Alsharif, Abdulhak Anwer; Brenner, Thomas

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RESEARCH

Special economic zones and innovation in developing and emerging economies: A cross-country analysis

Abdulhak Anwer Alsharif[1] · **Thomas Brenner**[1]

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Abstract

Special economic zones (SEZs) have become a widely adopted economic policy tool in developing and emerging economies, particularly over the last two decades. Despite the increasing importance of SEZs, the literature on their impact on innovation remains scarce and non-conclusive, with most existing literature focused on single-country case studies. Our research addresses this gap by offering an analysis across multiple countries. We employ a difference-in-differences (DiD) approach to find out whether SEZ establishment has an impact on innovation activity within these zones. Our results demonstrate a positive effect of SEZs on patent numbers, indicating that SEZs can indeed stimulate innovation. Additionally, we uncover heterogeneous effects on different innovation activities, with SEZs having a stronger influence on high-tech compared to low-tech industries. Moreover, the impact of SEZs varies across different technological fields, highlighting the sector-specific nature of innovation dynamics within SEZs.

Keywords Special economic zones · Innovation · Patents · Economic development

JEL Classification C31 · F21 · O14 · O38 · L52

1 Introduction

In recent decades, there has been a substantial transformation in the global production landscape. Several emerging and developing countries have successfully integrated themselves into the global economy, emerging as significant manufacturing centers (Farole & Akinci 2011). These economies, in general, have witnessed a growing share in trade flows and foreign direct investment (FDI). As Frick et al. (2019) state, this shift in global production dynamics has resulted in

✉ Abdulhak Anwer Alsharif
abdulhak.alsharif@uni-marburg.de

[1] Department of Economic Geography and Location Research, Philipps-Universität Marburg, Marburg, Germany

increased employment, expanded exports, and technological advancements in many nations. The rise in gross domestic product (GDP) per capita, poverty reduction, and improved living standards have been unprecedented. Although many countries achieved this through attracting low-tech industries, leveraging traditional cost advantages, the emergence of global production networks (GPNs) has also played a crucial role. GPNs, facilitated by advancements in transport and communication infrastructure, allowed the split of production into separate functions, with some of them situated across the most cost-effective locations (Henderson et al. 2002). Since the 1980 s, GPNs have significantly fueled trade between developed and developing countries, and through knowledge transfer and innovation, they present new opportunities for the latter to not only attract production but also ascend the value chain ladder (Ernst & Kim 2002). The economic development tool of special economic zone (SEZ), which is a designated area in a country that is subject to more favorable economic regulations, has been a longstanding policy for exactly this objective (World Bank 2017; Frick & Rodríguez-Pose 2021). Furthermore, SEZs are aimed to become, with time, an agglomeration for fostering economic development not only in their defined geographical boundaries but also generally in their respective regions through linkages with the local economy (UNCTAD 2019). In recent years, there has been a growing focus on regional innovation policies, driven by the acknowledgement of regional development through innovation as a top priority for many governments (Uyarra et al. 2017), in developed as well as in emerging and developing economies (Fagerberg et al. 2009). Consequently, SEZs are no longer considered only as policy tools to attract FDI but also as potential hubs for knowledge creation and transfer (Zeng 2010), which are necessary components of a successful technological catch-up (Ebersberger et al. 2023). Over the past four decades, China has witnessed rapid economic growth, with one contributing factor being the establishment of SEZs. Since the introduction of its first SEZs in the 1980 s, SEZs have played a crucial role in China's international trade, industrialization, and urbanization (Wu et al. 2021). Following the example of China and other success stories, there are today more than 6000 SEZs in more than 140 countries up from less than 200 in the late 1980 s (UNCTAD 2019; Singa Boyenge 2007), with the majority of developing and emerging economies having established them (Simo 2023). Given that innovation is a fundamental driver of competitiveness, productivity, and economic growth (Cantwell 2005; Nelson & Pack 1999; Cameron 1996), there is a need to assess whether SEZs have a positive impact on innovation. The literature has so far mostly focused on the effects of SEZs on economic growth and development (Frick & Rodríguez-Pose 2023; Frick et al. 2019; UNCTAD 2019; Leong 2013; Burgaud & Farole 2011; Farole 2011, World Bank 2017; Moberg 2017; Johansson & Nilsson 1997; Willmore 1995) and on more specific economic topics such as generating exports and employment (Zheng 2021: Jayanthakumaran 2003), firm performance and improving competitiveness (Li et al. 2021; Xi et al. 2021; Hsu et al. 2013; Madani 1999; World Bank 1992), connectedness with the local regional economy (Frick & Rodríguez-Pose 2021; Kiesel & Danneberg 2023; Stojčić et al. 2022), as well as on their economic institutional frameworks (Qumba 2023: Mugano 2021). Despite these valuable contributions, there remains a significant gap in the literature when it comes to exploring the role of SEZs as a driver of innovation. Existing research consists mainly of case studies focusing on individual countries—most notably China—and presents mixed empirical findings. Reports such as the UNCTAD World Investment Report (2019) do highlight the potential of SEZs to promote innovation, primarily through policy overviews and selected case illustrations. However, they do not offer causal identification of SEZ effects. This study addresses this gap by estimating the causal impact of SEZ implementation on innovation across multiple developing and emerging economies. We apply a difference-in-differences (DiD) approach to matched city pairs, each from the same country, where one city has a SEZ and the other does not. In doing so, we isolate the impact of SEZs from broader national trends. Additionally, we investigate how this relationship varies between high- and low-tech sectors and across different technological fields. This further analysis allows for a more nuanced understanding of how SEZs are associated with innovation dynamics in different technological contexts and adds another novel empirical layer to the literature.

