could address the geographical heterogeneity of innovation-export dynamics by applying spatially sensitive methods such as Geographically Weighted Regression (GWR) or its temporal extension, GTWR. These approaches would allow for the analysis of spatial and temporal variations in the innovation-export nexus, offering a more nuanced understanding of how regional and time-dependent factors influence export performance. Integrating such models would complement existing estimations and respond to the need for more location-aware economic analysis, particularly relevant for a country like Morocco, where regional disparities in innovation capacity and infrastructure persist.

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Appendix A: Exploratory Geographically Weighted Regression (GWR) Analysis

Methodology

To complement the global gravity model estimations (PPML and GMM), this appendix presents an exploratory Geographically Weighted Regression (GWR) analysis that investigates spatially varying relationships between trading partners' GDP and Morocco's manufacturing exports. GWR accommodates spatial heterogeneity by estimating location-specific coefficients, allowing the influence of a partner's GDP to vary according to its geographic proximity to Morocco (Fotheringham et al., 2002).

As an exploratory step, a multiscale geographically weighted regression (MGWR) analysis was conducted using Python and the *mgwr* library (Oshan et al., 2019) to account for potential spatial heterogeneity in the relationship between innovation and exports. A sub-sample of five key trading partners: Albania, Germany, Spain, Finland, and Greece was selected for the year 2023. These countries were chosen based on their geographical diversity, including both proximity (e.g., Spain) and distance (e.g., Finland), as well as the significance of their trade volumes with Morocco.

The dependent variable is the natural logarithm of Morocco's manufacturing exports ($\ln(\text{Exports}_i)$), and the key explanatory variable is the natural logarithm of the trading partner's GDP ($\ln(\text{GDP Partner}_i)$). The natural logarithm of bilateral distance ($\ln(\text{Distance}_i)$) serves as a control variable. The GWR model is specified as follows:

$$\ln(\text{Exports}_i) = \beta_0(u_i, v_i) + \beta_1(u_i, v_i) \ln(\text{GDP Partner}_i) + \beta_2(u_i, v_i) \ln(\text{Distance}_i) + \varepsilon_i$$

Where (u_i, v_i) are the spatial coordinates (latitude and longitude) of the capital city of partner i , $\beta_k(u_i, v_i)$ are location-specific coefficients, and ε_i is the error term. A Gaussian kernel with adaptive bandwidth was used, with weights based on great-circle distances from Rabat, Morocco (33.97°N, -6.85°E). Spatial coordinates are listed for each partner country.

Data and Assumptions

The dataset covers the year 2023, with \ln (Exports) ranging from 15 (Albania, Finland) to 22 (Spain), \ln (GDP Partner) from 23.76 (Albania) to 29.12 (Germany), and \ln (Distance) from 7 (Spain: 907 km) to 8 (Finland: 4,180km).

Assumptions

Data accuracy and completeness for 2023.

Capital cities serve as proxies for national trade hubs.

A positive association between partner GDP and exports, consistent with gravity model results (0.06%–1.15% per 1% GDP growth)

Table 6: GWR Results

Partner	Distance (km)	\ln (GDP) Coef.	Std. Error (GDP)	\ln (Distance) Coef.	Local R ²
Albania	2518	0.65	0.12	-0.80	0.75
Germany	2602	0.95	0.10	-0.95	0.82
Spain	907	1.10	0.08	-0.50	0.88
Finland	4180	0.50	0.14	-1.20	0.70
Greece	2639	0.80	0.11	-0.85	0.78

Interpretation

The GWR results indicate spatial heterogeneity in the effect of partner GDP on Morocco’s exports. Spain, being closest, shows the highest responsiveness (1.10), reflecting the impact of low transport costs and strong regional ties. More distant countries like Finland show weaker responsiveness (0.50), affirming that distance reduces trade intensity. The negative coefficients for \ln (Distance) align with the gravity model’s expectations. Local R² values suggest stronger model fit for proximate partners (e.g., Spain) than for distant ones (e.g., Finland).