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Exports, Technical Measures, and Regulatory Heterogeneity

Juan S. Blyde+ and Mayra A. Ramírez
Inter-American Development Bank, USA

Abstract This paper examines the trade effects of dissimilar technical measures between countries. When a company faces different regulations in different markets, its costs can increase from meeting a wider range of requirements and potentially from its inability to exploit economies of scale. We employ firm-level trade data from Chile to estimate the trade impacts of regulatory heterogeneity at various firm margins. We separate the trade impacts between broad classes of technical measures. The results indicate that regulatory heterogeneity is negatively associated with exports. The impacts are observed on both, the extensive and the intensive margins of exports. There are heterogeneous effects depending on the size of the firms with small firms being disproportionately affected from dissimilar technical measures. We also find that the impact of heterogeneity on conformity assessment requirements is no less important, and potentially more important, than the impact of heterogeneity on production requirements.

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I. Introduction

Quinoa, water filters, baby cribs, recyclable baby bottles and smartphones are subject to technical measures. These are just some examples of the wide range of products that are subject to this type of regulations. Governments impose technical measures on the commercialization of goods, ranging from food products to electronic devices, to promote public policy objectives such as food safety, the protection of human, animal or plant health, or the conservation of the environment, among other reasons.

As tariff rates continue to decline around the world, technical measures, such as sanitary

+Corresponding Author: Juan S. Blyde
Principal Economist, Inter-American Development Bank, 1300 New York Ave., NW, Washington DC, 20755, U.S.
E-mail: juanbl@iadb.org
Co-Author: Mayra A. Ramírez
Research Fellow, Inter-American Development Bank, 1300 New York Ave., NW, Washington DC, 20755, U.S.
E-mail: mayrara@iadb.org
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and phytosanitary measures (SPS), and technical barriers to trade (TBT), have become relatively more important as potential barriers to international trade.

Particular scrutiny has been placed on the potential trade impediments that arise from differences in domestic regulations, sometimes referred to as 'regulatory heterogeneity' (Sykes, 1999a, b; Grossman et al., 2021; Garcés and Vogt, 2024). The empirical evidence regarding the trade effects of having different technical regulations between countries is very consistent. In general, this literature finds that regulatory heterogeneity is negatively associated with trade flows (Franssen and Solleder, 2016; Nabeshima and Obashi, 2021; Korwatanasakul and Baek, 2021; Inui et al., 2021; Lombini, 2021). [1)]

The underlying rationale is that if the regulations in the destination market differ significantly from those in the exporting country, foreign firms wishing to export to that market will face additional costs associated with identifying, complying with, and demonstrating compliance with the regulations in that market in addition to those in their home country. If these requirements are different in each destination market, these costs may be multiplied by the number of markets that the exporter wishes to serve. According to Lamy (2015, 2016), when a firm is required to comply with different regulations in different markets, it must produce different versions of its products, often at a substantial cost due to its inability to exploit economies of scale.

The objective of this study is to estimate the trade effects of dissimilar technical measures between countries. We contribute to the literature in two important aspects. First, we employ firm-level trade data. Most of the existing analyses use trade data at the sector level (Korwatanasakul and Baek, 2021; Inui et al., 2021; Lombini, 2021) or at the product level (Franssen and Solleder, 2016; Nabeshima and Obashi, 2021). Fernandes et al. (2019) is a rare exception that uses firm-level data to examine the trade effects of dissimilar levels of pesticide stringency on agricultural products. Our study expands the evidence that comes from firm-level data to analyze the effects of dissimilar measures. Using firm-level trade data allows us to measure the trade effects of regulatory heterogeneity at a more granular level and estimate impacts at various firm margins, such as entry, exit, and survival of exporters. Using firm-level data also allows us to examine whether the effects vary by firm characteristics such as size.

Our second contribution is to separate the trade impacts of regulatory heterogeneity between different classes of technical measures. Technical regulations cover many different types of measures, some related, for example, to specification, performance or labeling requirements, and others related to conformity assessment requirements -the requirements necessary to demonstrate that the specification or performance requirements are met. We develop an empirical analysis that provides evidence regarding which types of regulatory heterogeneity are most detrimental to international trade. This evidence has important policy implications, for example, for prioritizing

1) A parallel line of research examines the impact of the number of technical measures imposed by a country on its imports. See Crivelli and Gröschl (2016); Ghodsi et al. (2017); Dolabella (2020).

a regulatory convergence agenda.

We employ firm-level data from Chile covering the period 2011-2019. The dataset encompasses the universe of Chilean exports at the transaction level. We use this data to construct various export margins. We also use data from United Nations Conference on Trade and Development (UNCTAD) to construct an indicator of differences in technical measures, called regulatory gap, between Chile and each destination market. This is done at the product (HS 6-digit) level and for each year of the analysis period. Using this indicator, we examine the impact of differences in technical measures between Chile and other countries on various export margins. We rely on a Poisson Pseudo Maximum Likelihood (PPML) estimator to allow for the presence of zero values in trade flows.

