Trade Liberalization and Innovation

An Empirical Study of the Effect of Trade Liberalization on Innovation: A Difference-in-Differences Approach

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Acknowledgments

This thesis remarks the end of my studies in economics at the University of Oslo. It has been five challenging yet fun and interesting years where I have learned a lot. As a student of economics, my main interest has always been the topic of international trade and technology. Hence, there has been no better way to end this era than by writing up a master thesis about the theme that inspired me to study in the first place.

First of all, I would like to thank my supervisor, Andreas Moxnes, for his excellent guidance from the beginning to the end of this thesis. Secondly, I would like to thank Daniel Fullman for helping me understand how Stata works. Last, but not least, I thank my boyfriend, friends and family for their support throughout this semester. It has been highly valued.

All mistakes, errors and inaccuracies are my responsibility.

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Abstract

Is innovation accelerating more in liberalizing countries compared to non-liberalizing countries? This thesis investigates the relationship between trade liberalization and innovation globally by using data on mean tariff rates and patent filings. To estimate the causal effect, I make use of a difference-in-differences method and view the Uruguay Round of the 1990s as treatment. I exploit the differences in the change of mean tariff rates before and after the Uruguay Round. Liberalizing countries are those that reduced their mean tariff rates by more than the sample-median tariff following the Uruguay Round, and non-liberalizers are those that did not. My results indicate that liberalizing countries have innovation rates that are about 4.4 percent higher than those of non-liberalizers. Furthermore, the results are significant at the 5 percent level using a discrete treatment variable and pass robustness tests on patent quality and two falsification tests evaluating the common trend assumption.

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1 Introduction

The topic of this thesis is the effect of trade liberalization on innovation. This topic is currently high on the political agenda and is indeed also an interesting and recurrent subject of economic research.

Innovations are important in our everyday lives. Perhaps more than anything, this is illustrated by the Covid-19 vaccine, an innovation that currently seems to be crucial for our prospects to return to a "normal life". The development of the vaccine demonstrates the importance of international cooperation in research and development. Furthermore, as the extraordinary demand for facemask textiles and hand disinfectant shows, the pandemic illustrates the importance of global cross-border exchange of scientific information and supplies. This exchange is to a large extent dependent on trade policies and regulations (WTO, 2020).

Despite the seemingly obvious benefits of globalization for innovation and trade, we have recently seen a growing skepticism of globalization. This is perhaps most clearly illustrated by Brexit in the United Kingdom and the popularity of Trump, the former President of the Unites States (US), whose trade war with China revived the idea of protectionism. According to economic theory, increased tariffs on imports will worsen the import opportunities and decrease import competition. A potential result could be less domestic innovation and reduced efficiency. The ongoing Covid-19 pandemic may also have strengthened the argument that it is important for countries to be self-sufficient and independent on imports from other countries. If it is true that trade liberalization promotes innovation, a growing anti-trade environment could negatively affect innovation. Thus, the current political climate has been a motivation for me to investigate the relationship between innovation and trade liberalization on a global level. More specifically, the objective of my thesis is to determine if tariff reductions have a significant effect on innovation. For 45 countries, I examine this relationship by using data on patent filings as a measure of innovation and changes in the mean tariff rate.

The research literature suggests that there is a positive relationship between trade liberalization and innovation (Bloom, Draca & Van Reenen, 2016; Long, Raff & Stähler, 2011; Cornea & Ornaghi, 2014). One way trade liberalization positively impacts innovation is through the improved import opportunities mechanism. That is, tariff reductions lower the price on intermediate inputs, resulting in higher profits and improved prospects for innovation. Another way the impact on innovation is felt is through the mechanism of import competition. This stimulates domestic firms to engage in an innovative activity to avoid losing their market position. Third, because undertaking innovation is potentially risky and costly, a stable and predictable trade and investment environment is favorable. Trading agreements that aim to reduce trade barriers can contribute to such stability. A fourth relationship concerns export opportunities. Trade liberalization can work to increase firms´ market size by allowing domestic firms to enter a foreign market. The improved export opportunities can increase returns on innovative activity by extending the markets to sell to. I, however, limit my thesis to focus on two mechanisms: improved import opportunities and import competition.

There are several ways to measure trade liberalization and innovation. Two articles, in particular, have influenced my approach. The first one is Estevadeordal and Taylor's (2013) article *Is the Washington Consensus Dead? Growth, Openness, and the Great Liberalization, 1970s-2000s.* The authors find that liberalizing tariffs on imported capital and intermediate goods resulted in faster economic growth. While their study is about growth and trade (and not innovation), there seems to be an established correlation between innovation and economic growth (Shu & Steinwender, 2019). Historically, this is proven by the industrial revolution. More generally, one could argue that innovations lead to higher efficiency through better production methods, which then result in higher productivity and economic growth; an example of better production methods is the assembly line (Allen, 2011).

However, what is of particular interest here is the way Estevadeordal and Taylor (2013) use a difference-in-differences (hereafter DiD) approach to measure trade liberalization taking the *GATT Uruguay Round* as the treatment in their analysis. The Uruguay Round lasted from 1986 to 1994 and included 123 countries, both developed and developing, and aimed to reform international trade (WTO, n.d.). The result of the Uruguay Round was a 40 percent global reduction of tariffs, as well as an agreement on a broader market opening for goods (Coelli, Moxnes & Ulltveit-Moe, 2020a). Estevadeordal and Taylor (2013) use the Uruguay Round as treatment and categorize the countries into liberalizing and non-liberalizing countries. Liberalizing countries are countries that reduced their mean tariff rates by more than the sample median tariff following the Uruguay Round, and non-liberalizers are those that did not.

I limit my thesis to investigating the relationship between trade liberalization and innovation but, similarly to Estevadeordal and Taylor (2013), I use the Uruguay Round as the treatment and use the terms liberalizing and non-liberalizing countries. While Estevadeordal and Taylor (2013) study the period 1975-2004, I use data for the period 1975-2010.

The second article on which I build my thesis is *Better, Faster, Stronger: Global Innovation and Trade Liberalization* (Coelli et al., 2020a). This article is thematically in line with my thesis and is also useful in terms of approach. Coelli et al. (2020a) use the Uruguay Round to estimate the effect of trade liberalization on innovation by using the most favored nation (MFN) tariff data and firm-level patent data. Interestingly, the authors find a large effect on innovation of increased marked access via trade liberalization. Moreover, the authors argue that patent filings are a good measure of innovation and maintain that so far, there is little research using patents as an observable output-based measure of innovation. Like Coelli et al. (2020a) I exploit the tariff cuts resulting from the Uruguay Round, and by employing patent data to study the effect of trade liberalization on innovation, I add to the scant empirical literature on this topic. However, my thesis will not focus on increased market access but will instead scrutinize the mechanisms of import competition and improved import opportunities. Furthermore, while Coelli et al. (2020a) study firm-level patent data, my thesis utilizes country-level data and thus provides a broader measure of the effect of trade liberalization on innovation.

The objective of this thesis is to determine if there is a significant effect of tariff reductions on innovation. My research question is: Is innovation accelerating more in liberalizing countries than in non-liberalizing countries?

For the empirical design, I use a quasi-experimental DiD approach. It is a common method when the objective is to analyze the effect of a policy intervention (e.g., trade policy) to which certain groups are exposed while others are not. By using a DiD approach, I exploit the differences in the change of the mean tariff rates before and after the Uruguay Round. Pre-Uruguay is Period 1 and lasts from 1975-1989. Post-Uruguay is Period 2 and lasts from 1990-2010. This allows me to identify the effects of trade policy changes on innovation.

My empirical findings suggest that innovation accelerate more in liberalizing countries than in non-liberalizing countries. My results are significant at the 5 percent level and indicate that liberalizing countries experience innovation rates that are 4.4 percent higher. Furthermore, my results hold when controlling for patent quality and when performing two falsification tests on the common trend assumption.

The remainder of this paper is organized as follows: Section 2 gives an overview of the empirical research literature to which I contribute. Section 3 presents the economic mechanisms and serves as the theoretical foundation for my thesis. Section 4 describes the dataset applied and presents descriptive statistics. Section 5 outlines the empirical design and discusses some econometric concerns. Section 6 presents and discusses the empirical results of my analysis and includes robustness checks. Lastly, Section 7 summarizes and concludes.

2 Literature review

There is a rich literature on the theoretical mechanisms of trade policy and innovation (see Section 3). To my knowledge, however, the empirical literature is more limited.

The literature generally finds a positive and significant relationship between access to intermediates and innovation – thus supporting the improved import opportunities mechanism, while the literature on the impact of import competition on innovation is less clear (Shu & Steinwender, 2019). For this mechanism, the empirical evidence varies from positive and significant, to positive but insignificant, and negative and significant (Shu & Steinwender, 2019).

The empirical findings of Akcigit, Ates and Impulliti (2018) belong to the group of studies that find a positive and significant effect on innovation of import competition at the firm-level. By using data on import tariffs and R&D subsidies, they show that increased import competition encourages innovation. The reason for this is that firms increase their R&D spending to retain their market position. It has been shown that R&D is highly correlated with both patenting and innovation (Griliches, 1990). Furthermore, Akcigit, Ates and Impulliti (2018) find that less import competition increases the need for R&D subsidies. In this way, increased competition itself works as an incentive to innovate. Without competition, however, the firms need incentives in the form of R&D subsidies. Likewise, Griffith, Harrison and Simpson (2012) treat the EU´s single market program as a policy tool and find that the program intensifies product market competition in some affected countries. They also find that the affected countries increased their R&D investment. R&D investments are commonly used as a measurement of innovation. For the empirical analysis in this paper, however, I use patent data as a measure of innovation. Since patent data can be understood as a successful output of an R&D process, patents can be regarded as a direct measure of innovation (Coelli et al., 2020a).

More relevant to my empirical approach is the research literature using patent data as a measure of innovation. Most of the literature on patents uses firm-level data. A benefit of using firm-level data is that it gives more detailed information on innovative activity. Cornea and Ornaghi (2014) use firm-level data on patent statistics and productivity growth. They observe that firms exposed to more competition innovate more. Coelli et al. (2020a) apply firm-level panel data on patent filings and use the Great Liberalization of the 1990s as a quasi-experiment to estimate the effect of increased market access on innovation. They find a positive and significant effect of tariff cuts on innovation. As mentioned in Section 1, my approach is similar, except whereas Coelli et al. (2020a) focus on better market access for exporters, I focus on import competition and better import opportunities for firms. Hence, I believe my research contributes to the empirical literature by using the Great Liberalization and patent data to measure the effect of trade liberalization on innovation.

