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Commodity price shocks and the gender wage gap: Evidence from the Metal Mining Prices Super-Cycle in Chile

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ABSTRACT

This paper analyzes the local impact of a natural resource shock on female and male wages as well as the gender wage gap. We contrast three hypotheses using the Dutch disease theory and gender-based segregation patterns in the labor market. Using household level data aggregated at a municipality-level from 2000 to 2015, we examine the case of Chile that was exposed to the Metal Mining Prices Super-Cycle between 2003 and 2011. We exploit the spatial heterogeneity in the exposure to the shock, and find a positive and significant impact on wages for both men and women. We also provide evidence of a significant reduction in the gender wage gap in municipalities more exposed to the commodity shock in comparison to municipalities with less exposure. In addition, we use spatial econometric specifications and find evidence suggesting the existence of spatial spillovers between neighboring municipalities.

1. Introduction

Despite the undeniable positive effects of high metal mining prices on countries' macroeconomic efficiency and finances, its effects might be the opposite on critical equity variables such as gender inequality. Given the existent male dominance in the metal mining sector, commodity price shocks have by definition gender-differentiated effects in diverse economical outputs. This is especially important in developing and resources-based countries. According to Busse and Spielmann (2006), developing countries hold high and sustained gender gaps in different welfare outcomes such as education, income and wages. These gaps are further exacerbated in resources-based countries, where socially assigned roles exclude women from participating in male-dominated sectors that are characterized by favorable labor benefits (Ross, 2008). Furthermore, resources-rich countries tend to be more disposed to the instability of commodity prices caused by shocks, causing even greater inequalities (Reeson et al., 2012). Given that mining deposits are not uniformly distributed around space, these inequalities can also be observed within the country, at the municipal level. Literature has addressed the effects of resources shocks for different regions and economical outcomes (Hajkowicz et al., 2011; Lawrie et al., 2011; Chapman et al., 2015). However, as far as the authors know, few studies differentiate between the expansion and contraction phases of shocks, and even less address gender-differentiated effects of such shocks.

The aim of this paper is to evaluate the gender differentiated effects of the Metal Mining Prices Super Cycle (MMPSC) on wages and the Gender Wage Gap (GWG) in Chile, one of the main resource rich countries in Latin-America. Chile is a particularly interesting case of study to analyze the local effect of commodity shocks on the GWG for two main reasons. First, the economy of the country is based on the extractive industry, mainly in natural resources, representing 52.1 per cent of its national exports in the 2010–2016 period (Figueroa and Calfucura, 2003; OECD, 2018). Second, according to the Economic Commission for Latin America and the Caribbean (ECLAC), the Chilean gender wage gap is higher than the Latin American average for the years 2000 to 2017. This is interesting considering that Chile is one of the most developed countries in the region, yet, inequality in different contexts persists.

In principle, it is plausible to expect that the direct effect of a resources shock will benefit men since the extractive activity labor force is predominantly masculine. There are, however, potential channels that could also indirectly affect women. To identify these channels and construct our hypotheses, we extend the Dutch disease theory (Corden and Neary, 1982) to include the gender-based segregation in the labor market, considering both phases of the shock: expansion and contraction (Frederiksen, 2007; Ross, 2008; Horton, 1999). We argue that, according to the Dutch Disease condition, the expansion phase of the

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MMPSC in Chile generated an increase in labor demand in the mining sector. Given that this sector is male-dominated, the increase affected specifically the demand for male labor and their wages, generating an increase in the GWG. The contraction phase, in contrast, negatively affected the demand for labor in the mining sector, affecting male labor and their wages, thus generating a decrease in the GWG. In this sense, given these opposing forces, the effect of the shock on the GWG would depend on which particular phase was stronger: if the expansion (contraction) phase was stronger, then the gender wage gap would increase (decrease). Also, it is important to note that these opposing forces could counteract each other, and therefore, whether positive or negative, the long term effect on the GWG might be small or null.