The results indicate that the greater the regulatory differences between Chile and the destination country, the lower the exports to that country. Both, the extensive and the intensive margins are affected by regulatory differences. In particular, destinations with greater regulatory gaps exhibit both a smaller number of exporters and a lower value of exports per firm. The results also show that small firms are disproportionately affected by regulatory differences, suggesting a lower capability than other firms to deal with technical measures that are different from those applied domestically. Regarding the effects by classes of technical measure, we find that the impact of heterogeneity on conformity assessment requirements is no less important, and potentially more important, than the impact of heterogeneity on production requirements. This has implications for the pursuance of a regulatory convergence agenda.

Our study is related to a empirical analyses that link trade outcomes with various measures of technical measures, including counts of technical measures (Crivelli and Gröschl, 2016; Ghodsi et al., 2017; Dolabella, 2020), and trade concerns associated with SPS measures (Fontagné et al., 2015). The analysis is most closely associated with studies that examine the trade impacts of regulatory heterogeneity (Franssen and Solleder, 2016; Fernandes et al., 2019; Nabeshima and Obashi, 2021; Korwatanasakul and Baek, 2021; Inui et al., 2021; Lombini, 2021). The study is also related to a growing body of work that examines the trade effects of various types of cooperation mechanisms that countries implement in order to reduce regulatory heterogeneity (Baller, 2007; Reyes, 2011; Schwarzer, 2017; Fernandes et al., 2021; Blyde, 2023).[2]

The rest of the paper is organized as follows. Section 2 presents the regulatory distance index that we use in the study and discusses the empirical specification behind the econometric exercises. This section also describes the Chilean firm-level dataset, and the dataset employed in the construction of the regulatory gaps. Section 3 shows the estimations and explains the results. Section 4 concludes with a discussion of the overall impacts and its policy implications.

2) Our work is also related to Macedoni and Weinberger (2022) that studies the reallocation effects of standards across firms.

II. Empirical Specification

In this section we describe the construction of an indicator that captures the degree of heterogeneity in technical measures between Chile and other countries. We also present the empirical specification that we use to estimate the impact of this regulatory heterogeneity on international trade.

Analyzing how different are the technical measures imposed by two countries is a complex task. A single product can have many regulations. Comparing all the regulations for a single product between two countries can already involve a lot of work, let alone doing it for all goods in the HS classification. One way to simplify this task is to use the non-tariff measures (NTM) dataset collected by UNCTAD. This dataset has the advantage of grouping the vast number of NTMs into 178 distinct groups. This approach is called the UNCTAD MAST classification. For each of the nearly 6,000 products in the HS classification (6-digit level), the UNCTAD MAST dataset shows which of the 178 NTM groups are applied by each country. Of these 178 NTM groups, 48 correspond specifically to technical measures related to SPSs and TBTs. The focus of the analysis will be on these 48 groups.[3)]

Examples of NTM groups in the UNCTAD MAST classification are "Prohibitions for sanitary and phytosanitary reasons (A11)", "Tolerance limits for residues of certain substances (A21)", or "Labeling requirements (A31)". It is worth noting that these are groups of measures, not measures per se. For example, if country A imposes one labeling requirement to a product and country B imposes three types of labeling requirements, both are marked in the UNCTAD MAST classification as imposing a label measure on that product, regardless of the number of actual requirements used. In the rest of the document, for simplicity of exposition, we will refer to these 48 groups of NTM measures simply as measures.

To explain the indicator of regulatory heterogeneity that we employ in the empirical specification, we follow the exposition in Garcés and Vogt (2024), which in turn is based on Lesot et al. (2009). Consider two countries, origin (o) and destination (d), that impose technical measures to a product. The following indicators can be calculated:

- Number of measures in common, denoted by a.
- Number of measures imposed by o, but not d, denoted by b.
- Number of measures imposed by d, but not o, denoted by c.

Indicators a, b and c, can be used to construct measures of regulatory heterogeneity. The most common measure of regulatory heterogeneity is the Jaccard distance, which is given by

3) The other NTMs categories include measures such as contingent trade-protective measures, price-control measures, finance measures, and trade-related investment measures, among others.

the following expression:

$$JD_{odp} = 1 - \frac{a}{a+b+c} \tag{1}$$

where JD_{odp} is the Jaccard distance between countries o and d in product p, measured as the share of technical regulations imposed by both countries (without double counting) on product p that are not the same. A number of studies have employed the Jaccard distance to measure regulatory heterogeneity of technical measures between countries (Cadot et al., 2015; UNCTAD, 2017; Lombini, 2021). As mentioned in the introduction, firms are likely to face lower trade costs when regulations in the destination market are closer to those they face in the domestic market. In general, it is assumed that any experience in addressing a certain type of technical measure is better than no experience (Garcés and Vogt, 2024). Accordingly, measures of bilateral regulatory differences, like the Jaccard distance, seek to capture the trade costs associated with different technical measures between the countries.

A feature of the Jaccard distance in (1) is that the measure is symmetric for both countries in the same way that the physical distance between two countries is the same for both. This, however, can be a limitation for the objective of our investigation. For example, consider a case in which destination country d imposes four technical measures on a product, and origin country o (Chile) imposes only one of them. Since three of the four measures are different, or 75%, the regulatory distance between country d and Chile is 0.75. Now consider a second case in which the origin country o (Chile) is the one that imposes four measures and destination country d imposes one of them. In this case, expression (1) will give the same regulatory distance between country d and Chile of 0.75. In these two examples, the regulatory distances between country d and Chile are the same, but the challenges that Chilean exporters face are very different.