The research literature exposes potential regional differences on the impact of import competition. For instance, European countries experience a clear positive effect of import competition, while Northern American firms experience a more negative effect of import competition (Shu & Steinwender, 2019). Bloom et al. (2016) use data on firm-level patents, informational technology, and total factor productivity. In addition, they use China´s 2001 WTO entry as an exogenous trade shock and find that exposure to Chinese import competition led to increased innovation in 12 European countries in the period 1996-2007. By contrast, Chinese import competition had a negative effect on innovation measured as a decrease in R&D spending among firms in the United States (US) (Autor, Dorn, Katz, Patterson, & Van Reenen, 2017). Moreover, Canadian firms self-report a negative effect of import competition on product and process innovation (Shu & Steinwender, 2019). Whether in terms of differences in research design or regional economies, what seems clear is that the relationship between import competition and innovation remains ambiguous.

Lastly, the literature on improved import opportunities generally finds a positive and significant effect on innovation (Shu & Steinwender, 2019). Lesser (2008) considers, among other policy tools, Finland's entry into the EU and WTO in 1995 and finds that the resultant trade liberalization has had a positive and significant effect on innovation. The author finds that the import of intermediates has been essential for technology adaption in the Finish telecom industry. The adaption was made possible through cheaper intermediates and better-quality products. Amiti and Konings (2007) use changes in tariffs to compare the effect of import competition and the effect of import intermediates on innovation among firms in Indonesia. The authors find that import intermediaries have the greatest effects. Like Amiti and Koning (2007), I use changes in the mean tariff rates as a measure of the effect on innovation. However, unlike them, I am not able to separate the two effects.

While many of the above-mentioned studies have a regional focus, one of the strengths of my study is that it includes several countries. In addition, my research is a contribution to knowledge in the field since it uses country-level instead of firm-level or industry-level data. Thus, I analyze the impact of trade liberalization more broadly and provide stronger external validity.

3 Economic mechanisms.

In this section, I examine the economic mechanisms of the relationship between trade liberalization and innovation. My focus is on the effects of competition and import opportunities on innovation. As reviewed in Section 2, the former has an ambiguous effect on innovation. One view is that competition promotes innovation. Another view claims that innovation only happens in a monopoly or oligopoly environment. The latter mechanism suggests a positive relationship between tariff cuts and innovation, as evidenced by improved import opportunities for the firms. The relationship can, however, be weakened by knowledge spillovers and technological diffusion. As a final point I briefly address the effect of market size on innovation.

3.1 Innovation and competition

The view that competition fosters innovation goes far back in history. Adam Smith believed that greater competition would lead to a higher innovation rate through reductions in production costs and through the adoption of the most efficient production methods (Cornea & Ornaghi, 2014). Trade liberalization implies that the domestic market experiences increased competition from abroad. The domestic firms compete not only with each other, but also with foreign firms. Competition can encourage innovative activity to protect a firm's market position (Griffith, Harrison, & Simpson, 2012). For example, intensified competition induces innovative activity through the incentive of lowering costs by adapting the most efficient production methods. In this way, increased import competition can motivate firms to always strive to adopt the newest technology. This effect has empirical support: Bloom et al. (2016) find that among surviving firms, increased import competition from China led to increased innovation. Firms exposed to import competition from China had more patent filings, lower prices and increased skill levels and productivity compared to those who were not exposed. The view that there is a positive relationship between competition and innovation is known as the escape-competition effect (Shu & Steinwender, 2019).

In addition to cost reduction and increased efficiency, greater competition may increase incentives for incumbent firms to reduce slack. They may perform better simply by generating greater effort to not lose business. For example, greater competition may induce firm managers to exert more effort and invest in innovation, to avoid the loss of private benefits such as a wage premium or a wage bonus that require the continued existence of the firm. This is what Shu and Steinwender (2019) call the preference effect, which also highlights a positive relationship between competition and innovation.

More than 150 years after Adam Smith, Joseph Schumpeter made the opposite claim (Cornea & Ornaghi, 2014). Schumpeter argued that increased competition might lower innovation. With increased competition, the profit motive to innovate is reduced due to lower price margins, and the firms need a clear incentive to engage in innovative activity. Put differently, the Schumpeterian claim is that innovation is only created in the context of very low competition, close to a monopoly setting. Hence, less import competition means less competition among domestic firms, and this promote innovation. In addition, less competition implies a larger market share which is an essential incentive to undergo risky, innovative activity. Furthermore, in a setting close to an oligopoly or monopoly environment, firms typically have sufficient resources to invest in innovation without any financial constraints. These firms are better suited for such projects, and they only invest if they expect to profit. At the same time, firms could potentially be "too big to fail". Without competition, a large firm might be reluctant to innovate because there is no other firm to take its share of the market.

Patents could also potentially contribute to both the escape-competition effect and the Schumpeterian effect. Firms need incentives to innovate. A patent can provide such an incentive by giving the firm with the patent temporarily monopoly power. Usually, a patent gives protection for 15-20 years (Rodriguez & Rodrik, 1999). As a consequence, the innovating firm no longer needs to worry about knowledge spillovers and technology diffusions to other firms. The free-rider-problem illustrates this situation: The inventions of one firm can be favorable for other firms adapting the new innovation without themselves having to contribute to the R&D expenditure. In fact, Grossman and Helpman (1991) and Romer (1990) characterize innovation as a positive externality because knowledge is typically a non-rivalrous and only partially excludable good. In other words, patents can help to reduce the free-rider problem. Since the expenditure on R&D[1] might be very costly for the firm that innovates, filing for a patent ensures that they are the only ones to use the invention.

[1] On the process of innovation: R&D can be seen as the input and patent filing can be seen as the output.

As the protection period of 15-20 years proceeds, the protection allows the advantage of learning-by-doing. The innovating firm may have discovered more effective methods related to their invention. If the protection incentive provided by a temporarily monopoly is strong enough, this could be in favor of the Schumpeterian argument. However, it is possible to have too much patent protection. In such a case, the innovating firm no longer operates as a temporarily monopoly but a permanent one. Thus, there is no incentive to file patents. Since patents are a measure of innovation, it follows that reduced competition also reduces innovation.

The discussion above demonstrates that the relationship of competition via trade liberalization has unclear effects on innovation. The escape-competition and Schumpeterian effect go in opposite directions. As explained in Section 2, there are mixed results in the empirical literature, and the effects show regional differences in the impact of import competition. Hence, further empirical evidence is needed.

3.2 Innovation and import opportunities

In my thesis, trade liberalization means tariff reductions. Reduced trade barriers can affect firms in several ways. Furthermore, the effect depends on how many countries and industries are affected. I focus on the improved import opportunities for firms experiencing trade liberalization. Importing firms may find themselves paying less for the imported intermediates than before the tariff cut. In addition, they may also get access to better-quality inputs that they otherwise could not have afforded. Compared to those in a country that does not experience trade liberalization, importing firms experience reduced costs and potentially increased efficiency; because of the tariff cuts they can now afford to buy better-quality inputs. To illustrate: A firm buys imported intermediates for its own production at a lower price than before the trade liberalization. Consequently, the firm manages to reduce its costs, which increases profits and enables the firm to invest in R&D in order to innovate. The R&D investment can lead to new technologies, product designs, or materials which can make the firm more productive. By contrast, a firm in a country with no tariff cuts does not experience the reduction in costs nor the increased profit made possible because of the trade liberalization. As a result, firms in non-liberalizing countries do not get the same cost-advantage as firms in liberalizing countries. This improvement of import opportunities may create differences in innovation rates between countries that experience a trade liberalization and those that do not.

It may be the case that the imported goods or intermediate goods enable firms to gain knowledge from abroad and to take advantage of another firm´s invention (positive externality). As a result, we may get knowledge spillovers and technology diffusion, and this works to lower the need for innovation in the domestic industry. Nonetheless, it leads to increased knowledge and potentially increased productivity of the firm but is not to be captured as increased innovation in my regressions. This may lower the effect of trade liberalization on innovation in liberalizing countries.

The effects of tariff cuts on innovation can be illustrated by a counterexample. Assume that a large country imposes import tariffs on steel. This can be seen as a protectionist policy because it protects the domestic steel industry from import competition. The tariff increases the domestic price for consumers while the domestic steel industry experiences an increased producer surplus. As a result of the increased price, consumers demand less, and this in turn reduces the imports of steel. Simultaneously, an increase in import tariffs on steel hurts firms that depend on importing steel as intermediate goods in their production. Furthermore, the trading partners of the country may retaliate by raising their import tariffs on other goods. This is demonstrated in the trade war between China and the US. Therefore, a protectionist policy may hurt domestic innovation through reduced import competition and a worsening of import opportunities. In view of these effects, liberalizing countries should have higher innovation rates compared to non-liberalizers with a protectionist policy.

3.3 Market size and innovation

Lastly, I briefly mention the effect of market size on innovation. This effect is *not* taken up by my regression tables as I am not focusing on the effects of export market expansion but rather on import competition and import opportunities. Nonetheless, I find it an interesting general mechanism that also affects innovation. Melitz (2003) presents a model where the effect of trade depends on the market size, competition, and the reallocation of productivity between firms. Even though Melitz (2003) does not explicitly mention innovation in his model, the same mechanisms are likely to affect innovation, for instance, through a trade liberalization such as the Uruguay Round. To illustrate: Country X goes from a closed to an open economy enabled by the tariff reform of the Uruguay Round. The firms in country X experience a change in the market size, increased competition, and potentially exit the market.

A trade liberalization increases the market size by allowing domestic firms to compete in the foreign market. This can in turn lead to higher profits for exporting firms that benefit from access to larger markets. Hence, some firms may experience increased market share while others lose market share. Furthermore, the prospects concerning future market size can affect innovation. One reason for this is that the number of patents filed can reflect expectations about the future. If a firm expects a larger market share, it may expect greater profits, and this can increase the incentive to invest in innovation. This is empirically supported by Banerjee and Duflo (2020) and Acemoglu and Joshua (2004), who find that there is a strong correlation between R&D and market share. Contrastingly, firms typically do not undertake risky investments in R&D if they believe the future market may shrink, for example, due to the fear of higher tariffs or other trade barriers. This could also be seen as a response to an increased protectionist policy.