The remainder of this paper is structured as follows: The second section introduces the political instrument of SEZs, provides a theoretical framework and explores the specific mechanisms through which SEZs could promote innovation activity and reviews relevant literature. The third section presents our data, method, and model. The fourth section outlines the findings, followed by a discussion of the results in the fifth section. Finally, the last section draws conclusions, highlights policy implications, and suggests directions for future research.

2 Theoretical background

2.1 Brief overview of SEZs

SEZs have played a significant role in international trade for centuries. Historically, entrepôts and citywide free zones, such as Gibraltar, Hamburg, and Singapore, provided secure storage and exchange along major trade routes (Farole & Akinci 2011). The modern era of SEZs began with the establishment of the first SEZ in Shannon, Ireland, in 1959. Prior to the 1970s, most zones were concentrated in developed nations. However, starting in the 1970s, regions like East Asia and South America began developing SEZs (Baissac 2011), and later also in Africa (Zeng 2010). Known by various names and exhibiting diverse structures and dimensions, SEZs, in the modern sense, are defined as geographically demarcated areas governed by a distinct regulatory framework tailored to offer conditions for businesses and investors that are typically more liberal than the broader national norms (Farole 2011). In addition to the fundamental benefits of relief from customs duties and tariffs, the majority of these zones extend fiscal incentives to businesses. Furthermore, they provide an environment characterized by business-friendly regulations relating to land access, permits, and licenses. Administrative processes are also often streamlined and facilitated to encourage a favorable business atmosphere (UNCTAD 2019). Governments, in exchange, anticipate equal commitments from investors within SEZs. These commitments include generating employment opportunities, increasing exports, diversifying the economy, and enhancing productive capacity

(Kiesel & Dannenberg 2023). The symbiotic relationship between governments and businesses operating in SEZs underscores the reciprocal nature of concessions and expectations, which should form a basis for economic development and growth.

2.2 SEZ as an innovation policy

2.2.1 Conceptual framework

Innovation does not occur in isolation but is shaped by broader systemic and spatial contexts. Two strands of literature, innovation systems (IS) and entrepreneurial ecosystems (EE), offer complementary theoretical perspectives for understanding how innovation processes are organized, especially in relation to place-based policy interventions like SEZs and their effects in developing and emerging economies.

The IS perspective, at both the national and regional levels, emphasizes that innovation emerges from interactive learning processes among diverse actors, including firms, universities, and government agencies (Lundvall 1992; Nelson 1993; Asheim et al. 2019). These interactions are embedded within institutional and infrastructural environments that shape both the capacity for and the direction of innovation. Effective innovation systems depend on well-functioning knowledge flows between these actors, supportive public policies, access to finance, and strong linkages between science and industry. Beyond highlighting the spatial embeddedness and systemic nature of innovation, the IS framework is particularly useful for identifying structural barriers to innovation. From this perspective, systemic failures such as weak institutions, fragmented networks, and missing infrastructure can substantially hinder innovation. These conditions are often present in developing and emerging economies (Stojčić 2024; Lundvall et al. 2009). In such settings, innovation often faces greater obstacles and tends to remain limited, typically taking the form of technological adaptation and incremental upgrading rather than patentable frontier inventions (Vujanović et al. 2022). SEZs, therefore, can be understood as deliberate policy interventions designed to address these structural weaknesses by concentrating institutional, regulatory, and physical support within specific geographic areas.

In parallel, the EE literature (Spigel 2017; Stam & van de Ven 2021) focuses more explicitly on local dynamics, emphasizing how spatially embedded networks, cultural norms, and enabling infrastructure influence entrepreneurial and innovation outcomes. While EE shares many of the premises of IS, it places greater emphasis on how place-specific combinations of local tangible and intangible resources, such as trust, talent, local infrastructure, and local institutions, might enable or constrain innovation (Fritsch 2024). Drawing on Stojčić et al. (2022), SEZs can be interpreted as engineered entrepreneurial ecosystems, offering concentrated bundles of both types of resources necessary for fostering innovation. A further relevant insight from the EE perspective is that such ecosystems can function effectively even in settings where broader innovation systems remain underdeveloped, provided the local environment contains the right enabling conditions (Spigel 2017).

Building on these theoretical perspectives, the following section outlines the detailed mechanisms through which SEZs may influence innovation outcomes.

2.2.2 Innovation dynamics of SEZs

Regarding how SEZs promote innovation, the literature suggests this may occur through various mechanisms. First, local SEZ governments often develop a range of targeted policies aimed explicitly at fostering innovation - interventions that address innovation barriers such as institutional and financial gaps emphasized in IS concept. For example, many SEZs offer more favorable tax and credit policies for research and development (R&D) expenses than the national standard. Additionally, many SEZ governments have established innovation and development funds, venture capital funds, and industrial investment funds to provide financial subsidies supporting innovation projects (Farole & Akinci 2011). Further policies include rewards for patent applications, patent-related honors and collaborative efforts among enterprises, universities, and research institutions. In terms of improving innovation efficiency, many SEZs actively promote the development of financial intermediaries and patent intermediaries, providing intellectual property training for enterprises (Wu et al. 2021).