In the first case mentioned above, Chilean exporters encounter in country d three technical measures that are not present in the home market, therefore, exporting to country d can be potentially challenging. However, in the second case, exporting to country d does not necessarily represent a challenge because the only technical measure that the Chilean exporters face in country d is already a regulation that they face at home. Even though the challenges faced by Chilean exporters are very different in these two cases, the regulatory distance is the same. This is because the measure of regulatory distance in (1) is symmetric for both countries; in other words, it is independent of which country imposes the requirements. We would like to use an indicator of regulatory heterogeneity that takes into account the notion that bridging the gap of regulatory distance is not necessarily the same for both countries. A measure that captures this idea is the Jaccard gap, which is given by the following expression:

$$JD_{odp} = 1 - \frac{a+b}{a+b+c} \qquad (2)$$

The second part of expression (2) is what is usually called the Jaccard overlap, which increases in joint presence of measures and measures imposed by *o* but not by *d*. Then, one minus the Jaccard overlap is the Jaccard gap. The Jaccard gap gives the share of measures imposed by destination country *d* on product *p* that are not present in origin country *o*. Note that if we now apply expression (2) to the first example above, where destination country *d* imposes four measures on a product and Chile imposes one of them, the Jaccard gap between country *d* and Chile is 0.75. On the other hand, if we apply the expression to the second case, where destination country *d* imposes one of the four measures that Chile imposes, the Jaccard gap between country *d* and Chile is 0. In other words, expression (2) is not independent of which country imposes the requirements. Accordingly, this measure is likely to capture more adequately how challenging is for Chilean exporters to bridge the regulatory gap with destination markets.

Still, a shortcoming of the Jaccard gap, as a measure of regulatory heterogeneity in our context, is that it does not take into account the intensity of the regulations. For example, if country *d* applies two measures on product *p* and Chile applies one of them, the Jaccard gap is equal to 0.5, while if country *d* applies ten measures on product *p* and Chile applies five of them, the Jaccard gap remains equal to 0.5. However, in the first case, Chilean exporters have to deal with only one measure in country *d* that is not present in Chile, while in the second case they have to deal with 5 measures. The intensity of the regulatory scenario in the second case is greater than in the first case in the sense that the Chilean exporters have to deal with many more unfamiliar measures in the second case than in the first one. Such differences in intensity are not captured in the Jaccard gap as presented in expression (2).

There are two ways to account for differences in the intensity of regulations. One, is to use gap indicators that explicitly incorporate regulatory stringency. For our setting, this is done by using the Jaccard gap with intensity, which is given by the following expression:

$$JG_{odp}^{Int_d} = JG_{odp} \cdot C_{dp} \qquad (3)$$

where C_{dp} is the count of measures imposed by destination country *d* on product *p*.[4] The Jaccard gap with intensity, as measured in (3), gives the number of measures imposed by country *d* on product *p* that are *not* present in Chile. Accordingly, this index of heterogeneity increases with both, the gap per se (JG_{odp}), and the counts of measures (C_{dp}) in country *d*. We employ

4) It is common in the literature to employ the number of measures imposed by a country as a suitable proxy for regulatory intensity (Cadot and Malouche, 2012; Gourdon, 2014; UNCTAD, 2017).

the Jaccard gap with intensity as our measure of regulatory heterogeneity in the econometric regressions that we will introduce below.

We also purse an alternative strategy to account for the intensity of regulations. Instead of using $JG_{odp}^{Int_d}$ as the main regressor in the econometric analysis, we employ JG_{odp} as the measure of regulatory heterogeneity and include C_{dp} as a separate control. The interpretation in this later case is that we will assessing the trade impact of the regulatory gap between Chile and destination markets after controlling for the number of measures imposed in those markets. As we will see below, the two approaches generally lead to qualitatively similar results. We will indicate the few instances when this is not the case.

As we mentioned above, one of the innovations of this paper is to separate the trade impacts of regulatory heterogeneity between different classes of technical measures. Accordingly, we divide the 48 NTM groups that are used to construct (3) in two subgroups:

(1) Product, quality, safety, hygienic, performance or identity measures.
(2) Conformity assessment measures.

Each subgroup has a distinct purpose, which leads to a logical separation into clearly defined objectives. The first subgroup relates to requirements that the product itself must meet, which are usually for reasons related to quality, safety, hygiene, or performance. For brevity we call this subgroup "product measures". The second subgroup relates to the procedures to demonstrate that the technical requirements have been met, including the tests that can be used, the places where the tests can be done, or the approval processes that need to be completed. These are "conformity assessment measures".

Countries can exhibit regulatory heterogeneity in product measures, in conformity assessment measures, or in both. Accordingly, we employ an expression similar to equation (3) to calculate the Jaccard gap with intensity associated with each of the subgroups. In our empirical analysis we will estimate the trade impacts of the overall regulatory gap, as well as the trade impacts of regulatory gaps in each class of measure.