To achieve the objective of this paper, we use the Chilean National Socioeconomic Characterization (CASEN) Survey, which is available for 2000, 2003, 2006, 2009, 2011, 2013, and 2015. We aggregate CASEN's household data at the municipal level and as a result have an unbalanced panel for seven waves of the survey. We use a difference-in-difference (DID) approach and use the MMPSC that occurred in Chile between 2003 and 2015 as a quasi-experiment. Following the literature, we claim that this is an exogenous shock given that it was generated by demand and no supply shifts. Its main causes were the increasing demand of commodities by China (Radetzki et al., 2008; Farooki and Kaplinsky, 2013), and the impact of investment flows driving through speculation in the stock markets (Singleton, 2014).

Since the expansion phase started in 2003, and the contraction phase started in the years following 2011, the dataset used allows us to identify local changes in time periods when the commodity shock occurs and those when it does not. We expect the intensity of each phase of the shock to be different across geographical areas, since mining municipalities would have a greater effect than non-mining. To identify the level of exposure, mining and non-mining municipalities, we use the share of employment held in the metal mining sector in each municipality in the year 2000. To identify the intensity of the shock, we follow Álvarez et al. (2018) and construct a price index that accounts for the price of the five principal metals in the overall Chilean production. The interaction of both intensity and exposure, allows us to address the impact of the shock as a heterogeneous phenomenon along Chilean municipalities.

Our main results suggest that municipalities that are relatively more exposed to the mining sector price fluctuations experienced larger increases in wages for both men and women during the MMPSC. However, male wages were more affected than female wages during the contraction phase, resulting in a reduction in the GWG. These results are robust through a variety of checks and specifications. In addition, we test for spatial heterogeneity and spillovers using different data aggregation levels, as well as spatial econometric techniques allowing for spatial interdependence between neighboring municipalities. Results are in line with our general findings and confirm the existence of spatial interdependence between municipalities. Insights deriving from our results are manifold. First, we provide resources for the implementation of tailor-made policies that attempt to protect labor conditions for women facing natural resources shocks, as well as to create more gender sensitive mining policies. Second, we provide empirical evidence to the discussion of whether large endowments of natural resources exert positive or negative effects on different economic welfare dimensions, in this case the GWG. Third, given the current political Chilean context facing the draft of a new Constitution, we provide resources for policy and decision-making, which entails comprehensive and exhaustive understanding of gender perspectives and their complex relations in the social and economic system (Kumar and Quisumbing, 2014).

The rest of the paper is organized as follows: Section 2 deepens on the MMPSC and its phases. Section 3 presents a description of the theory and hypothesis. Section 4 describes the data and presents some descriptive evidence regarding the Chilean mining labor market and the GWG. The empirical strategy is addressed in Section 5, while results, robustness checks and spatial spillovers aspects are presented in Section 6. Finally, conclusions and discussion are presented in Section 7.

2. The Metal Mining Prices Super-Cycle (MMPSC)

The commodity boom we will study throughout this article consists of an exogenous and substantial international price increase of commodities. Starting in 2003, oil and mining metals prices tripled (Baffes and Haniotis, 2010). Specifically, we refer to the MMPSC as an exogenous increase in the principal mining metal prices in the overall Chilean production, that started in 2003 and was followed by a decline since 2011. To claim exogeneity, this shock would have to be large, variable, temporary and generated outside an industry or country (Davis and Weinstein, 2008). It must be large and variable enough to generate an impact in municipalities' local conditions. It has to be temporary to clearly identify its phases and years in which it occurred. And finally, it has to be generated outside of the country. There is a consensus among scholars that the MMPSC was caused mainly by demand and no supply shifts (Erten and Ocampo, 2013). Its main causes were the increasing demand of commodities by China (Farooki and Kaplinsky, 2013; Radetzki et al., 2008), and the impact of investment flows driving through speculation in the stock markets (Singleton, 2014). This is especially important for our study, since it confirms that the three conditions mentioned by Davis and Weinstein (2008) are fulfilled. Therefore, and in line with the literature, we claim the exogeneity of the shock for the case of Chile. This shock is especially relevant for this country because its economy is mostly based on extractive industries, representing 52 per cent of its national exports in the 2010–2016 period, and around 13 per cent of the Chilean Gross Domestic Product between 2003 and 2017 (Figueroa and Calfucura, 2003; OECD, 2018).