Secondly, SEZs, as newly opened investment areas, often operate free from the constraints of existing systems that might hinder innovative activities. Borrowing from the practices of developed nations, SEZs have established laws and regulations conducive to business operations, significantly improving judicial quality and contract execution efficiency (Huang et al. 2013). Many SEZs offer "one-stop" services to enterprises, enhancing efficiency while simultaneously reducing the likelihood of corruption enhancing trust among actors and improving the overall business environment, which in turn might positively influence innovation (Wu et al. 2021)

Last but not least, SEZs exhibit a heightened level of economic agglomeration that can stimulate innovation across various mechanisms, most importantly the impact of factor sharing - a condition central to the EE concept (Spigel 2017). Agglomerations allow enterprises to collectively utilize production factors like specialized labor and services. Research by Gerlach et al. (2009) revealed that enterprises in agglomeration areas, as opposed to spatially separated ones, exhibited higher R&D investment, a greater likelihood of making risky R&D decisions, and a preference for diversified R&D projects. Then there's the matching effect within the labor market. Agglomeration enhances the quality of labor market matching, reducing costs and increasing profits for enterprises. This, in turn, might boost their capacity for R&D investment. Additionally, improved labor market matching in agglomeration areas facilitates recruitment of R&D personnel, contributing to the seamless execution innovation projects. Furthermore, agglomeration fosters knowledge spillover, especially the diffusion of tacit knowledge. Innovation thrives on inspiration, and the geographic proximity of enterprises facilitates the exchange of ideas among technical personnel, thereby promoting the generation of innovative ideas (Kiesel & Dannenberg 2023; Feldman 1994). Finally, there's the competition effect. Economic agglomeration heightens competition among enterprises, prompting them to accelerate product upgrades and drive innovation (Richardson 1996).

2.3 Literature review

As Baissac (2011) highlights, only a few economic development policy tools have been as controversial as SEZs. For over 35 years, they have been the focus of intense and polarized debates surrounding nearly every aspect of their configuration. And this is also the case regarding the question, whether SEZs have a positive effect on innovation. While theoretical frameworks offer a rationale for expecting such outcomes from SEZs, empirical evidence presents two contrasting perspectives. One perspective contends that even though SEZs may accelerate regional economic growth, they do not necessarily promote innovation. Research by Schminke & Biesebroeck (2013) suggests that enterprises in SEZs exhibit increased exports but not a higher total factor productivity (TFP). Xiang and Lu (2015) found reduced enterprise efficiency inside SEZs, and Yuan et al. (2015) observed no significant improvement in the TFP of enterprises in SEZs. Wu and Huang (2017) argue that SEZs might increase industrial output scale but have a notably negative impact on TFP.

On the other hand, an opposing view asserts that SEZs have a positive effect on innovation. Wang (2013) discovered that SEZs increased the growth rate of city-level TFP by 1.6%. Alder et al. (2016) explored the impact of SEZs on national economic growth, noting a significant improvement in TFP. Wang and Zhang (2016) investigated the productivity distribution of enterprises in SEZs, finding higher TFP, primarily attributed to economic agglomeration and the selection of high-quality enterprises. Wu et al. (2021) found that the establishment of a SEZs can increase the number of patents in its respective region by up to 25%. Concerning the effect of SEZs on innovation in different technological sectors, to our best knowledge, we have been able to find only two studies that do some kind of distinction. The first one by Wu et al. (2021) studies China's SEZs and finds that after the establishment of these zones, the number of newly-granted patents in new technical fields increased by 13.5%, while those in existing technical fields rose by 10.8%. This suggests that SEZs not only enhance innovation within established technical areas but also stimulate the development of new technical fields. The other study was done by Liu et al (2022) and analyzes the effect of SEZs on innovation in green technology in China. The authors found an increase in the number of green patent applications in the SEZs of 17.02%.

The conflicting conclusions in existing studies, according to Wu et al. (2021), can be attributed, in part, to differences in the measurement of innovation. Although TFP is widely accepted as an innovation indicator, its calculation means that factors such as changes in industrial structure, economic policies, market systems, and enterprise organization can also impact TFP, leading to varying assessments of SEZs' influence on innovation. Moreover, SEZs influence production efficiency through diverse channels, rendering TFP an imperfect measure of innovation. To address this limitation, researchers explore alternative indicators to measure innovation. Some studies, such as Hall et al. (2010) use factors like the introduction of new products or the proportion of new products as innovation measures. However, relying on new product indicators poses challenges due to the absence of a standardized definition, leading to potential measurement errors. The dynamic nature of new product standards and varying definitions across enterprises and in different countries further complicates the issue, resulting in the incomparability of related indicators (Wu et al. 2021). In response to these challenges, recent studies have increasingly turned to patents as a more reliable and a more straightforward measure of innovation (Hall & Jaffe 2018; Nadal et al. 2020). Patents serve as tangible outcomes of innovative activities and adhere to standardized criteria in both application and authorization processes, ensuring robust data comparability (Brenner & Broekel 2010).

3 Method and data

In our study we use the difference-in-differences method (DiD). The DiD approach is widely favored as a key statistical tool in evaluating policy effects due to its capacity to address the endogeneity issue. A DiD analysis involves two time periods and two groups: during the first period, neither group receives the treatment, while in the second period, one group is treated (the treated group), and the other is not (the comparison group). Under the assumption that, in the absence of the treatment, the average outcomes for both groups would have followed parallel trends over time, the average treatment effect can be estimated by comparing the average change in outcomes for the treated group with that of the comparison group (Callaway & Sant'Anna 2021).

This paper uses the annual count of patents as a measurement of innovation. We extracted the patent count from PATSTAT Global of the European Patent Office (EPO) for the time period 1980–2021. In our study, we use patent data for applicants and inventors. The *applicant* is the owner of the patent rights, while the *inventor* is the person who made the invention. In many cases, the applicant is a company, while the inventors are individuals working for that company. Moreover, we perform the DiD analysis across different patent categories. We distinguish between high-tech and low-tech patents according to the industries they are assigned to. The classification was done according to the Statistical Classification of Economic Activities in the European Community NACE-2-Codes[1]. Furthermore, we separately apply the analyses to patents in different technological sectors: electrical engineering, mechanical engineering, chemistry, instruments, and other fields[2]. This approach provides broader insights into understanding the relationship between SEZs and innovation across different fields. At this stage, it is important to point out that using patents as a proxy for innovation naturally captures only the dimension of innovation based on formal knowledge creation. The advantage of patent data is the comparability between countries. However, it restricts our perspective on a certain kind of innovation activity. This important issue will be further addressed in the discussion section.