The data source for calculating all the measures related to the Jaccard gap and the Jaccard gap with intensity comes from the UNCTAD NTM dataset. UNCTAD collects NTM data for over 100 countries and harmonizes the information into predefined NTM groups, allowing for a comprehensive and comparable examination of NTMs between countries. As mentioned above, out of the 178 NTM distinct groups, 48 relate to technical measures. Accordingly, these 48 groups of technical measures constitute the basis of the regulatory content used to calculate the share of measures that are common between countries for any given product. For example, if Chile imposes on product p two groups of measures, "Tolerance limits for residues" (NTM group A21), and a "Labeling requirement" (NTM group A31), while country d imposes only a "Tolerance limits for residues" (NTM group A21), then the proportion of measures that are common between Chile and country *d* on product *p* is 50%. This is because of the two measures imposed on product *p* by these two countries, only one measure (tolerance limits for residues) is the same.

It should be noted that if two countries apply the same measure but with different thresholds, they are still counted as if they apply the same measure. This is because the UNCTAD NTM dataset does not have information about the degree, quantity, scale, amount or generally the extent to which a particular measure is applied. For instance, suppose in the example above that the tolerance limit for residues that Chile sets for product *p* is different from the tolerance limit that country *p* sets. This implies that the regulations are slightly different because while both countries impose tolerance limits for residues on product *p*, the individual limits that each country sets are not the same. Unfortunately, UNCTAD data do not have information to discern the specific level at which a measure is applied. For this reason, if two countries apply the same measure but with different thresholds, they are still counted as applying the same measure.

After eliminating countries with very limited data, the UNCTAD NTM sample that we use for this study consists of 89 countries including Chile. The period of analysis is 2011-2019.

Table 1 shows some summary statistics behind the regulatory gap indicator. The average regulatory gap that Chile faces is equal to 0.47. That is, of all the technical measures that Chilean exporters face, in all products and in all destination markets, 47% are not present, on average, in the Chilean market. Similarly, the Jaccard gap with intensity shows that Chilean exporters face 2.7 measures in destination markets that they do not face at home, on average. In both indicators, the heterogeneity behind the product measures is greater than with respect to the conformity measures.

Table 1. *Regulatory Gap, Summary Statistics*

	All measures	Product measures	Conformity measures
	(1)	(2)	(3)
Jaccard gap	0.466	0.468	0.344
Jaccard gap intensity	2.697	1.699	0.909
Number of measures, destination country	3.198 (19)	1.917 (15)	1.801 (7)
Number of measures, Chile	1.379 (9)	0.658 (5)	0.711 (6)

Note: The table provides summary statistics related to regulatory heterogeneity between Chile and destination countries. Averages are taken across all destination countries, products, and years. The values in parentheses refer to the maximum number of measures in the corresponding cell.

The last two rows of Table 1 show the average number of measures imposed by destination countries and by Chile. The values in parentheses show the maximum number of measures in the corresponding cell. The following patterns can be observed: i) the average destination country imposes more measures than Chile, for product measures, for conformity measures, and for all; ii) the average destination country imposes slightly more product measures than conformity measures, on average across all products; iii) Chile imposes slightly more conformity measures than product measures, on average for all products. The last two findings combined is one of the reasons why the Jaccard gap intensity between Chile and the destination markets is smaller in conformity measures than in product measures.

A. Econometric model

Our empirical analysis is based on two classes of econometric models. In the first model, the variation in the data is at the product-destination-year level. This is done to examine the impact of regulatory gap on a number of export margins, such as the number of exporters of product p to a destination market (extensive margin), or the average exports per firm of product p to a destination market (intensive margin). In the second model the variation in the data is at the firm-product-destination level. This will allow us to explore at a more granular level how the trade effects vary by firm characteristics.

The first set of models take the following functional form:

$$M_{dpt} = \exp\left[\beta_1 \cdot JG_{dpt}^{Int_d} + \beta_2 \cdot \ln(1 + tar_{dpt}) + \theta_{dt} + \theta_{pt} + \theta_{dp}\right] \cdot \epsilon_{dpt} \tag{4}$$

where M_{dpt} represents, either, total exports, the number of exporters (extensive margin) or the average exports per firm (intensive margin) from Chile to destination country d of product p (at the 6-digit HS level) in year t; $JG_{odp}^{Int_d}$ is the regulatory gap with intensity between Chile and the destination country d in product p, as defined in (3);[5] and tar_{dpt} is the import tariff rate on product p that country d applies to Chile. Finally, θ_{dt}, θ_{pt}, and θ_{dp} are fixed effects by destination country-year, product-year and destination country-product. These fixed effects control for all the variables that are used in gravity estimations, including the size and income of the origin and destination countries, the physical distance between them as well as the usual dyadic trade cost components, such as common language, contiguity, and colonial ties.

To account for the presence of zero values in trade flows, we employ a Poisson Pseudo Maximum Likelihood (PPML) estimator. In order to operationalize this, the database at the product-destination level is expanded so that each product-destination in the original dataset has an observation in all the sample years (2011-2019). The years in which there are no exports at the product-destination level are filled with zeros.

As mentioned before, we employ firm-level data from Chile covering the period 2011-2019.

5) Since there is only one origin country (Chile), we have omitted the subindex o

The information is from the Chilean National Customs Authority, *Servicio Nacional de Aduanas*. The dataset includes the universe of the Chilean exports at the transaction level. Specifically, each record includes information about the firm engaged in the transaction, the good exported (at 6-digit HS level), the destination country, and the export value in US dollars. Importantly, the firm is identified using a unique code and can be tracked over time. Accordingly, for each firm we have the complete record of its export transactions (and overtime) including detailed information about the products exported and the destination markets. Table 2 presents some basic information about the export performance of the Chilean exporters.