There is also a potential concern that access to a larger market will make entry more attractive and lead to increased domestic competition. This can in turn lead to a winner-takes-it-all effect which works to reduce competition. As Melitz´s (2003) model predicts, opening to trade leads to reallocation of firms, where the most productive survive and the unproductive exit. Thus, the economy retains the most innovative and productive firms, which serve both the domestic and the export markets. This allows them to expand their business even further and to increase their profits. The remaining firms may achieve an even larger market size and consequently reduce the competition in the economy. The larger market size can enable economies of scale that can reduce the cost of investments in R&D, for instance by spreading the costs. This would support the Schumpeterian effect, where increased market size caused by low competition fosters innovation.

4 Data and descriptive statistics

4.1 My Data

The data on mean tariff rates are taken from the Economic Freedom in the World (EFW) 2020 database (Fraser Institute, 2020). This is an updated version of the EFW 2005 database used by Estevadeordal and Taylor (2013). I use Area 4-A(iii), which contains data on the unweighted mean tariff rate. From this dataset, I include 78 countries that participated in the Uruguay round. The dataset is available in five-year increments, starting in 1970 and up to 2000. After the year 2000, it provides data on an annual basis up until 2018. I use data from 1975-2010. One advantage of using unweighted mean tariff rates instead of weighted mean tariff rates is that this does not underestimate countries with high tariff rates (protectionism). Thus, if a country has very high tariff rates on a wide range of categories of products, and low tariffs on just a few of them, it will not be considered as a country with a low mean tariff. Lastly, I measure the tariff rate as the log of the mean tariff in 1985, and the log of the mean tariff in 2005.

The data on patents are taken from the European Patent Office´s Worldwide Patent Statistical Database (hereafter PATSTAT). I am using the same patents data set as Coelli et al. (2020b). *Innovation* is the dependent variable, and I use the number of patent filings as a measure of innovation. The dataset I use contains information about the earliest filing year, starting from year 1782 up until 2019. However, I only use the period 1975-2010, which is equivalent to the time period for the tariff data and the control variables. I have excluded 192 missing values on patents filings.

I use the earliest filing year of patents rather than the grant date or the patent publication date because the earliest filing year is linked more closely to the timing of the R&D process (Coelli et al., 2020a). This is convenient because patenting has been shown to be highly correlated with both innovation and R&D (Griliches, 1990). The dataset includes information about the number of patents filed in each country, the patent family size, and number of inventors. Patentees can be universities, governmental agencies, private businesses, or individual inventors. For simplicity, I refer to all these types as firms. I measure *innovation* as the log number of patent filings at the end of each period subtracted by the log number of patent filings at the beginning of each period with 1990 as an overlapping year, divided by total years elapsed.

I have chosen to add three control variables: *institutional quality*, *human capital* and *lagged growth*. The former is taken from the same database as the tariffs (EFW) (Fraser Institute, 2020). I have chosen *institutional quality* as a variable for two reasons. Firstly, the information on this is available and easy to interpret. Secondly, there is a large literature that emphasizes the impact of institutions on policy changes. The institutionalist view is that institutions trump everything in explaining economic development. Furthermore, high-quality institutions can make it easier for firms to file patents. Hence, there is an empirical basis for including institutions in this analysis (Rodrik, Subramanian, & Trebbi, 2002; Easterly & Levine, 2002; Easterly, 2005). *Institutional quality* is a composite that measures the legal system and property rights. The index is found in area 2AD. *Institutional quality* is measured on a scale from 0-10, where a higher score means higher institutional quality. I calculate *institutional quality* as the log of institutions in 1985, divided by 10 and the log of institutions in 2005, divided by 15. This corresponds to total years elapsed since the start of each period.

The second control variable is *schooling* (human capital) and is taken from the Penn World Table 10.0 (PWT), specifically from the section on additional data and programs: labor details (Feenstra, Inklaar, & Timmer, 2015). As a measure of *schooling*, I have chosen the variable yr_sch, which measures the average years of schooling for the population above age 25. I have selected *schooling* as a variable because innovation requires knowledge. Technology is highly skill-biased and adapting to new technology requires competence (Krugman, Melitz, & Obstfeld, 2018). Increased knowledge may also affect the efficiency of adopting new inventions. I measure *schooling* by the first year in each period, 1975 and 1990.

The third control variable is the initial innovation rate in Period 1. By taking the initial innovation rate of Period 1 into a difference form it measures the lagged level of growth. The inclusion of the control variable, *lagged growth,* is inspired by Estevadeordal and Taylor´s (2013) variable on lagged growth which they use to estimate the convergence of GDP growth (and not innovation growth). According to economic growth theory (e.g. the Solow model), poor countries tend to grow faster compared to rich countries (Banarjee & Duflo, 2020). If it is the case that poor countries are liberalizers, then omitted variable bias arises. Hence, the inclusion of *lagged growth* controls for this. The idea behind *lagged growth* in my thesis is the possibility of a convergence of innovation growth. *Lagged growth* is measured as log patent filings at the end of Period 1 subtracted by log patent filings at the beginning of Period 1, divided by total years elapsed. For this variable I use the same data set on patents as Coelli et al. (2020b).

Lastly, it is important to mention the missing values in my dataset. I started my empirical approach with 78 countries from the EFW dataset, Penn World Table 10.0 and PATSTAT. However, after treating the data, I had only 63 countries because I do not have sufficient data on the remaining 15 countries. Furthermore, after creating the discrete treatment variable, *liberalizer,* the set of countries is further reduced to 51 countries. The reason for this reduction is that some countries have missing data on tariffs in either Period 1 and/or in Period 2. This has consequences for how many countries are assigned either the value 0 as untreated or 1 as treated. The treatment variable, *liberalizer* sets value 1 for countries that reduced their tariff cuts following the Uruguay Round by more than the sample median tariff for the whole period. Lastly, the number of countries is further reduced in my regressions from 51 observations to 45 observations at the most due to missing data on schooling and/or patent filings. Thus, the reason for the reduced number of observations is missing data.

4.2 Descriptive statistics

Table 1 gives a summary of the variables used in my dataset. The variable *patents* clearly shows a large variation between countries with a minimum patent filing of 1 and a maximum of 746493. One weakness of the variable is that it does not distinguish between high-value versus low-value patents. In other words, it is not necessarily true that more patent filings mean a higher degree of innovation. The variable *institutional quality* shows an average score of 6.054 out of 10, which seems reasonable. It is well known that the institutional quality differs between countries. The variable *schooling* also shows considerable variation, reflecting large differences between average schooling years ranging from 0.8 years to 13, with a mean of 7.7 years. Lastly, the *mean tariff rate* has an average of 10.89 which is fairly low, especially when considering the maximum rate of 98.8 percent. Furthermore, the variables each have a different number of observations. This implies that my data are unbalanced. One reason for this is that the *mean tariff rate* and *institutional quality* are only observed every five years from 1975-2000, while the other variables are observed every year.

Table 1. Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Patents	1,972	26584.690	77983.139	1	746493
Institutional quality	902	6.054	1.587	2.108	8.486
Schooling	1,972	7.779	3.041	0.861	13.429
Mean tariff rate	869	10.896	10.277	0	98.8
Year				1975	2010

Table 2 shows the mean tariff rate and the mean of the log number of patent filings for liberalizers and non-liberalizers in Period 1 and Period 2. It also captures the change in mean tariff rates and the change in mean innovation rates between the two periods. As expected, liberalizers experience both a larger change in the mean tariff rate and in mean log patent filings as compared to non-liberalizers. Liberalizers experienced a reduction of -0.22 in its mean tariff rate and an increase of 0.010 in mean log patent filings. In comparison, the non-liberalizers had very little change in their mean tariff rate of -0.03 and a reduction of -0.068 in mean log number of patent filings. These numbers seem promising in addressing my research question of whether liberalizers experience an increased innovation rate compared to non-liberalizers. However, further empirical research is needed to fully answer the research question.

Table 2. Differences in mean outcomes for liberalizers and non-liberalizers

	Mean tariff rate period 1	Mean tariff rate period 2	Change in mean tariff rate
Liberalizer	0.31	0.09	-0.22
Non-liberalizer	0.08	0.06	-0.03
	Mean log patents period 1	Mean log patents period 2	Change in mean log patents
Liberalizer	0.042	0.072	0.010
Non-liberalizer	0.072	0.003	-0.068

Figure 1 shows the top 10 most innovative countries in 2005. As can be seen from this table, there is a large variation among the top 10 countries, with the US at the top with just under 500000 patent filings and Austria at the bottom with just under 50000 patent filings. Interestingly, only three of these countries are considered liberalizers in my study because the remaining countries did not experience large enough tariff reductions to be considered liberalizers. To compare, figure 2 reports the top 10 countries with the biggest change in log patent filings from Period 1 to Period 2. Figure 2 shows that nine out of ten countries with the biggest change in innovation were liberalizers. This comparison highlights two important points: 1) There is a difference between those that innovate the most and those that experience the largest growth in innovation rates. 2) My thesis only focuses on the latter. Therefore, I only estimate the effect on those countries which experienced the largest change in tariff rates and innovation rates — leaving out those that have always had low tariff rates and high patent filings, such as the USA which was the most innovative country in 2005 (as shown in figure 1).