For the SEZs, we built a novum dataset of 56 cities constituting 28 city pairs (see Appendix Table 7), each pair consists of one city with a SEZ (the treated group)

[1] Available per link: https://ec.europa.eu/eurostat/documents/3859598/5902521/KS-RA-07-015-EN.PDF

[2] The classification is given in the PATSTAT database.

and a comparable city without one (the comparison group) from the same country. One potential threat when using the DiD method is that the empirical results may be confounded by national factors. That's why in this study, both the treated and the comparable city were selected from the same country, which helps control for national-level factors and enables a more accurate assessment of the SEZs' impact on innovation. A further potential problem is that the cities do not follow the same parallel trend and that there might be a self-selection of cities with a SEZ. To minimize this issue, we first choose cities for comparison that have the most similar initial situations and do not have a SEZ. This was decided according to the following factors: initial economic situation (this was qualitatively estimated according to available historical literature), similar population, presence of a university, a port and an airport, and distance to the next populous city. We report the balance between the two more systematically in the section for robustness checks.

The country selection, in which the SEZs are located, was done considering the following factors. First, the country has to have at least a city with an established SEZ and also has another one that is to a certain extent comparable. Countries with none or very low patenting activity as well as those that are experiencing conflicts or political instability over prolonged periods were excluded. Additionally, the unavailability of data was another limiting factor. Nonetheless our data represents a good portion of developing and emerging countries from Africa, Eurasia and South America (see Fig. 1). Including SEZs from many different countries in our analysis implies that we estimate the average effects across a diverse international sample. It is important to recognize that SEZs are not homogeneous. As Stojčić et al. (2022) show, SEZs differ in design and impact, with effects

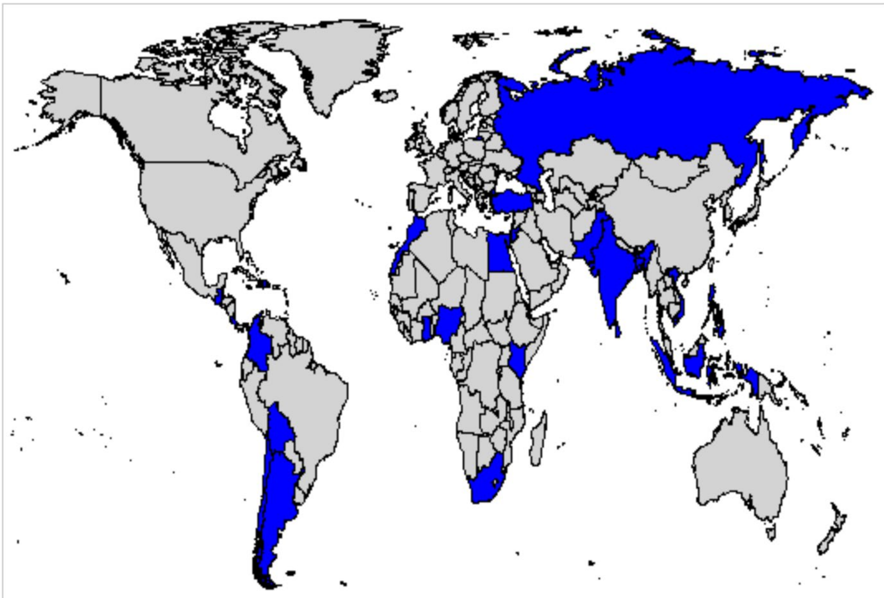

Fig. 1 World map highlighting countries considered for the study. Author's illustration

shaped by industry focus, local linkages, and institutional context. Our statistical approach is therefore only shows whether there are effects on average.

While the two cities in each pair were controlled for comparability before the analysis, we additionally use the population size as a further control variable. Moreover, the country-level patent count was used as a control variable to account for the broader national innovation environment. By including this variable, we ensure that the analysis accounts for the wider innovation trends, further enhancing the reliability of the results. Although other factors, such as GDP per capita and R&D expenditures, are also influential for innovation, these were not incorporated due to data limitations for this study. Nevertheless, the parallel trend assumption, which is the cornerstone of robustness in DiD analysis, is assessed using an event study, further strengthening confidence in the validity of our findings.

The DiD model to estimate the impact of SEZs on innovation can be mathematically expressed as follows:

$$log\left(E\left(Y_{it}\right)\right) = \beta_0 + \beta_1 Treatment_i + \beta_2 Time_{it} + \beta_3\left(Treatment_i \times Time_{it}\right) + \gamma X_{it} + \alpha_i + \lambda_t + \epsilon_{it}$$

Where $E(Y_{it})$ represents the expected count of patents for city i at time t, and β_0 is the intercept term. The variable $Treatment_i$ is a binary indicator of whether city i has a SEZ (1 if the city established a SEZ and 0 otherwise). The variable $Time_{it}$ is a binary variable that takes the value 0 for the period before SEZ establishment and 1 for the period after SEZ establishment, *specific to each city and its comparable counterpart*. The interaction term $Treatment_i \times Time_{it}$ is the indicator in question, which captures the causal effect of SEZ establishment on patent count after its establishment for each city. X_{it} represents a set of control variables accounting for other factors that might influence patent counts. The terms α_i *and* λ_t represent city-specific and time-specific fixed effects, respectively, which control for unobserved heterogeneity across cities and over time. As most countries in our sample are represented by only a single treated-control city pair, we do not include country fixed effects. In such a structure, country fixed effects would be collinear with the city fixed effects. Finally, ϵ_{it} is the error term. Table 1 gives descriptive statistics for the variables. The model is estimated using a negative binomial regression to handle the overdispersed nature of patent count data.