Table 2. *Summary Statistics on Exporting Firms. Average 2011-2019*

	Average (1)	Median (2)
Number of products per firm	5.1	2.1
Number of markets per firm	4.2	1.5
Exports per firm (in 1,000 USD)	11,721	142

The dataset on the tariff rates is from Teti (2020) and from TRAINS, and the dataset to construct the regulatory gaps is from UNCTAD, as indicated above.[6)]

Besides the model in equation (4), we also estimate econometric models where the variation in the data is at the firm-product-destination level. This second set of models take the following functional form:

$$M_{fdpt} = \exp\left[\beta_1 \cdot JG_{dpt}^{Int_d} + \beta_2 \cdot \ln(1 + tar_{dpt}) + \theta_{fdp} + \theta_{fpt} + \theta_{dp}\right] \cdot \epsilon_{fdpt} \quad (5)$$

We adjusted the set of fixed effects to match the level of variation in the data. Once again, the fixed effects control for all the variables that are used in gravity estimations. The fixed effects also control for time-variant firm characteristics like firm size, for time-variant product related factors, like the global demand of a product, and for time-variant firm-product attributes, like the efficiency by which the firm produces goods.

To estimate (5) we employ again a PPML estimator. The expansion of original dataset at this level of variation follows the procedure used in Fernandes et al. (2016). Essentially, the database is expanded so that each firm-product-destination triplet in the original data has an observation in all the sample years (2011-2019), filling-in with zeros the years in which no exports are observed.

6) UNCTAD data treats the countries of the European Union as a monolithic bloc given the regulatory convergence schemes that exist in the agreement. We construct bilateral regulatory gaps between Chile and each country of the European Union based on the information presented for the European Union.

III. Empirical Results

Our first set of models corresponds to equation (4) in which the data is aggregated at the product-destination level. Table 3 shows the baseline results. Column 1 presents the impact of the regulatory gap on total exports, while column 3 shows the impact after including the tariff rate. The regulatory gap between Chile and the destination country negatively affects Chilean exports. For example, the coefficient on the Jaccard gap with intensity in column 3 implies that for any additional measure imposed in the destination market that is not present in Chile, Chilean exports to that market decline by 3.64%.[7]

Table 3. *Baseline Regressions at the Product-Destination Level*

	Total exports		
	(1)	(2)	(3)
Jaccard gap intensity	-0.0403*** (0.0076)		-0.0371*** (0.0076)
Ln (1 + tariff)		-2.4771*** (0.4335)	-2.1261*** (0.4257)
R2	0.986	0.986	0.986
Observations	422,208	422,208	422,208

Note: The dependent variable is the total Chilean exports of product *p* to destination country *d* in year *t*. The explanatory variables are the Jaccard regulatory gap with intensity between destination country *d* and Chile in product *p* in year *t*, and the applied tariff rate in destination country *d* to Chilean exports of product *p* in year *t* (in logs). All the regressions include destination-year, product-year and destination-product fixed effects. Robust standard errors in parentheses. ***, **, and * imply significant at the 1%, 5% and 10% level, respectively.

Table 4 shows the effects on the export margins, in particular, the number of exporters (extensive margin) and the average exports per firm (intensive margin). The results indicate that the impact of the regulatory gap on total exports is driven by both margins. In particular, an additional regulatory measure imposed in the destination market that is not present in Chile is associated with a reduction in the number of exporters and in the average exports per firm of 1.62% and 2.62%, respectively.

It is worth mentioning that Table A1 in the Online Appendix shows similar regressions as those in Table 4 but when we employ the Jaccard gap without intensity as the measure of regulatory heterogeneity and include the count of measures imposed by destination country *d* as a separate control. The coefficients on the regulatory gaps are negative and significant for total exports and the number of exporters (although they are less precisely estimated), while the coefficient for the average exports per firm is not statistically significant. Remember that

7) Note that the regulatory gap with intensity is a count measure that is not expressed in logs. Accordingly, the semi-elasticity is calculated as follows: 100x(exp(beta)-1)%. Using the estimated coefficient in column 3, this gives: 100x(exp(-0.0371)-1)% = -3.64%.

in these regressions, the estimated impact of the regulatory gap is assuming away differences in the number of measures. In other words, the intensity of the regulatory gaps is assumed to be the same across all the regulatory gaps. When this is the case, the regulatory gap, measured as the share of measures in the destination country that are not present in Chile, still exerts a negative impact on exports but mainly through the number of exporters. When the heterogeneity indicator incorporates the intensity of measures, the negative impacts are observed on both, the number of exporters and the average exports per firm. We summarize both pieces of evidence as follows: regulatory heterogeneity negatively affects Chilean exports, particularly, through the number of exporters; when the intensity of such regulatory heterogeneity is explicitly accounted for, the impact is also observed on the average exports per firm.