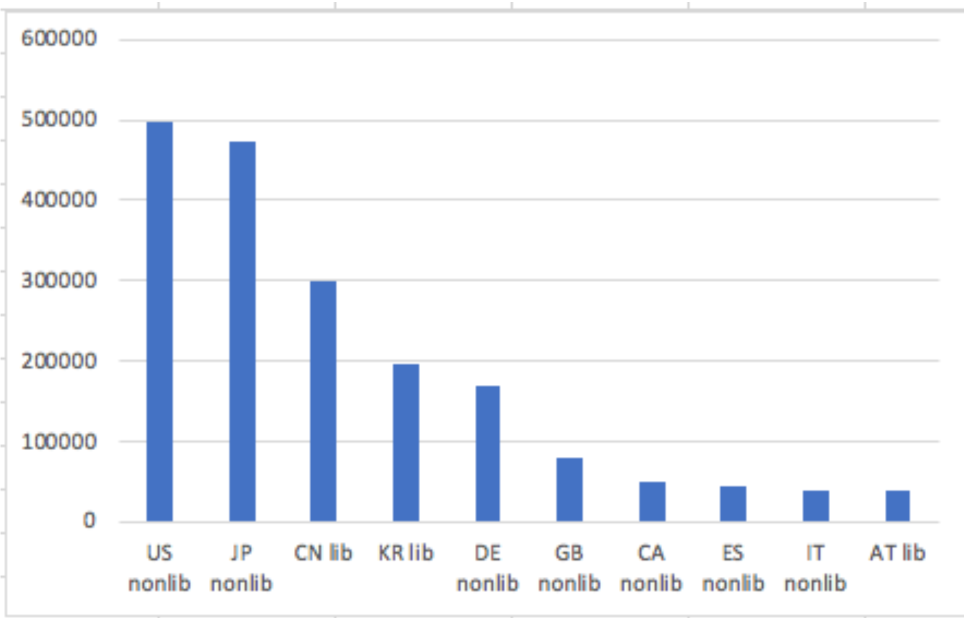

Figure 1. Top 10 innovating countries in 2005. Note: lib stands for liberalizer and nonlib stands for non-liberalizer. Innovation is displayed on the vertical axis and is measured as the number of patent filings.

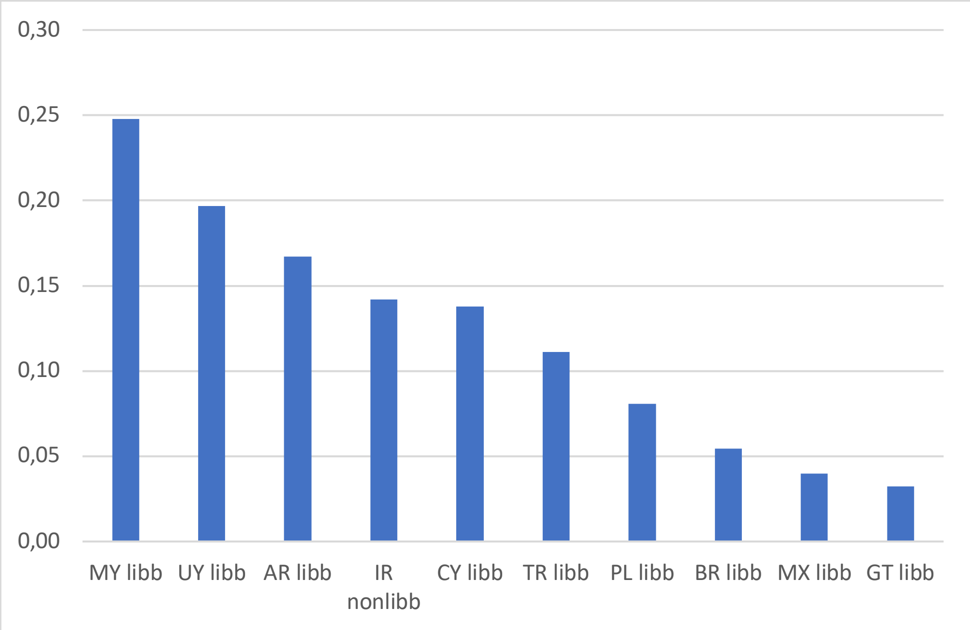

Figure 2. Top 10 largest change in innovation from Period 1 to Period 2. Note: lib stands for liberalizers and nonlib stands for non-liberalizer. The change in innovation is displayed on the vertical axis and is measured in logs.

5 Empirical design and econometric concerns

My objective in this section is to present the empirical design used to analyze the research question of whether innovation accelerates more in liberalizing countries than non-liberalizing countries. I address this by using a DiD method and the post-1990 trade liberalization as a treatment. For the remainder of the section, I follow Estevadeordal and Taylor's (2013) approach by using two distinctive methods. The first is a discrete 0-1 treatment of trade liberalization, while the second is a continuous treatment. The econometric concerns are addressed in Subsection 5.3, and this is where the continuous treatment is discussed.

5.1 Difference-in-Differences

The main advantage of using a DiD method is that it is easy and intuitive. The method consists of identifying a specific treatment (here: trade liberalization), and then comparing the differences in outcomes before and after the treatment for control and treatment groups (here: liberalizing and non-liberalizing countries). Those that were affected by trade liberalization are called liberalizers, and those that were not, are called non-liberalizers. By focusing on the changes in mean innovation rates, this comparison of differences makes it possible to eliminate unobserved factors that may vary between countries as long as they are time-invariant, by simply differencing them out. Cultural attitudes and norms are two examples of constant unobserved factors that may influence the effect on innovation. It is possible to avoid this type of omitted-variable bias by using a DiD-approach.

Nonetheless, a worry might be that other important independent variables are omitted from the empirical design. The two control variables, *institutional quality* and *schooling* are considered to be constant over time but to vary across countries. Both variables are unlikely to change in the short to medium run. However, there are many factors that influence innovation. If those factors are constant across countries but vary over time and are correlated with the treatment, this creates another source of omitted bias. The consequence of this type of omitted bias would be an inconsistent and biased estimator of the effect on innovation.

Furthermore, there are some requirements that need to hold to have valid results using the DiD method. Firstly, there needs to be exogenous and random variation in the treatment variable. I argue that using the Uruguay Round as a treatment for trade liberalization satisfies the exogenous and random variation criteria. One reason for this is the large number of countries represented, which is a requirement for valid estimates on the DiD approach. There were 123 countries, both developed and developing, engaging in the Uruguay Round, which aimed to reform international trade (WTO, n.d). It can also be argued that amongst international agreements, the Uruguay Round seems to be best suited to use as a treatment. Similar agreements such as the Kennedy Round (1962-1967) and the Tokyo Round (1972-79) do not display the same strength when it comes to exogeneity and random variation. One reason for this is that prior to the Uruguay Round, the GATT negotiations included mostly developed countries and excluded developing ones. Omitting the latter may have a large impact on the results. Another reason for my choice is the limited number of countries participating in the earlier rounds. For instance, the Kennedy Round only had 48 countries (Estevadeordal & Taylor, 2013). It is important to have sufficient countries receiving the treatment to produce valid results. This is the main reason for choosing the Uruguay Round instead of other GATT negotiations.

Another important requirement is the time horizon. It is important that enough time goes by to estimate the before-and after-treatment phases in this quasi-experiment. I focus on the period 1975-2010. Whereas Period 1 is the pre-treatment period and lasts from 1975-1989, Period 2 is post-treatment period and lasts from 1990-2010. By having two fairly long time periods, it is possible to avoid disturbances of the conclusions related to lags in policy implementation and/or short-run output fluctuation, for example as a result of an economic crisis (Estevadeordal & Taylor, 2013).

Lastly, both the treatment (liberalizers) and the control (non-liberalizers) groups must share a common trend. This means that in the absence of the Uruguay Round, liberalizers and non-liberalizers should have the same innovation rate. This is, of course, a very strong assumption. Nevertheless, it is a central assumption of the DiD method and needs to hold for robust inferences.

5.2 Liberalization as a discrete indicator

I start my empirical work by creating a dummy indicator for whether a country can be considered a liberalizer. A country is considered a liberalizer if it reduced its mean tariff rate by more than the sample median tariff for the whole period. For this purpose, I use the following method: I calculate the change in mean tariff rate in year 1985 (pre-Uruguay) and the mean tariff rate in year 2005 (post-Uruguay). Next, I calculate the median of this change and define countries that had a larger reduction in their mean tariff rate than the median tariff as liberalizers. Those that had less of a reduction are defined as non-liberalizers.

Figure 3 illustrates what the Uruguay Round accomplished in terms of reductions in the average tariff. To demonstrate, I have plotted the post-Uruguay year 2005 tariffs against pre-Uruguay year 1985 tariffs. Furthermore, figure 3 shows the differences in the change in mean tariffs for different countries pre- and post-Uruguay. The change allows a classification into liberalizers and non-liberalizers, which is later used to measure the effects of trade policy changes on innovation outcomes.

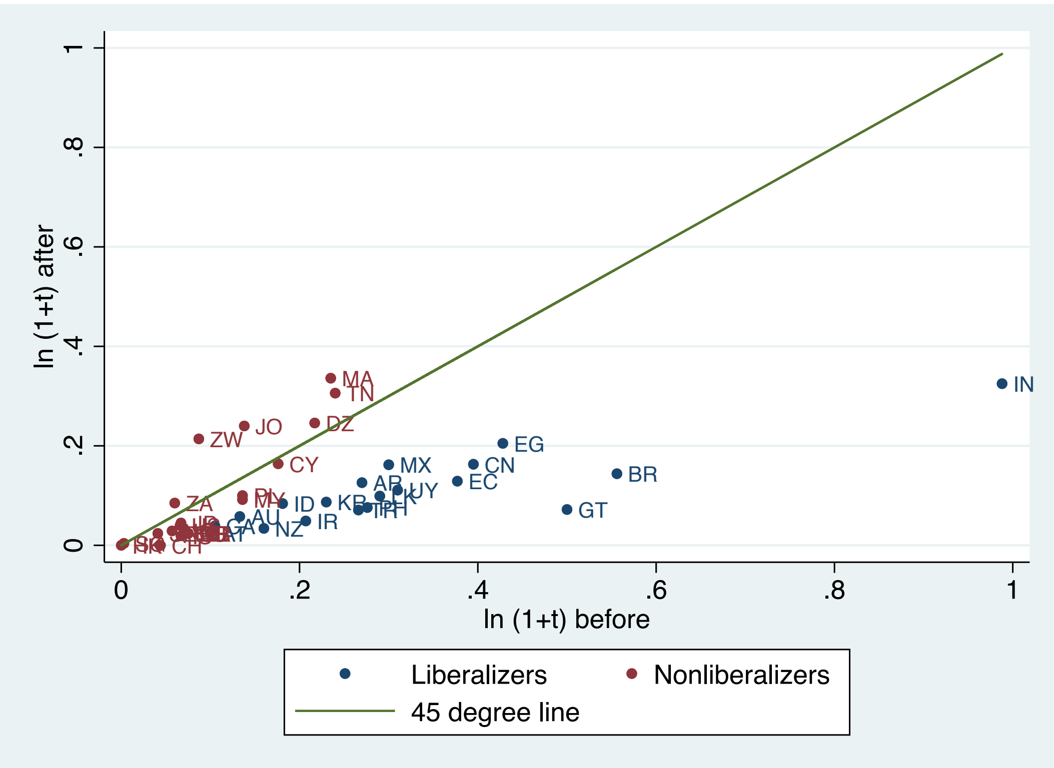

Figure 3. Trade liberalization. Mean tariff rates, ln(1+t): before and after the Uruguay Round for liberalizers and non-liberalizers.