4 Results

4.1 Effect of SEZs on patent count

Table 2 reports the impact of establishing SEZs on the number of patents based on the fractional applicants and inventors' count. The results reveal that the establishment of SEZs has a significantly positive effect on both inventor-based and applicant-based patent counts. Furthermore, we also find a significant positive impact of SEZs on high-tech patents. Although the effect on low-tech patents is also positive,

Table 1 Statistical summary of the variables

Variable	Observations	Mean	Standard deviation
Treatment dummy	2352	0.5	0.5
Time dummy	2352	0.69	0.45
Patents (inventors)	2352	6.08	47.6
Patents (applicants)	2352	2.55	13.1
High-tech patents (inventors)	2352	5.1	43.6
Low-tech patents (inventors)	2352	0.9	4.2
High-tech patents (applicants)	2352	1.93	11.45
Low-tech patents (applicants)	2352	0.7	3.54
Patents in electrical engineering (inventors)	2352	2.2	24.9
Patents in electrical engineering (applicants)	2352	0.58	4.85
Patents in instruments (inventors)	2352	0.67	3.73
Patents in instruments (applicants)	2352	0.42	2.18
Patents in chemistry (inventors)	2352	1.7	12.27
Patents in chemistry (applicants)	2352	0.79	4.39
Patents in mechanical engineering (inventors)	2352	0.91	6.01
Patents in mechanical engineering (applicants)	2352	0.57	2.97
Patents in other fields (inventors)	2352	0.41	2.6
Patents in other fields (applicants)	2352	0.26	1.58
Control variables			
Patents (inventors, country level)	2352	169.08	867.4
Patent (applicants, country level)	2352	97.71	377.3
High-tech patents (inventors, country level)	2352	90.77	335
Low-tech patents (inventors, country level)	2352	22.17	102.1
High-tech patents (applicants, country level)	2352	71.05	268.2
Low-tech patents (applicants, country level)	2352	18.67	95.1
Patents in electrical engineering (inventors, country level)	2352	36.7	168.1
Patents in electrical engineering (applicants, country level)	2352	26.07	140.1
Patents in instruments (inventors, country level)	2352	18.7	99.6
Instruments (applicants, country level)	2352	12.44	74.04
Patents in chemistry (inventors, country level)	2352	41.2	185.9
Patents in chemistry (applicants, country level)	2352	34.18	159.79
Patents in mechanical engineering (inventors, country level)	2352	23.03	108.5
Patents in mechanical engineering (applicants, country level)	2352	18.56	93.5
Patents in other fields (inventors, country level)	2352	11.3	43.8
Patents in other fields (applicants, country level)	2352	10.16	42.29
Population	2352	1424465	2011273

[a]Individual coefficients for time and treatment are omitted, as they are absorbed by the fixed effects

Table 2 The effects of SEZs on patent count

Variable	Patent count (inventors)	Patent count (applications)	High-Tech patent count (inventors)	High-Tech patent count (applications)	Low-Tech patent count (inventors)	Low-Tech patent count (applications)
Treatment	0.188 (0.20)	– 0.138 (0.24)	0.232 (0.215)	– 0.1293 (0.2526)	0.169 (0.320)	– 0.0543 (0.3690)
Time	0.580 ** (0.18)	0.729 *** (0.20)	0.490 ** (0.186)	0.7941 *** (0.2170)	0.840 ** (0.265)	1.262 *** (0.3083)
Interaction Term	**0.832 *** (0.20)**	**0.929 *** (0.23)**	**0.900 *** (0.208)**	**0.9596 *** (0.2549)**	**0.502 (0.291)**	**0.3714 (0.3437)**
City fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes

Significance levels are represented by ***, **, and *, corresponding to 0.001, 0.01, and 0.05, respectively. Standard errors are shown in parentheses

it is only significant at 0.1 level for inventors and not significant for applicants, suggesting that SEZs primarily stimulate patentable innovation in high-tech industries.

4.2 Heterogeneous results in different technological sectors

Tables 3 and 4 present the impact of SEZs on patent activity across five technological sectors. The results indicate a statistically significant positive effect of SEZs on inventor-based patents in electrical engineering and chemistry and on applicant-based patents in electrical engineering, chemistry, and instruments. The

Table 3 The effects of SEZs on inventor-based patent count in different technological sectors

Variable	Electrical engineering	Instruments	Chemistry	Mechanical engineering	Other fields
Treatment	– 1.046* (0.468)	– 0.062 (0.415)	0.524 (0.277)	0.5996 (0.339)	– 0.139 (0.579)
Time	0.745* (0.304)	1.299 *** (0.319)	0.620 ** (0.221)	0.985 *** (0.291)	0.853 * (0.417)
Interaction term	**1.061 ** (0.341)**	**0.3083 (0.3571)**	**0.699 ** (0.245)**	**0.2565 (0.3190)**	**0.5710 (0.4533)**
Time and city fixed effects	Yes	Yes	Yes	Yes	Yes
Control	Yes	Yes	Yes	Yes	Yes

Significance levels are represented by ***, **, and *, corresponding to 0.001, 0.01, and 0.05, respectively. Standard errors are shown in parentheses

Table 4 The effects of SEZs on applicant-based patent count in different technological sectors

Variable	Electrical engineering	Instruments	Chemistry	Mechanical engineering	Other fields
Treatment	– 0.6231 (0.5250)	– 0.6162 (0.4918)	– 0.3910 (0.3802)	0.3373 (0.3766)	0.8971 (0.7111)
Time	0.8687 * (0.3802)	0.8807 ** (0.3340)	0.8879 ** (0.2765)	0.8847 ** (0.2924)	1.337 * (0.5853)
Interaction Term	**1.0432 *** **(0.4417)**	**0.9243 *** **(0.3926)**	**0.7887 *** **(0.3194)**	**0.4496** **(0.3299)**	**– 0.09487** **(0.6138)**
Time and city fixed effects	Yes	Yes	Yes	Yes	Yes
Control	Yes	Yes	Yes	Yes	Yes

Significance levels are represented by ***, **, and *, corresponding to 0.001, 0.01, and 0.05, respectively. Standard errors are shown in parentheses

effect on mechanical engineering and other fields is not significant in both patent categories.