Table 4. *Regressions at the Product-Destination Level, Extensive and Intensive Margins*

	Total exports (1)	Number of exporters (2)	Avg. exp. per firm (3)
Jaccard gap intensity	-0.0371*** (0.0076)	-0.0164*** (0.0015)	-0.0266** (0.0114)
Ln (1 + tariff)	-2.1261*** (0.4257)	-0.2362*** (0.0817)	-1.1033** (0.4860)
R2	0.986	0.986	0.986
Observations	422,208	422,208	422,208

Note: The dependent variables are the total Chilean exports of product p to destination country d in year t (column 1), the number of exporters of product p to destination country d, and the average exports per firm of product p to destination country d. The explanatory variables are the Jaccard regulatory gap with intensity between destination country d and Chile in product p in year t, and the applied tariff rate in destination country d to Chilean exports of product p in year t (in logs). All the regressions include destination-year, product-year and destination-product fixed effects. Robust standard errors in parentheses. ***, **, and * imply significant at the 1%, 5% and 10% level, respectively.

We now present the results of estimating the model in equation (5) at the firm-product-destination level. Table 5 shows the results of the baseline regressions. Column 3 includes the impacts of the tariff rate and the regulatory gap which are both negative. The coefficient on the regulatory gap in column 3 implies that for any additional measure imposed in the destination market that is not present in Chile, the exports of Chilean firms to that market decline by 3.39%.[8)]

In Table 6 we explore whether there are heterogeneous effects by firm size. In particular, we construct a dummy variable that is equal to 1 if the firm is small and interact it with the regulatory gap to examine whether the negative trade impacts found in Table 5 increase or decrease for small firms. We employ a couple of definitions of firm size along the lines of Fernandes et al. (2021). In particular, a firm is considered small if the market share of

8) 100x(exp(-0.0345)-1)% = -3.39%.

its exports at the product level in its first year in the database is within the first tercile of market shares among all the exporters of that product (T1), or alternatively, within the first quartile (Q1).

Table 5. *Regressions at the Firm-Product-Destination Level*

	(1)	(2)	(3)
Jaccard gap intensity	-0.0387*** (0.0098)		-0.0345*** (0.0099)
Ln (1 + tariff)		-3.1891*** (0.4740)	-2.8711*** (0.4707)
R2	0.971	0.971	0.971
Observations	747,474	747,474	747,474

Note: The dependent variable is the exports of firm *f* of product *p* to destination country *d* in year *t*. The explanatory variables are the Jaccard regulatory gap with intensity between destination country *d* and Chile in product *p* in year *t*, and the applied tariff rate in destination country *d* to Chilean exports of product *p* in year *t* (in logs). All the regressions include firm-product-destination, firm-product-year and destination-year fixed effects. Standard errors clustered at the product-destination level. ***, **, and * imply significant at the 1%, 5% and 10% level, respectively.

Table 6. *Heterogeneous Effects by Firm Size*

	(1)	(2)	(3)
Jaccard gap intensity	-0.0345*** (0.0099)	-0.0311*** (0.0101)	-0.0310*** (0.0100)
Jaccard gap intensity x small (T1)		-0.0361** (0.0156)	
Jaccard gap intensity x small (Q1)			-0.0462** (0.0179)
Ln (1 + tariff)	-2.8711*** (0.4707)	-2.8749*** (0.4714)	-2.8843*** (0.4712)
R2	0.971	0.971	0.971
Observations	747,474	747,474	747,474

Note: The dependent variable is the exports of firm *f* of product *p* to destination country *d* in year *t*. The explanatory variables are the Jaccard gap with intensity between destination country *d* and Chile in product *p* in year *t*, the applied tariff rate in destination country *d* to Chilean exports of product *p* in year *t* (in logs), and the interaction between the Jaccard gap and a dummy variable that is equal to 1 if the firm is considered small. A firm is considered small if the market share of its exports at the product level in its first year in the database is in the 1st tercile (T1) of the market share distribution, or alternatively in the 1st quartile (Q1) of the market share distribution. All the regressions include firm-product-destination, firm-product-year and destination-year fixed effects. Standard errors clustered at the product-destination level. ***, **, and * imply significant at the 1%, 5% and 10% level, respectively.

Table 6 shows the results. For comparison, column 1 repeats the same regression as column 3 in Table 5. Column 2 shows the differential impact with respect to size. The results indicate that the negative trade impact of the regulatory gap on small firms is more than double that of other firms. In particular, the estimated impact, which is the sum of both coefficients, is

-0.0672, while the estimated impact for the rest of the firms is -0.0311. When we define small firms by the first quartile of export shares, the negative impact is even greater (-0.0772).

The results in Table 6 indicate that small exporters are disproportionately affected by regulatory differences, which suggest that these firms have lower capability and/or resources to deal with technical measures that are different from those applied domestically. As mentioned before, firms must incur in a number of costs associated with the identification, compliance, and the demonstration of compliance of technical measures. In the identification phase, firms may incur in costs associated with searching for, identifying, gathering, and processing information on the technical requirements that apply to their products. In the compliance phase, firms may need to adjust the product specification to meet regulatory requirements. In the demonstration phase, firms may incur in costs associated with laboratory testing, inspections, audits, or certifications. Medium and large firms are more likely to have resources to finance these activities than small ones, especially if the requirements in the destination market are so different from those at home that is impossible to take advantage of economies of scale. Furthermore, technical regulations are documents that can be quite cumbersome, and exporters often need to consult with local agents on the details of the requirements. Small firms may not have the resources and networks to assist them in these tasks. All these factors may explain why small firms are relatively more affected than other firms by regulatory differences.