We consider two phases in the analysis of the MMPSC: expansion and contraction. The expansion phase consists in the increase of the metal mining prices since 2003. Fig. 1 presents the prices for the five principal mining metals in the overall Chilean production, which are copper, silver, gold, molybdenum, and iron ore, for the period of 1998–2015. We observe that, in general, prices began to increase since 2003, reaching most of their maximum levels in 2011. Faced with the rise in prices, mining companies employed strategies to maximize their production before the probable fall in prices. Therefore, we also observe changes in the production of these minerals between those same years, as observed in Fig. 1. After 2011, the contraction phase began, which consisted in the decline of the metal mining prices in about 30%.

In Chile, the mining activity is highly spatially concentrated in northern municipalities, as observed in Fig. 2. This figure depicts the Metal-mining employment share with respect to total employment for the year 2000 for each municipality. Municipalities whose main activity is mining are expected to be more exposed to the metal mining price shock than others. In this sense, we would expect that the higher the metal-mining employment share, the higher the local effect of the shock.

Following Álvarez et al. (2018), we construct a price index to account for the regional variation of metal mining prices throughout the years, and the price effect of the shock in each of its phases.[1] The metal mining price index from 2000 to 2015 is represented in Fig. 3, allowing us to visualize the shock phases more clearly. According to the index, years prior 2003 are considered the pre-shock years. After 2003, we can observe a pronounced increase in the price index, which is when the expansion phase of the shock began, reaching its maximum in 2011 with a value of more than twice the index value in 2003. From 2011 onwards, it began the contraction phase or the end of the MMPSC.

The effects of the MMPSC on different variables has been broadly addressed. Pellandra (2015) examines the effects of the shock on local wages and employment between 2003 and 2011. Results show that municipalities exposed to the shock experienced an increase in average

[1] Details about the construction of this price index are addressed in Section 4 as well as in Appendix A.