4.3 Robustness checks

4.3.1 Covariate balance test

To examine whether SEZ cities differ systematically from their comparison counterparts before SEZ establishment, we conducted a covariate balance test using pre-treatment characteristics. Table 5 reports mean differences and standardized mean differences (SMDs) for variables including population size, presence of a university, port, and airport, as well as distance to the nearest populous city (> 250 k). None of these differences is statistically significant, and all SMDs have low values, indicating that the two groups are reasonably balanced. Although population size only

Table 5 Covariate balance between treated and control cities

Variable	Control mean (standard deviation)	Treated mean (standard deviation)	*p* value	SMD
Population (×1000)	1149 (1985)	1689 (2197)	0.337	0.262
University	0.93 (0.27)	0.93 (0.26)	0.971	0.010
Port	0.78 (0.42)	0.82 (0.39)	0.692	0.107
Airport	0.96 (0.19)	0.96 (0.19)	0.980	0.007
Distance to the next populous city (km)	480.3 (536.3)	523.9 (662.7)	0.790	0.072

Significance levels are represented by ***, **, and *, corresponding to 0.001, 0.01, and 0.05, respectively shows a slight imbalance compared to the other characteristics, it was included as a control variable in the main analysis, ensuring that this minor difference is also accounted for.

Furthermore, it is important to note that SEZs locations are most probably not chosen randomly. However, the balance observed in our data indicates that, within our sample, treated and control cities are sufficiently comparable in their baseline characteristics. This supports the validity of the identification strategy and decreases concerns about selection bias.

4.3.2 Event study

A key identification assumption underlying our DiD approach is that, in the absence of SEZ establishment, treated and control cities would have followed parallel trends in innovation outcomes. To assess the validity of this assumption, we implement a dynamic pre- and post-treatment test by constructing relative event-time indicators for the 10 to 2 years preceding SEZ establishment, using year –1 as the omitted reference category, as well as for the 30 years following the establishment. As shown in Figs. 2 and 3, the estimated coefficients for the pre-treatment years are statistically insignificant, indicating that treated and control cities followed similar patenting trajectories before the introduction of SEZs. After treatment, the estimates increase steadily and become statistically significant, consistent with SEZs generating a sustained rise in innovative activity. The absence of significant pre-treatment differences as well as the increase in patenting in treated cities after SEZ establishment, provide an additional support for the

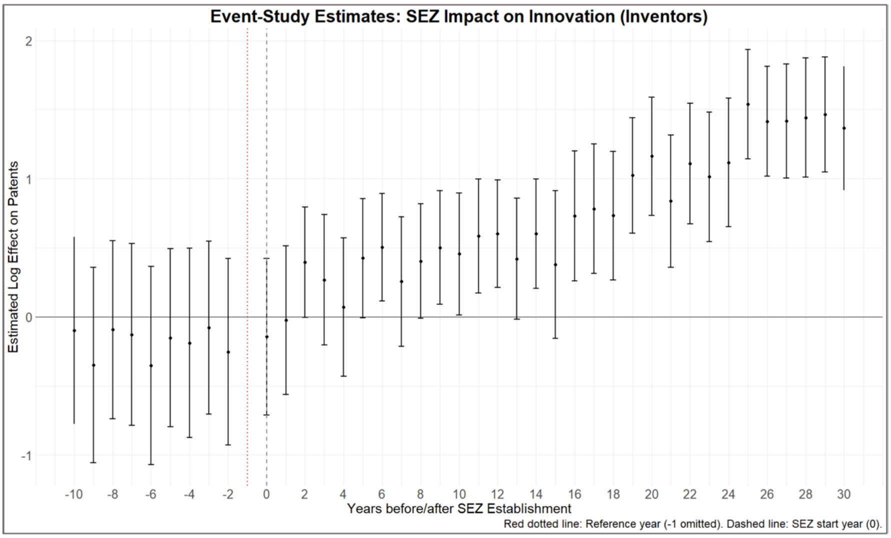

Fig. 2 Event-study estimates: SEZ Impact on innovation (inventors)

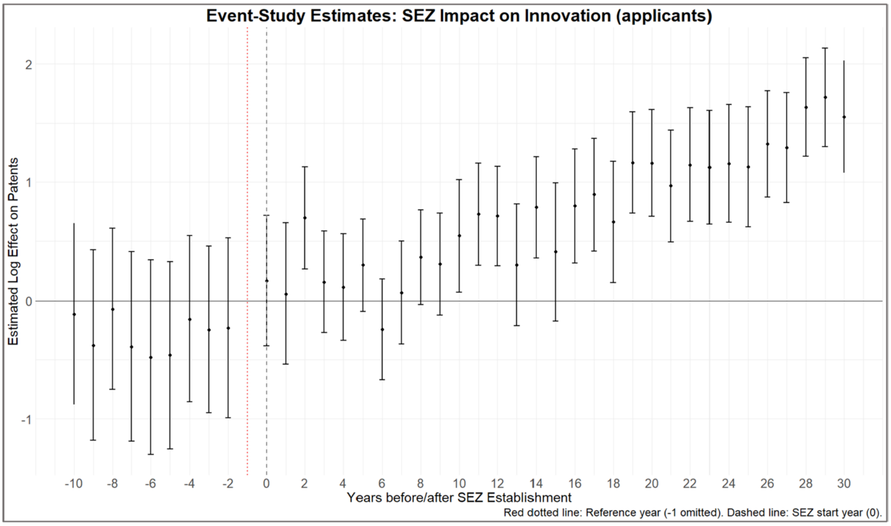

Fig. 3 Event-study estimates: SEZ impact on innovation (applicants)

credibility of the DiD design. The dynamics of the effects in the period after the treatment will be further discussed in Sect. 5.