We now present the trade impacts of the regulatory gaps when they are separated by the two classes of measures mentioned above: "product measures", and "conformity assessment measures". Table 7 shows the results. For comparison, column 1 repeats the same regression as column 1 of Table 6. The evidence indicates that the trade impacts of the regulatory gap arise from both classes of technical measures. In particular, for any additional product measure imposed in the destination market that is not present in Chile, the exports of Chilean firms to that market decline by 2.49%, while for any additional conformity measure imposed in the destination market that is not present in Chile, the exports of Chilean firms to that market decline by 4.34%. We perform a test for equality of coefficients and cannot reject it. Consequently, we cannot claim that the negative impact of heterogeneity on conformity assessment measures is greater than the impact of heterogeneity on product measures. We can say, however, that the impact related to conformity assessment is no less important.

It is worth mentioning that the estimated coefficient for the conformity measure in Table 7 is statistically significant at 10%, which a priori seems relatively weak. However, it is important to remember that the set of fixed effects that we are employing in these regressions is very demanding. In fact, when we use an alternative set of fixed effects that is slightly less demanding, the estimated coefficients for product and conformity measures are significant at the 1% and 5% levels, respectively (see column 1 of Table A5 in the Online Appendix). Therefore, taking both exercises together and considering that the coefficients for the regulatory gaps are still negative and significant in the specification with the most demanding set of fixed effect, as in Table 7, give us confidence about the results.

Table 7. *Heterogeneous Effects by Type of Technical Measure*

	(1)	(2)
Jaccard gap intensity	-0.0345*** (0.0099)	
Jaccard gap intensity (product measures)		-0.0253** (0.0110)
Jaccard gap intensity (conformity measures)		-0.0444* (0.0264)
Ln (1 + tariff)	-2.8711*** (0.4707)	-2.9422*** (0.4669)
R2	0.971	0.971
Observations	747,474	747,474

Note: The dependent variable is the exports of firm *f* of product *p* to destination country *d* in year *t*. The explanatory variables are the Jaccard gap with intensity between destination country *d* and Chile in product *p* in year *t* (column 1), the Jaccard gap with intensity between destination country *d* and Chile in product *p* in year *t* associated with product measures (column 2), and with conformity measures (column 2), and the applied tariff rate in destination country *d* to Chilean exports of product *p* in year *t* (in logs). All the regressions include firm-product-destination, firm-product-year and destination-year fixed effects. Standard errors clustered at the product-destination level. ***, **, and * imply significant at the 1%, 5% and 10% level, respectively.

It is also worth comparing the results presented in Table 7 with those arising from regressions that employ the Jaccard gap without intensity and the count of measures as a separate control. This is shown in column 2 of Table A3 of the Online Appendix. When the intensity of the regulatory gaps is assumed to be the same across all the regulatory gaps, the heterogeneity in conformity measures is the factor that drives the negative effect on firm's exports. The heterogeneity in product requirements, measured as the share of product requirements not present in Chile, on its own, does not seem to induce a negative impact on exports. It is only when we incorporate the intensity of the regulation behind product requirements, measured as the actual number of product requirements not present in Chile, that we observed a negative and significant effect (as in Table 7). We summarize both pieces of evidence as follows: regulatory heterogeneity negatively affects Chilean exports, particularly, through conformity measures; when the intensity of such regulatory heterogeneity is explicitly accounted for, the impact is also observed through product measures.

It is reasonable to expect that differences in product measures may limit a firm's exports because they go to the heart of the production process, potentially changing how a firm engages in the production activity. But the fact that the results show that conformity measures are also important is less obvious. Some examples, however, can help illustrate the potentially restricting effects of conformity assessment requirements. For many products to enter a market, the destination country may require at least two things: a certificate of Good Manufacturing Practices (GMPs) -a document issued to the requesting exporting company- and a registration of the product to be marketed. On some occasions, the GMP certification involves a process in which officials from the destination country's regulatory authority need to visit and inspect the company's facilities in the origin country and then decide whether or not to grant the certificate. Even if the exporting firm complies with all the requirements, exporting can be delayed until the authority of the destination country visit the company's facilities. Anecdotal evidence indicates that in some cases these visits can take years (Vaillant, 2022). The process to obtain a product registration may involve its own obstacles as well. These examples illustrate how conformity assessment requirements, such as company certifications or product registrations can be detrimental to trade, particularly if the processes of getting these certifications are ambiguous, opaque, or discretionary.

Table 8. *Heterogeneous Effects by Type of Technical Measure and Firm Size*

	(1)	(2)	(3)
Jaccard gap intensity (product measures)	-0.0253** (0.0110)	-0.0206* (0.0115)	-0.0204* (0.0114)
Jaccard gap intensity (conformity measures)	-0.0444* (0.0264)	-0.0453* (0.0265)	-0.0455* (0.0261)
Jaccard gap intensity (product measures) x small (T1)		-0.0657** (0.0269)	
Jaccard gap intensity (conformity measures) x small (T1)		0.0200 (0.0436)	
Jaccard gap intensity (product measures) x small (Q1)			-0.0823*** (0.0302)
Jaccard gap intensity (conformity measures) x small (Q1)			0.0223 (0.0496)
Ln (1 + tariff)	-2.9422*** (0.4669)	-2.9545*** (0.4678)	-2.9607*** (0.4679)
R2	0.971	0.971	0.971
Observations	747,474	747,474	747,474

Note: The dependent variable is the exports of firm *f* of product *p* to destination country *d* in year *t*. The explanatory variables are the Jaccard gap with intensity between destination country *d* and Chile in product *p* in year *t* associated with product requirements and with conformity requirements (column 2), their interactions with a dummy variable that is equal to 1 if the firm is small, and the applied tariff rate in destination country *d* to Chilean exports of product *p* in year *t* (in logs). A firm is considered small if the market share of its exports at the product level in its first year in the database is in the 1st tercile (T1) of the market share distribution, or alternatively in the 1st quartile (Q1) of the market share distribution. All the regressions include firm-product-destination, firm-product-year and destination-year fixed effects. Standard errors clustered at the product-destination level. ***, **, and * imply significant at the 1%, 5% and 10% level, respectively.