It is worth mentioning that the non-liberalizers consist of two groups of countries. Firstly, there are countries that initially had low tariffs and kept those tariffs low in the next period. These countries are represented to the left of the graph and close to the origin. Countries belonging to this group were, in other words, always liberalizers. As a result, they are not taken up as liberalizers according to the definition given above. The US and Singapore (SG) are two examples of countries that belong to this group. Secondly, there are countries that initially had high tariffs and kept them high throughout. These countries are shown in the upper-left diagonal. By definition, these countries are also considered to be non-liberalizers. Zimbabwe (ZW) and Jordan (JO) are examples of countries that belong to this group.

By contrast, liberalizers are those countries that had large tariffs pre-Uruguay and lowered them post-Uruguay. What is common for liberalizers is that they had tariff cuts that were above the sample median. In figure 3, these are represented at the lower right of the graph, below the diagonal. These are the countries that received the treatment. China (CN) and India (IN) are examples of such countries. It is worth noticing the extreme values for India. The country experienced the largest tariff change in this sample. Pre-Uruguay, India had a mean tariff of 98.8 percent, and post-Uruguay, the country had reduced its mean tariff rate to about 30 percent. This is still a relatively high tariff rate and many non-liberalizing countries have lower tariff rates. Nevertheless, the only criteria needed to be classified as a liberalizer is that the country had a tariff cut larger than the reduction in the sample median tariff.

5.2.1 Tariff development

Figure 4 demonstrates the evolution of the average tariffs in the sample period 1975-2010 for non-liberalizers and liberalizers. The intention is to exploit the differences between liberalizers and non-liberalizers to identify the impact on innovation of trade liberalization. The figure illustrates a clear difference between the two groups, which is expected.

Figure 4 shows that there is little movement in the average tariff for non-liberalizers throughout the sample period. Notably, their tariff rate stayed around 8 to 9 percent. In comparison, the liberalizing group experienced a substantial change in their average tariffs. In Period 1 (1975-1989), the liberalizing countries had mean tariffs as high as 35 percent. At the end of Period 2 (1990-2010), the liberalizing countries had reduced their mean tariff rate to about 10 percent. In addition, figure 4 indicates some convergence among liberalizers and non-liberalizers at the end of Period 2. This is in line with the fact that the mean tariff rate is relatively low globally (Stiglitz, 2020).

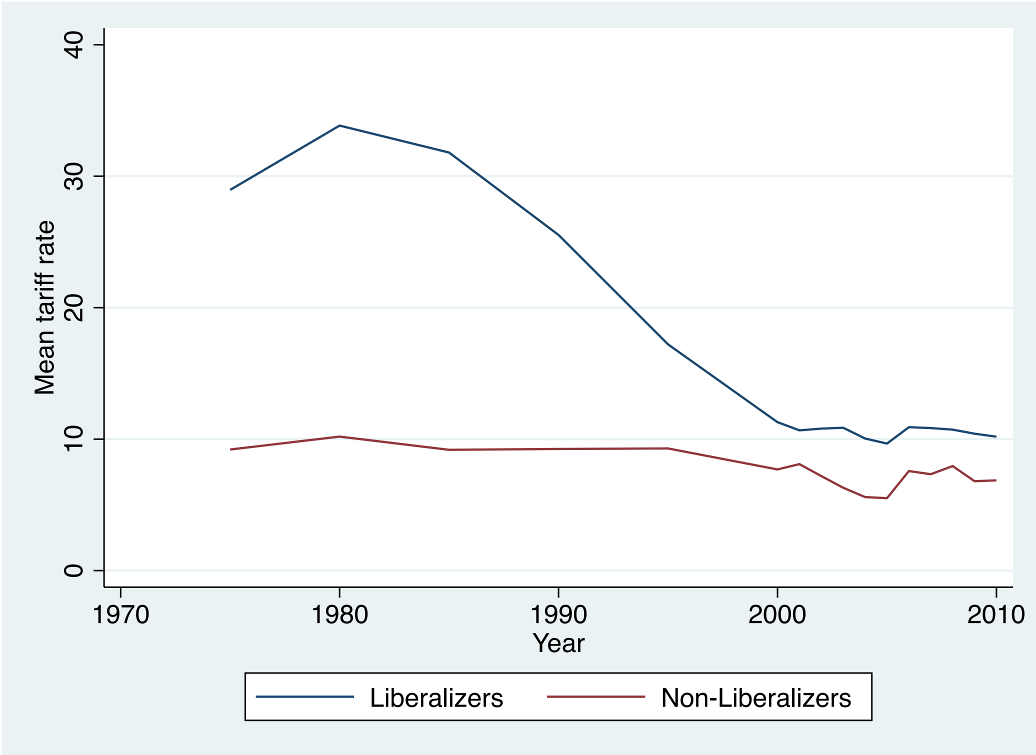

Figure 4. Development of tariffs from 1975-2010 for liberalizers and non-liberalizers.

5.3 Discrete treatment: DiD estimates

I now make use of the discrete treatment variable defined in Section 5.1, the *liberalizer.* The variable is a 0-1 dummy and gives liberalizing countries the value 1 and non-liberalizing countries the value of 0. The following approach is inspired by the analog of the 0-1 openness indicator of Sachs and Warner (1995)[2]. I start the empirical model by writing out the levels regression as follows:

$$innovation_{it} = \beta(liberalizer_{it}) + \eta X_{it} + \varepsilon_{it}, \quad (1)$$

where innovation is measured as:

$$innovation_{it} = \frac{\log(patents_{(t=year)}) - log(patents_{(t=year)})}{total\ years\ elapsed} \quad (2)$$

[2] Hence, I will refer to openness and liberalizer as the same.

The mean of the error term, ε, conditional on *liberalizer* is assumed to be zero. This suggests that the error term and the treatment *liberalizer* are uncorrelated. Formally it can be written as:

$$\mathbb{E}\,(\varepsilon_{it}|\ liberalizer_{it}) = 0$$

Equation (1) consists of the discrete treatment variable *liberalizer,* the control vector X, which includes *institutional quality*, *schooling* and *initial innovation rate*, and lastly the error term, ε. The following subscripts are $i \in (\text{liberalizer, non} - \text{liberalizer})$ and $t \in (1,2)$ where 1 denotes the pre-Uruguay period and 2 denotes the post-Uruguay period. Equation (2) consists of the dependent variable measured in logs, and the subscripts are the same except that now $t \in (1,2)$, where 1= (1990-1975) and 2= (2010-1990). Moreover, the subscript *year* expresses the last year and the first year of each Period 1 and Period 2, with 1990 as an overlapping year.

Equation (1) is suitable when analyzing changes in levels, for example, in a cross-section method. My empirical design, however, involves a DiD approach. To get equation (1) to represent a DiD estimation, I take the changes in the dependent variable and for the regressors. Formally, the DiD equation can be written as:

$$\Delta innovation_{it} = \beta(\Delta liberalizer_{it}) + \eta \Delta X_{it} + v_{it}, \quad (3)$$

where the change in innovation is,

$$\Delta innovation_{it} = innovation_{it=2} - innovation_{it=1} \quad (4)$$

The next step is to obtain the DiD estimator. This is done by taking the change in the dependent variable for liberalizers minus the change in the dependent variable for non-liberalizers:

$$\hat{\beta} = (\overline{Inn}^{lib,after} - \overline{Inn}^{lib,before}) - (\overline{Inn}^{nonlib,after} - \overline{Inn}^{nonlib,before}), \quad (5)$$

where $\overline{Inn}$ stands for average log innovation, lib and nonlib is short for liberalizers and non-liberalizers, respectively. It follows that if the treatment is *as if* randomly assigned, then the

DiD estimator, $\hat{\beta}$, is an unbiased and consistent estimator of the causal effect of trade liberalization on innovation. Furthermore, the simplicity of equation (3) offers a clean and predictable test of the research question regarding whether liberalizers experienced more innovation as compared to non-liberalizing countries.

Choosing two periods is justified with respect to the standard errors. If I analyze more than two time periods, the chance of biased standard errors increases dramatically and leads to misleading results (Bertrand, Duflo, & Mullainathan, 2004).

5.4 Econometric concerns

In this section, I address some econometric concerns regarding the empirical design. These concerns include limitations to tariffs, endogeneity issues, measurement of the treatment, and limitations to the PATSTAT dataset. Lastly, I address whether patents are a good measure of innovation.

5.4.1 Limitations of tariffs and endogeneity issues

The choice of tariff measure is important for the results. To exemplify: Estevadeordal and Taylor (2013) find that the support of their hypothesis that liberalizing countries experienced higher growth, varies depending on the tariff measure being used. This demonstrates the importance of being aware of the benefits and the limitations to the chosen measure for the empirical design. Estevadeordal and Taylor (2013) only find significant results for more detailed tariff measures. Having said that, one concern is that I only have data on the unweighted mean tariff rate. This captures the tariff on several products and services in many different categories and calculates the mean of this sum. Hence, using an unweighted mean tariff rate might underestimate the degree of liberalization. This could occur if a country has zero tariffs on a small range of categories of products and very high tariffs on a wide range of other categories. Some examples are agricultural products that the country has an interest in protecting and/or high tariffs on categories that the country has a comparative advantage in, for instance, fish. Hence, there are many ways to measure the average tariff and indeed tariffs themselves. Therefore, differing tariff measures might lead to different answers to the same question. This also highlights the importance of using different measurements on the same research questions to check the robustness of the empirical results.