4.3.3 Accounting for national heterogeneity

Since treated and control cities are sampled from multiple countries, a further concern is that national-level policy changes or macroeconomic shocks could confound the estimates. To address this, we re-estimate the main model including Country-by-Year fixed effects in addition to City fixed effects, thereby absorbing all country-specific shocks and policy changes varying over time. Identification therefore comes from within-country, within-year differences between SEZ and comparison cities. This specification was estimated using Poisson regression, which efficiently handles high-dimensional fixed effects[3]. As shown in table 6, the treatment effect remains positive and significant for both inventor- and applicant-based patent counts, further strengthening the robustness of the results.

5 Discussion

As presented in the literature review, some studies suggest that SEZs primarily boost trade and employment without significantly impacting innovation, while others argue that SEZs can create environments conducive to technological advancements,

[3] We retain our negative binomial specification as the main model, as it better accounts for over-dispersion in patent counts.

Table 6 Model re-estimation with country–by-year fixed effects

Variable[a]	Patent count (inventors)	Patent count (applicants)
Interaction term	1.030 ** (0.363)	1.813 *** (0.377)
City fixed effects	Yes	Yes
Country–year fixed effects	Yes	Yes
Control	Yes	Yes
Adj. Pseudo R^2	0.827	0.933

Significance levels are represented by ***, **, and *, corresponding to 0.001, 0.01, and 0.05, respectively. Standard errors are shown in parentheses

particularly when measured through patent activity. The results of our study align with the latter view, providing evidence that SEZs have a positive and significant impact on innovation, as reflected in increased patent counts. That SEZs have positive effects of similar size on both inventor- and applicant-based patent counts suggests that SEZs provide an environment that enhances the patent-related processes managed by the firms in the zone, which are usually the applicants, and not only innovative activity of foreign firms, which would only enhance inventor-based counts. The effect on applicant-based patent counts is even slightly higher, suggesting that SEZs seem rarely able to attract foreign R&D activity, but are able to either attract innovative firms and/or make firms in the area more innovative.

The positive effect of SEZs is especially seen in high-tech industries. This finding suggests that SEZs are not merely zones of increased industrial output and low-level innovativeness, but can also serve as hubs for high-level innovative activities, especially in comparison to other places in the same country. A potential interpretation is that SEZs provide a more favorable institutional support and infrastructure needed by high-tech industries, such as R&D, knowledge spillovers, and agglomeration effects. Three kinds of processes might take place: high-tech firms might especially (re-)locate in SEZs, high-tech firms might be more successful in SEZs, or firms become more high-tech in SEZs. The two latter kinds of processes support the notion that SEZs can help countries move up the value chain by enabling more technologically advanced production, thus contributing to long-term economic development. The policies often associated with SEZs, such as tax incentives for R&D and access to innovation funds, which can be helpful with risky innovation projects, appear to play a critical role in this regard. Additionally, and as mentioned before, SEZs usually offer stronger intellectual property protection and regulatory support, which is critical for safeguarding innovation. High-tech sectors rely heavily on protecting their patents.

Furthermore, the results show variation in SEZ impact across different sectors. SEZs have a significant impact on patents in fields like electrical engineering, instruments, and chemistry, whereas the impact is insignificant in mechanical engineering and other fields. Several key aspects may explain these differences. Firstly, the insignificant impact in “other fields” may be due to this category mainly comprising low-tech industries, where SEZ incentives have limited effectiveness in driving patent activity. Similarly, although mechanical engineering includes various high-tech segments, SEZs have an insignificant effect here as well. This could be due to the sector's traditional nature, where well-established and patent-saturated fields provide relatively fewer opportunities for patentable innovations. Consequently, developing and emerging countries might generally encounter fewer prospects for innovation in these mature areas. In contrast, the fields of electrical engineering, instruments, and chemistry encompass more frontier technologies, where rapid advancement and lower patent saturation foster greater opportunities for innovation. Research by UNCTAD (2023), Lee (2021), and Lee et al. (2021) provides further insights into the topic of technological catch-up, as well as how developing and emerging economies might benefit from these frontier technologies.

While SEZs appear to have a more significant impact on high-tech sectors, it is important to recognize that low-tech industries may engage in different types of innovation, such as incremental improvements of products and processes. These sectors may not exhibit the same levels of patent activity; nonetheless, their innovations can still contribute to productivity gains and overall economic development.

In addition, we excluded countries with no or very low levels of innovation activity as measured by patents. However, the existence of countries that host multiple SEZs yet show (almost) no patent activity can be interpreted as well. It suggests that the impact of SEZs at least on this particular form of innovation is dependent on the presence of a certain level of pre-existing capacity. The findings indicate that SEZs appear to be more effective in enhancing patent activity where a basis for it, such as adequate R&D infrastructure, skilled workforce, and supportive policies, already exists. In contrast, SEZs may have limited influence on this type of innovation in contexts where such a basis is limited or does not exist, while other effects might still be given.