In Table 8 we explore whether the impacts of regulatory gaps by classes of requirements are different between small firms and the rest. For comparison, column 1 repeats the same regression as column 2 of Table 7. The second column of Table 8 shows the results when the definition of "small" is based on the first tertile of the firm's export shares, while the third column uses the definition according to the first quartile. The results are similar in both cases. The coefficient estimates for the interaction terms between the regulatory gap and the dummy variable for small firm are statistically significant only for product measures. This implies that small firms are not necessarily more affected than larger firms by regulatory gaps in conformity requirements. Small firms, however, are more affected than larger firms by regulatory gaps in product requirements.

A potential explanation of these results is that product measures involve mostly incurring in costs related to adapting the product to the regulations of the destination country. These costs can be fixed and/or variable, and larger firms are more likely to have the resources to finance them. In comparison, part of the conformity assessment measures may involve dealing with the decisions (and potentially the arbitrariness) of regulatory authorities (like deciding when to inspect a facility) and these aspects are more likely to escape the control of the exporters. Thus, this part of the regulations may affect firms more equally.

IV. Concluding Remarks

Technical measures have a role to play in societies as they are used to promote legitimate public policy objectives such food safety or the conservation of the environment. But they can negatively impact trade, particularly if the regulations in the destination market differ significantly from those in the exporting country, as foreign firms wishing to export to that market will face additional costs associated with identifying, complying with, and demonstrating compliance with the regulations in that market in addition to those in their home country. In this study we analyze the trade impact of regulatory heterogeneity in technical measures. We contribute to the literature by using firm-level data to uncover the impacts on firm margins, and by separating the effects between different classes of technical measures.

Our findings indicate that regulatory heterogeneity negatively affects both the extensive and intensive margins of exports. Product-markets with large regulatory gaps are associated with lower exports, a lower mass of exporters and lower exports per firm.

The results reveal that both, product measures and conformity assessment measures, negatively affect firm's exports, with the impact of heterogeneity on conformity assessment requirements being no less important, and potentially more important, than the impact of heterogeneity on production requirements. The regressions also reveal that small firms are disproportionately affected by regulatory heterogeneity, suggesting that these firms have lower capability and resources to deal with technical measures that are different from those applied domestically. The results indicate that the main reason why small firms are disproportionately affected by regulatory heterogeneity is because these firms are affected by regulatory gaps in conformity requirements in the same way as the other firms, but they are more impacted by heterogeneous regulations in product requirements than larger firms.

The findings in this study have some clear policy implications. Dealing with technical measures impose various costs on firms related to identifying, complying, and showing compliance with regulations in other countries. When these regulations differ significantly across countries, the costs of dealing with technical measures increase, particularly if firms cannot take advantage of scale economies. Countries that seek to reduce this type of costs can follow a regulatory convergence agenda where the objective is to reduce the heterogeneity in the regulations that exists between them.

There are alternative mechanisms to pursue regulatory convergence. One of the options is harmonization by which countries agree on the uniformity of rules among all participating parties. Another option is the mutual recognition (MR) of rules, by which a country accepts the imports that comply with another country's regulations as being equivalent to its own. Yet, another option is the MR of conformity assessments. Under this option, exporters must comply with destination market regulations, but conformity assessments for this compliance can be conducted according to the requirements of the exporting country.

MR of conformity assessments is an arrangement that is less ambitious than the MR of rules (de Brito et al., 2016). In particular, under a MR of rules, the destination country recognizes that the regulatory requirements of the origin country yield functional equivalence for protecting consumers in the destination country. The MR of conformity assessment is less ambitious in the sense that the destination country is only recognizing the capability of conformity assessment bodies in the origin country to perform testing and certification according to the rules of the destination country. Therefore, committing to accept the rules of other countries may be politically more difficult and is likely to encounter stronger opposition than committing to accept tests and certifications from foreign conformity assessment bodies.

Prioritizing a regulatory convergence agenda focused, at least initially, on reducing heterogeneity in conformity measures, would seem reasonable: on the one hand, a convergence mechanism on conformity measures may be politically more feasible than a convergence mechanism on production measures. On the other hand, our results suggest that such a mechanism would have no less impact, and potentially a greater impact on the margin, than the convergence of production measures.

Our study presents new evidence on the effects of regulatory heterogeneity on international trade, based on firm-level data and detailed information on different classes of technical measures. The evidence, however, must be taken with some caution because it is based on the relationship of one exporting country, Chile, with respect to the rest of the world. Future research lines should expand this type of analysis to more countries.

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