Using the mean tariff rate as the only measure of trade liberalization may also underestimate the magnitude of liberalization. The reason for this is that I only include the mean tariff rate, excluding all other types of nontariff barriers that might influence the degree of liberalization and, henceforth, innovation. One reason for the exclusion is that nontariff barriers are usually difficult to measure. Some examples of nontariff barriers are export subsidies, quotas, import licenses, and domestic content rules. As a result, the effect nontariff barriers have on the trade flows is not be captured through my mean tariff rate. This can potentially lead to the validity of the results being reduced.

Endogeneity issues may be a secondary concern concerning tariffs. It may be that tariff reductions are a symptom and not a cause of higher innovation rates. The causal link could run through my control variables or other uncontrolled factors such as government subsidies and financial constraints. If it is institutional quality that has a causal effect, it might be that tariff cuts made by the Uruguay Round are a symptom of institutional changes that are, indirectly, or directly, the main driver of higher innovation rates. If this is the case, it could support the institutionalist view that emphasizes the importance of institutions on policy outcomes, including trade policy. The causal link would then be:

$$\text{Institutions} \Longrightarrow \text{Trade policies} \Longrightarrow \text{Higher innovation growth} \quad (6)$$

Another possibility might be that tariff reductions are a symptom of intensified lobbying and not a result of the Uruguay Round. If this is the case the institutions variable could be replaced with lobbying in the causal chain above. To solve the endogeneity issue, the instrument used must be both relevant and exogenous. Coelli et al. (2020a) solve this by using MFN as an instrument. Typically, firms located in different countries are differently affected when selling abroad because of the variation in the tariff cuts across export markets. To overcome this problem, Coelli et al. (2020a) exploit the variation of applied MFN tariffs cuts across firms' exports markets. They claim that MFN tariff cuts are likely to be exogenous to other determinates of innovation in the home country and at industry-level for firms. Due to limited time and resources, I do not pursue an instrument to test for the possible endogeneity of the tariffs.

Lastly, there may be a concern that there are systematic differences between countries that liberalize and those that do not. If this is true, then the liberalizers would innovate just as much even in the absence of the treatment, the Uruguay Round. This would lead to a violation of the central assumption of the DiD method of a common trend. It is important for the validity of my results that this assumption is not violated. Hence, I perform a placebo treatment to control for systematic differences. I also perform a graphical falsification test to check for the validity of the common trend assumption. These tests are carried out in Section 6.

5.4.2 Liberalizer: discrete versus continuous variable

I have chosen to treat the *liberalizer* indicator as a discrete variable. One reason for choosing this particular estimate, is that it easily captures those who liberalized and received the treatment and those who did not. However, the way of treating liberalization as a 0-1 measure has been criticized for discarding too much information. For instance, it does not capture countries that had low mean tariffs throughout the sample period. According to the discrete variable, Singapore is a non-liberalizer in the same way as Jordan, even though Singapore has substantially lower mean tariff rates than Jordan. Another example is the US which also has low tariffs throughout the sample period. The two countries were always liberalizers, but they do not satisfy the criteria for being recognized as a liberalizer in the discrete measurement.

More commonly the literature on trade openness treats openness as a continuous variable. It is thus possible to avoid putting countries such as the US and Singapore into a non-liberalizing category. One way to obtain a continuous measure is to use the changes in the average tariff, $\ln(1+t)$. The latter could replace the discrete liberalization indicator in the measure of trade policy change. In Section 6, I use the change in the average tariff as a continuous variable for liberalization and perform a robustness check to show whether the same results hold as for the discrete variable.

5.4.3 Limitations to PATSTAT

The richness of the dataset on patents is both a blessing and a curse. It is a blessing because PATSTAT provides detailed information necessary for good and reliable results. Nevertheless, it is also a curse due to the abundance of information, which does not correspond to the limited time available writing this thesis. My dataset only includes data for the country-level and not on firm-level. As a consequence, my data does not capture detailed information about the patent activity at the firm-level, and it does not capture the large variation of patenting between firms and across industries. It could well be that innovation activity is mainly deducted from a few firms or a small number of industries. My data does not capture this. Nonetheless, it captures the overall patent activity in a country.

5.4.4 Patent as a measure of innovation

An advantage of using patent filings as a measure of innovation is that it seems to be a highly objective measure (Griliches, 1990). Another benefit is that, compared to other measures such as R&D, patents provide a measure of successful research outputs (Cornea & Ornaghi, 2014). However, there are some problems with using patents as a measure of innovation. For instance, there is considerable variation in the technical and economic significance of patents. Some patents may be of very little value, while some might be very valuable. The problem is that it is difficult to disentangle the qualities of the patents. This could result in an overestimation of the effect of liberalization on innovation. One possible question to ask is if every patent should count the same when measuring innovativeness. A potential solution is to use a citation count as an alternative index of the quality of patents. A high citation count may demonstrate how claimed the invention (patent) is. Patents with relatively high economic value are cited more often than patents with relatively low value (Harhoff, Narin, Scherer, & Vopel, 1999). Unfortunately, my dataset does not include a citations count. Instead, I use the number of inventors, which is arguably an equally significant aspect of patent quality; the size of the research team behind a patent (number of inventors) is connected to its economic and technological value (OECD, 2009).

The increasing interest in intellectual property rights in several trade agreements (resulting from trade liberalization) might lead to more patent filings to protect an idea or product, and thus does not reflect new inventions. In addition, firms can attain intellectual property rights just for the purpose of suing infringers to make money (Stiglitz, 2020). This is what Coelli et al. (2020a) call the lawyer effect. If this is true, then patent filings do not capture innovation but are instead used as a protectionist tool. This would also produce a bias in my results.

For this reason, I perform a robustness check in Section 6 to analyze if patents are, indeed, a good measure of innovation. This is the same as to check for the lawyer effect. Following the same approach as Coelli et al. (2020a), I calculate the average quality of innovation by using information about the number of inventors. More specifically, I measure the *average patent quality* by dividing the log number of patent filings by the log number of inventors three years prior to the patent filings at the end and at the beginning of each period. This is again divided by total years elapsed. I replace the current *innovation* variable with the *average patent quality* variable as the new dependent variable and estimate the regression once again, using the discrete treatment. This test will be performed in section 6.

6 Empirical results

In this section, I present my empirical results. In addition, I perform several robustness checks to ensure the validity of my results. Lastly, I discuss the empirical findings.

6.1 Innovation and trade liberalization

Table 3 gives the main results of the effect of trade liberalization on innovation. The dependent variable captures the innovation rate and is measured as the differences in the average change in log patent filings from Period 1 to Period 2. Tariffs are measured in 1985 and 2005. Column (1) is without any control variables, and Column (4) includes all control variables. All columns use the discrete *liberalizer* and set *liberalizer*=1 for countries that experienced that their mean tariff rate fall by more than the median tariff rate. Table 3 shows that liberalizing countries have higher innovation rates compared to non-liberalizing countries. The Columns (2)-(4) have a coefficient estimate ranging from 0.0516 to 0.0440, indicating that liberalizers had an innovation rate which is more than 4 percent higher than non-liberalizers. Moreover, the discrete treatment *liberalizer* is significant at the 5 percent level after including control variables. The control variable *lagged growth* is the lagged level of innovation growth. In Column (4), the *lagged growth* coefficient is -1.177. If the *lagged growth* is divided by the time horizon of 15 years, you will get the annual convergence speed. The calculation thus gives an annual convergence speed of 7.8 percent in log levels for liberalizers. The *lagged growth* variable is highly significant (p <.001) in Columns (2)-(4).

Furthermore, table 3 shows no significant effect of either change in schooling or change in institutions. This suggests that these variables do not significantly explain increased innovation growth. Hence, trade policy seems to better explain the effect of increased innovation rates than schooling and institutional quality.

Table 3. Difference-in-Differences estimates.

	(1)	(2)	(3)	(4)
	ΔInnovation	ΔInnovation	ΔInnovation	ΔInnovation
Liberalizer	0.0781	0.0516*	0.0463*	0.0440*
	(0.0412)	(0.0208)	(0.0206)	(0.0215)
Lagged growth		-1.138***	-1.170***	-1.177***
		(0.120)	(0.126)	(0.132)
Change in schooling			0.0203	0.0202
			(0.0144)	(0.0145)
Change in institutions				0.0254
				(0.0731)
N	45	45	45	45

Robust standard errors are in parentheses

** p<0.05, ** p<.0.01, *** p<0.001*

6.2 Robustness: Liberalization as a continuous indicator

Until this point, the treatment-variable has been a 0-1 dummy indicator of whether a country is considered a liberalizer. I will now perform a robustness check replacing the 0-1 indicator with a continuous treatment measure using the change in the average tariff, $\ln(1+t)$. The empirical approach is the same as before, except the measure of policy change is different. I perform this robustness test to determine if using a different measurement that is not bound by 0-1 dummy gives different results. I also control for outliers by using Huber Weights.

Table 4 reports the results of the continuous treatment variable on innovation. In contrast to the main table 3, it does not show any significant results. This is somewhat surprising considering that this measure should contain more information. One reason for the surprising result is that having a more detailed treatment measure could work in both directions, either increasing or decreasing the effect. Table 4 reports values of the treatment estimates between -0.0785 and -0.232. Furthermore, the change in institutions and the change in schooling remain insignificant. The only robust variable is the *lagged growth* variable, which is highly significant. However, the variable of interest, $\ln(1+t)$, shows no significance. As a result, only the discrete treatment contributes to significantly explain innovation.

Table 4. Treatment as a continuous measure using Huber Weights.