Taken together, these observations prompt a broader reflection on the use of patent counts as a proxy for innovation. Although patent data provide a standardized and internationally comparable measure of innovation, they primarily capture formalized, codified knowledge creation (Brenner & Broekel 2010). In emerging and developing economies, however, innovation often takes the form of knowledge use, technological adaptation, and incremental upgrading. As Vujanović et al. (2022) point out, such activities may not result in patents. Moreover, legal, institutional, and financial barriers to patenting may further suppress otherwise observable patenting activity.

While incremental innovations are essential for the initial stages of technological catch-up and mid-term economic development, focusing on patentable innovation in the context of developing and emerging economies remains important. As Ebersberger et al. (2023), Verspagen (1991), and Malerba & Lee (2021) emphasize, sustainable and long-term economic catch-up in latecomer economies ultimately requires a shift from imitation to original knowledge creation. Patents, in this sense, offer insights into whether these economies are generating new knowledge -- a hallmark of more profound technological upgrading.

Our findings should thus be understood in relation to these contextual considerations. On the one hand, the significance of our results suggests that SEZs may help overcome some of the obstacles to patenting -- as many SEZs explicitly offer patenting grants and legal support- and thus assist in creating an important pathway to advanced knowledge creation and long-term economic catch-up. On the other hand, our analysis captures only one dimension of innovation -- the patentable output -- and does not reflect the full range of other non-patented but equally important forms of innovation occurring in developing and emerging economies.

Lastly, it takes time to see the first effects of SEZ on innovation taking place. As the event study shows (see Figs. 2 and 3), the post-treatment coefficients start becoming positive and statistically significant after roughly 5–10 years and remain more consistent after that. This gradual rise suggests a long-term build-up process, where the benefits of SEZ policies start appearing as firms settle, networks form, and knowledge spillovers intensify. These findings imply that SEZs, like many other innovation policies, promote innovative activities primarily in a cumulative manner.

6 Conclusion

In this paper, we have analyzed the effect of establishing SEZs on innovation as measured by patent numbers. We used a difference-in-differences model. Overall, our findings provide evidence that SEZs can promote innovation in the local economies. The effects are particularly pronounced in high-tech fields compared to low-tech field, highlighting the potential of SEZs to drive technological advancements. Furthermore, we find a similar effect on applicant- and inventor-based patent counts, suggesting that the effect comes (mostly) from firms with their headquarters in the SEZs and not from firms only conducting their R&D activity there. Hence, SEZs either attract innovative firms or make the firms located there more innovative, or both.

Given the results and taking into account the regional and national contexts, SEZs can indeed be viewed by policymakers as a viable tool for promoting innovation-driven economic growth. Policies aimed at fostering innovation within SEZs should, step by step, be extended to encompass broader regions of the host country while also strengthening linkages with the wider economy. Given our findings of a greater impact of SEZs on patents from high-tech sectors, policymakers should prioritize creating more incentives specifically tailored to these industries. Lastly, to ensure that innovative outputs are fully utilized, policymakers must develop institutions capable of capturing and commercializing the value of the innovations generated.

While SEZs are more effective in regions with a pre-existing innovation activity, this should not imply that SEZs are irrelevant in less developed areas. Rather, SEZ policies should be phased or tailored to match the local context. For regions with weaker innovation capacity, initial efforts could focus on building essential infrastructure, such as research facilities and education centers, to gradually elevate innovation potential. Over time, as the region develops a stronger innovation basis, SEZ policies could shift towards more advanced incentives, such as R&D subsidies and intellectual property protection, ensuring sustained innovation growth.

For a final conclusion about how helpful SEZs are for the development of the whole country, it is important to examine whether the positive effect within the SEZs is based on firms moving there or firms improving within the SEZs. Further studies are necessary to disentangle these two possible mechanisms, which is beyond the scope of this paper focusing on SEZs.

Region-specific case studies offer an option to better understand the local dynamics influencing SEZ success. They can also address the questions of which specific policies or characteristics of and within SEZs have a more profound impact on innovation. Analyzing spillover effects on innovation in neighboring regions and using alternative indicators of innovation would also provide deeper insights into the broader impact of SEZs on innovation.

Appendix

Table 7 City pairs considered for the study

Treatment group	Control group	Country
San Luis	Río Cuarto	Argentina
Chittagong	Rangpur	Bangladesh
Dhaka	Mymensingh	Bangladesh
Belize City	Belmopan	Belize
La Paz	Cochabamba	Bolivia
Iquique	Osorno	Chile
Bogota	Medellín	Colombia
Barranquilla	Ibague	Colombia
Alajuela	Limon	Costa Rica
Santo Domingo	Monte Plata	Dominican Republic
Alexandria	6th Of October	Egypt
Accra	Kumasi	Ghana
Guatemala City	Mixco	Guatemala
Pune	Lucknow	India
Surabaya	Bekasi	Indonesia
Kingston	Portmore	Jamaica
Amman	Irbid	Jordan
Nairobi	Mombasa	Kenya
Casablanca	Fès	Morocco
Lagos	Kano	Nigeria
Manila	Antipolo	Philippines
Karachi	Lahore	Pakistan
Kazan	Chelyabinsk	Russia
Port Elizabeth	Vereeniging	South Africa
Colombo	Dehiwala	Sri Lanka
Izmir	Konya	Turkey
Gaziantep	Diyarbakir	Turkey
Ho Chi Minh	Da Nang	Vietnam

Author Contribution A.A.A. and T.B. conceptualized the study, designed the methodology, collected and analyzed the data. A.A.A. wrote the main manuscript text and prepared the Figures. All authors reviewed and approved the final manuscript

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Declarations

Competing interests The authors declare no competing interests.

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