	(1)	(2)	(3)	(4)
	ΔInnovation	ΔInnovation	ΔInnovation	ΔInnovation
Δln(1+t)	-0.232	-0.0785	-0.0649	-0.0486
	(0.131)	(0.0728)	(0.0877)	(0.0758)
Lagged growth		-0.894***	-1.094***	-0.926***
		(0.0803)	(0.1000)	(0.0805)
Change in schooling			0.270	0.0140
			(0.0168)	(0.0130)
Change in institutions				0.0710
				(0.0697)
N	45	45	45	45

Standard errors are in parentheses

** $p<0.05$, ** $p<.0.01$, *** $p<0.001$*

6.3 Falsification tests: Placebo treatment and the common trend

The purpose of the falsification tests is to make sure that countries that were classified as liberalizers in Period 2 were not already different from non-liberalizers in Period 1. The placebo treatment is a way of evaluating the validity of the common trend assumption. To check for systematic differences between liberalizers and non-liberalizers, I perform a falsification test using a placebo treatment. For this test I create Period 0 (1960-1974). The dependent variable captures the innovation rate and is measured as the differences in the average change in log patent filings from Period 0 to Period 1. I use the same empirical design as I did with the discrete 1990-treatment, the *liberalizer*, but this time it will be applied on Period 0 and Period 1 instead of Period 1 and Period 2. This placebo test assigns a group of countries a counterfactual trade liberalization in 1975, which corresponds to the actual treatment they received in 1990.

Table 5 shows the results of the placebo treatment. The discrete treatment, *liberalizer*, gives a null-result with no significant values in Columns (2)-(4). This is good news because it indicates that there were no systematic differences in innovation growth between liberalizers and non-liberalizers in the two periods prior to the actual treatment.

Table 5. Placebo treatment using discrete treatment

	(1)	(2)	(3)	(4)
	ΔInnovation	ΔInnovation	ΔInnovation	ΔInnovation
Liberalizer	-0.195**	0.0205	0.0243	0.0144
	(0.0657)	(0.0401)	(0.0362)	(0.0360)
Lagged growth		-1.132***	-1.317***	-1.339***
		(0.126)	(0.123)	(0.136)
Change in schooling			-0.0132	-0.00994
			(0.0290)	(0.0309)
Change in institutions				0.161
				(0.130)
N	36	36	36	36

Robust standard errors are in parentheses

** p<0.05, ** p<.0.01, *** p<0.001*

A second way to evaluate the common trend assumption is to check graphically whether liberalizers and non-liberalizers follow a common trend. This is done by calculating the Period 1 (1975-1989) trend of the mean log patent filing count for each of the two groups: liberalizers and non-liberalizers. Both groups should preferably display the same trend before the treatment is imposed (1960-1989) and a divergence of trends post-treatment (1990-2010). This should correspond with the placebo treatment shown in table 5 above, which indicates no systematic differences in innovation rates pre-treatment. Figure 5 shows the common trend of mean log patent count relative to the 1975-89 trend.

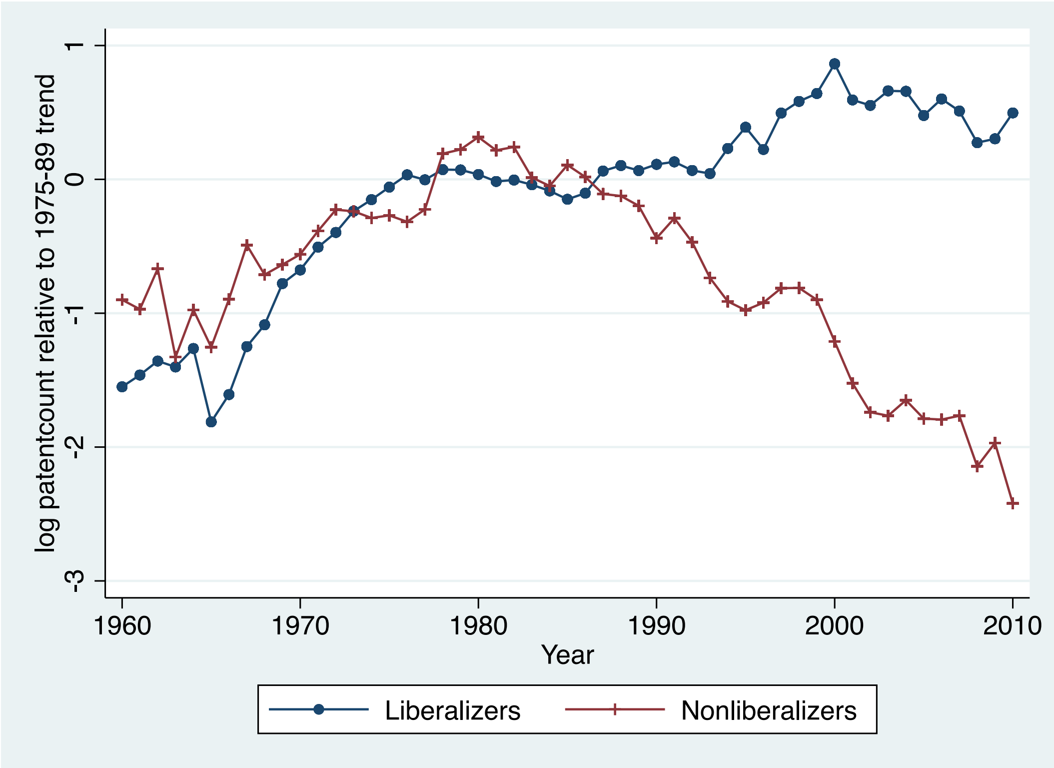

Figure 5. The common trend: Log patent count relative to 1975-1989 trend for liberalizers and non-liberalizers.

If liberalizers and non-liberalizers were similar ex-ante, one could expect them to share comparable cyclical behavior as well. The common trend is to some degree confirmed by figure 5, with some small deviations around 1975 and in the early 1980s. Nevertheless, the figure shows that liberalizers and non-liberalizers follow each other closely when it comes to their pre-treatment innovation rate. It is interesting to note that the two groups begin to diverge around 1986, a little prior to the 1990 treatment. I remind the reader that the Uruguay Round lasted from 1986-1994, so it could well be an effect of this. For example, expectations about future tariff reductions may have led to an increase in patent filings for liberalizers. But it could also be a finding in support of a failure to show a common trend since the divergence of trends happens prior to the 1990 treatment variable. Nevertheless, there is substantial divergence after 1990 that lasts throughout the sample period. Compared to Period 0 and Period 1, liberalizers and non-liberalizers have different trends in Period 2. This supports of the validity of the common trend assumption. Furthermore, the common trend may be weaker when graphically illustrated as in figure 5, but the non-significant results of the placebo treatment in table 5 contribute to strengthen the falsification test of no systematic differences in innovation rates pre-treatment and hence, the common trend assumption.

6.4 Lawyer effect- testing patent quality

In this section I check if there is evidence of a lawyer effect and the quality of the patents. The new dependent variable is the change in *average patent quality* from Period 1 to Period 2. It is measured as the log number of patent filings divided by the log number of inventors three years prior to the patent filings at the end and beginning of each period, divided by total years elapsed. I follow the same empirical exercise as before. Preferably, one would like to see a null result which implies that the quality of the patent has not gone up or down. If this is the case, then increased patent filings are caused by increased innovation and not by increased protection.

Table 6 uses the discrete measure, *liberalizer*. The table does not report any significant results using the discrete treatment variable. The coefficient estimates from Columns (2)-(4) suggests a null result with coefficients ranging from 0.0588-0.0290. In addition, both changes in *schooling* and changes in *institutions* seem to be irrelevant in explaining patent quality. The results shown in table 6 are encouraging because there is no evidence of a lawyer effect. The quality has not gone down as the patent filings have gone up. Trade liberalization has not reduced the quality of the patents. Thus, table 6 confirms the robustness of the discrete variable after controlling for the patent quality.

Table 6. Patent quality as dependent variable. Using discrete treatment.

	(1) ΔPatent quality	(2) ΔPatent quality	(3) ΔPatent quality	(4) ΔPatent quality
Liberalizer	-1.137	0.0588	0.0569	0.0290
	(0.595)	(0.153)	(0.158)	(0.163)
Lagged growth		-1.052***	-1.053***	-1.054***
		(0.0423)	(0.0408)	(0.0404)
Change in schooling			0.0123	0.0107
			(0.0679)	(0.0671)
Change in institutions				0.281
				(0.516)
N	35	35	35	35

Robust standard errors are in parentheses

** p<0.05, ** p<.0.01, *** p<0.001*

6.5 Discussion of the findings

The empirical analysis of the effect of trade liberalization on innovation has been shown to be significant at the 5 percent level using the discrete treatment. As shown in table 3, the results are significant after including control variables in Columns (2)-(4), with an approximately estimated coefficient of 0.0440. This means that the innovation rate of liberalizers is more than 4 percent higher than that of non-liberalizers. Thus, the results suggest that the answer to my research question is that the innovation accelerates more in liberalizing countries than in non-liberalizing countries. Furthermore, the results remain after performing robustness checks on the lawyer effect and falsification tests evaluating the common trend assumption. However, my results were not robust when the treatment variable is treated as a continuous measure using $\ln(1+t)$ instead of the discrete 0-1 variable.

My empirical findings are well in line with the ambiguous effects in the research literature and the theoretical mechanisms explained in Sections 2 and 3. My main results from table 3 fit the prediction of a positive relationship between trade liberalization and innovation. The discrete treatment shows a significant effect of tariff cuts on innovation at the 5 percent level after the inclusion of control variables. However, I cannot disentangle which economic mechanism that dominates by looking only at table 3. Firstly, it could be the forces of increased import competition that dominate. The escape-competition effect emphasizes the positive relationship between competition and innovation. Secondly, it could be the effect of improved import opportunities made possible through tariff cuts. Both the effects of increased competition and improvement of import opportunities can contribute to significantly explain the effect of tariff cuts on innovation as seen in table 3.

My empirical findings also suggest that the effect of trade liberalization on innovation is still quite unclear. My results were only significant when using a discrete treatment. The robustness check on the continuous treatment measure, shown in table 4, failed to report significant results. I only got significant coefficient estimates on *lagged growth,* and not on the continuous treatment variable. This reduces the statistical power of my empirical findings. This could be due to the continuous measure itself and as such it is in line with the critique of the discrete treatment that too much information is discarded (Estevadeordal & Taylor, 2013). It may be that the continuous measure is better at capturing negative effects of the relationship between trade liberalization and innovation. An example of such is the Schumpeterian effect, which emphasizes the negative relationship between import competition and innovation. It may also be that trade liberalization has given rise to super-firms that have outcompeted their competitors and thus see no incentive to engage in innovative activity. Hence, they have become “too big to fail”. This would reduce the effect of trade liberalization on innovation. Another possible effect runs through positive externalities, such as knowledge spillovers and/or technology diffusions. For example, if the innovative activity is concentrated in a few industries, or even a few firms, while the majority are engaged in very little innovative activity, this would result in tariff cuts having a reduced effect on innovation in my empirical design. The reason is that only a few firms would file for patents, not considering the knowledge spillovers and the technology diffusion to the majority of firms. It is true that many of the big technological inventions are made by a few countries while the productivity gains of the inventions are spread globally (Chiang & Xu, 2005). If the continuous measure captures more of these effects, it could explain the lack of significant coefficients in table 4.

It could also be that tariff reductions are not the most effective way to boost innovation growth. There may be other better-suited policy interventions such as government subsidies of R&D. Because of the positive externalities of innovation, inventors might need an extra incentive to innovate, and this can take form of subsidized R&D, which will hopefully lead to patent filings. I have discussed the incentives firms need to engage in innovative activity, such as a profit motive and a protection motive to address knowledge spillovers. A patent serves to protect the idea or product for several years. But, this protection may not matter much if the research prior to the patent filing is too expensive for the firm. In this way, subsidizing R&D may engage more firms to undertake costly and risky R&D, which could result in more patents and increased innovation later. Another possible policy intervention is a deregulation of polices. For instance, according to Stiglitz (2020), the EU and US overprotect intellectual property rights. This overprotection could lead to a lawyer effect. However, based on my own robustness test of the lawyer effect in table 6, there is no evidence of such an effect.

Compared to related research literature, my overall empirical findings seem to belong to the group of studies that find ambiguous effects of trade liberalization on innovation due to the failure of strong robustness. The ambiguous effects could result from the impact of import competition, which has been shown to have mixed results, often because of regional differences. My empirical findings when using a discrete treatment belong to the group of studies that find a positive and significant effect of tariff cuts on innovation. Thus, my results are in company with Bloom et al. (2016), who find a positive effect of import competition on innovation at the country-level, and Lesser (2008), who finds a positive relationship between improved import opportunities and innovation at industry-level in the Finnish telecom sector. However, my empirical findings when using the continuous treatment belong to the group of studies that find a nonsignificant effect (see Shu and Steinwender, 2019). I stress the important point that there is evidence of a positive and significant effect of trade liberalization (in general) on innovation by others, such as Coelli et al. (2020a), Long et al. (2011) and Cornea & Ornaghi (2014). Taking the earlier empirical research on this matter into account, I argue that the reason for the lack of robustness of my results is mainly the limitations of my dataset. Hence, the rest of this subsection is devoted to a discussion of my robustness tests, the data, and the empirical design used.

6.5.1 Robustness checks

My empirical result in table 3 is somewhat weakened after performing four robustness tests. Three out of four indicate robustness to various degrees: The two falsification tests evaluating the common trend assumption and the test for the lawyer effect. The falsification tests are used to check for systematic differences, and figure 5 clearly shows that liberalizers and non-liberalizers share a common trend pre-treatment and diverge post-treatment. One major concern, however, is that the divergence happens approximately four years before the treatment is imposed. The ideal common trend figure would have shown a divergence exactly the same year as the treatment was imposed in 1990. As a result, the validity of the common trend in my empirical results is not perfect. However, it does, on average, show a common trend thus indicating some validity. Hence, I argue that the absence of a perfect common trend in figure 5, can be compensated by the strong results of the placebo treatment which indicates no systematic differences in innovation rates, as shown in table 5.

Thirdly, the lawyer effect reported in table 6 shows a zero result and strengthens the robustness of my results from table 3. This suggests that the quality of the patents has not gone up or down. In other words, trade liberalization has not led to a decrease of the economic or technical value of patents according to my robustness check. However, this is not to say that trade liberalization has increased the patent quality. Table 6 only shows that there is no effect in either direction. This is in line with the empirical findings of Coelli et al. (2020a), who find no evidence of a lawyer effect after controlling for citations counts, the research team (number of inventors), and IPC codes.

Fourthly, switching the treatment from a discrete to a continuous measure gave somewhat surprising results considering that I controlled for extreme values. I expected to get significant values using a continuous measure, but table 4 shows no significant results on the treatment measure. Clearly, using a broader measure could go both ways. Preferably, it would contain details that could give the result even higher significance. But in this setting, the opposite seems to have occurred. This implies that my result is only valid when using a discrete treatment, which reduces the statistical power of my main findings. For strong statistical inference, the results should remain the same after using different measurements. This would ensure the strong validity of my results. A topic for future research would be to use even more detailed data on tariffs and nontariff measures and look for stronger robustness.

6.5.2 Data and empirical design

There are some further concerns regarding the variables used in my data. As elaborated in Section 5.4, these concern limitations to both the tariff measure and the patent measure. An overall weakness of my dataset is that I have crude data that do not capture effects at a detailed level. Most of the earlier research that has found significant effects have used a more comprehensive and detailed dataset than I have used. For example, if I had firm-level data on patent filings, I could potentially have captured the large diversity of innovative activity that exists between firms in an industry. There are some empirical papers considering innovation at the firm-level. For instance, Coelli et al. (2020a) use firm-level patent data and find a significant effect on innovation of the increased market size (via trade liberalization). Furthermore, using data on patent filings only may underestimate the effect of innovation. For instance, it does not capture positive externalities that come along with innovation. A topic for future research may be to include other potential measures of innovation.

The methodology used in this thesis can also affect the empirical results. I have used a DiD method to estimate the effect of trade liberalization on innovation by studying the differences in the mean outcomes before and after the Uruguay Round for control and treatment groups. One motivation of this choice is that it is a common approach to analyzing the effect of a policy intervention. However, the strong assumption of the common trend to hold may have reduced the validity of my results. As already discussed, the graphical test for the common trend assumption is not perfect. For this reason, using a different methodology might give different results, possibly ones that are even more significant. Another common method is a cross-section analysis which measures the effect in levels instead of in terms of changes. However, it is important to note that every research design has its advantages and disadvantages. A major advantage of the chosen method compared to a cross-section method is the elimination of omitted bias relating to factors that are unobservable but constant over time. Nevertheless, it would be interesting to apply other empirical designs to see if the results change significantly.

Furthermore, I have only managed to obtain data for 45 countries (at the most) out of a total 78 countries in my regressions. This clearly reduces the robustness of my results because the more observations there are, the more accurate results. Hence, some precision is lost. For the sample period of 1975-2010, some countries had missing values on one or several variables, thus reducing the number of observations in my regression results. This had consequences for the empirical design, which strongly relies on having data on the variables of interest in specific years of each period. The ideal dataset would be a dataset with no missing values, but this is difficult to obtain.

Overall, my empirical results show an effect at the 5 percent significance level using a discrete treatment. Because of the failure to show robustness using a continuous treatment, I cannot safely say that there is a causal effect of trade liberalization on innovation. Further research is needed to ensure stronger robustness and higher validity of the effect of trade liberalization on innovation.

7 Conclusion

The objective of this thesis has been to determine if there is a significant effect of tariff reduction on innovation. My research question was: Is innovation accelerating more in liberalizing countries than in non-liberalizing countries?

I have focused on two mechanisms: import competition and improved import opportunities. Both the theoretical and empirical literature on the impact of import competition on innovation report ambiguous effects. On the one hand, the escape-competition effect claims that increased competition is good for innovation. On the other hand, the Schumpeterian effect asserts that innovation only happens in a setting of low competition. By contrast, the empirical findings concerning the impact of improved import opportunities are shown to be positive and significant. However, the potential impact of knowledge spillovers and technology diffusion may work to decrease domestic innovation.

The unclear theoretical effects and the findings of earlier empirical literature stimulated the need for further empirical research. I have contributed to the literature by applying a DiD method to estimate the causal effect of trade liberalization on innovation and the Uruguay Round has been used as a binary treatment. This approach has enabled the estimation of the differences in the average change of the mean tariff rates pre- and post-Uruguay Round on innovation rates for the period 1975-2010. By using this approach and viewing liberalization as a discrete treatment, I find that innovation is accelerating more in liberalizing countries compared to non-liberalizing countries. The coefficient *liberalizer* is significant at the 5 percent level and indicates a positive relationship between tariff cuts and innovation. The innovation growth of liberalizing countries is 4.4 percent higher than in non-liberalizing countries.

My empirical findings support the two mechanisms, the escape-competition effect and improved import opportunities, and highlight a positive relationship between trade liberalization and innovation. However, I cannot disentangle which effect dominates due to the limitations of my data and research design. Moreover, I perform two falsification tests, a placebo treatment, and a graphical checking of the common trend assumption. The placebo treatment gives non-significant results, thus supporting the common trend assumption. The graphical test shows somewhat weaker results. Nonetheless, I argue that the robustness of the placebo treatment compensates for the weaker graphical test. Lastly, I perform a robustness check on average patent quality and show that trade liberalization has not led to a reduction in the economic or technological value of patents.

Despite the significant empirical findings, my results fail to show robustness for the continuous treatment measure. This reduces the statistical power and validity of my empirical research. Therefore, I cannot say that that trade liberalization is causally related to innovation. Nonetheless, this thesis is a contribution to the relatively small research literature investigating the effect of tariff cuts on innovation by using patent data as a measure of innovation. It also contributes to increasing knowledge of the relationship between tariff cuts and innovation at the country-level.

I have argued that the main reason for the lack of robustness is my crude data. Hence, future research would benefit from using a more comprehensive dataset on patents and on tariffs yet with the same empirical design.

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Appendix

The appendix includes the 51 countries used in this thesis. The countries are separated into treatment (liberalizers) and control (non-liberalizers) groups.

Liberalizers

Brazil
Philippines
Argentina
Malaysia
Poland
Austria
South Korea
Mexico
Egypt
Cyprus
New Zealand
India
China
Turkey
Australia
Guatemala
Kenya
Ecuador
Canada
Indonesia
Uruguay
Tunisia
Sri Lanka
Zambia
Columbia

Non-Liberalizers

Finland
France
Norway
Luxembourg
Ireland
Switzerland
Greece
Sweden
Algeria
South Africa
Italy
Germany
Denmark
Japan
Zimbabwe
United States of America,
United Kingdom of Great
Britain and Northern Ireland,
Jordan
Morocco
Singapore
Hong Kong
Spain
Iran
Belgium
Iceland