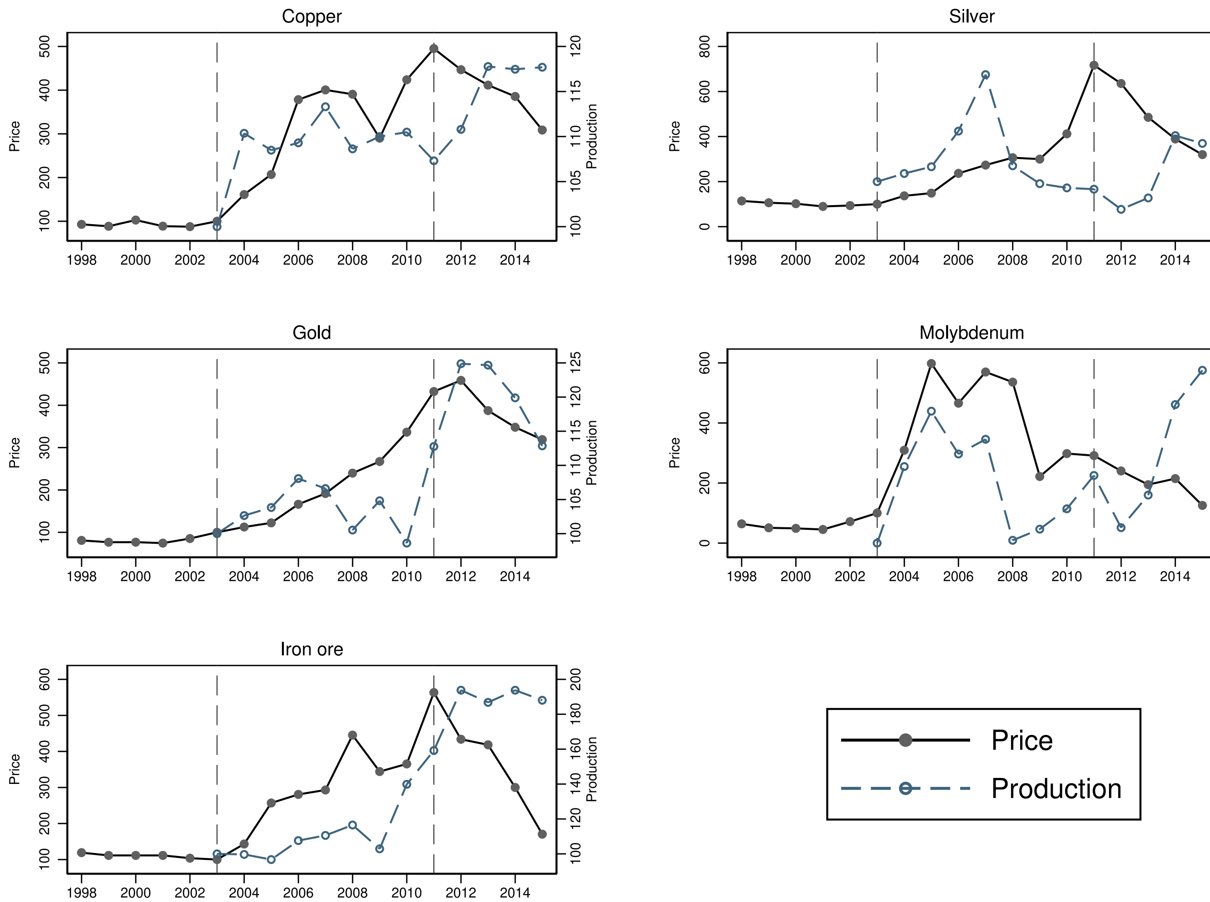

Fig. 1. Price and production values for the five principal metals in the overall Chilean production, 1998–2015.
Notes: Prices and production are normalized to 2003 values (2003=100). Data obtained from the Chilean copper commission (COCHILCO).

unskilled workers wages, compared to other municipalities that were not exposed. Álvarez et al. (2018) examine the impact that this shock had on poverty in Chile. Their findings suggest that there was at least a 2% reduction of poverty in municipalities exposed to the shock, in comparison to the ones not exposed. Atienza and Modrego (2019) analyze the effect of this shock on the performance of Chilean mining services suppliers. They find that the expansion phase benefited suppliers in mining municipalities, while the contraction phase affected negatively suppliers in both mining and non-mining municipalities. Pérez-Trujillo and Rodríguez-Puello (2021) analyze the effect of the shock on youth incentive to participate in the labor market rather than continuing their education in Chile. The authors find that the shock affected negatively the returns to schooling, which simultaneously reduced school enrollment rates and increased youth labor participation. However, as far as we know, the effect of the MMPSC on the GWG has not been addressed yet, and this paper attempts to close this gap.

3. Dutch disease and labor market segregation by gender

While research about the existence and causes of variation of the gender wage differential is important, an issue that has received less attention is how these wage gaps respond to exogenous shocks that change local labor market conditions. The few studies that exist use data from developed countries and have found mixed evidence (Aller and Arce, 2001; Marchand and Olfert, 2013; Mahajan, 2017). The existing literature does not offer a hypothesis about the effect of a resource-based shock on the GWG, but we can infer possible outcomes using standard theories of resource-based economies and labor economics.[2] Resource rich countries usually suffer a common economic condition called the Dutch Disease. Although the Dutch disease is generally analyzed at the country level, it can also be applied on a regional scale (Allcott and Keniston, 2018). This condition is characterized by a change of the economy away from the non-traded sector, and towards the export-oriented traded sector (Corden and Neary, 1982).[3] It argues that a boom in a resource sector (like mining) will increase the labor demand in that sector (traded sector) and reduce it in others (Corden and Neary, 1982). This high labor demand will encourage workers to join the resource sector, looking for higher wages.

However, classic models of the Dutch disease do not consider whether the effect of the shock will be differentiated for men and women (Frederiksen, 2007; Ross, 2008). They ignore that social structures could influence the way labor markets respond to natural resources shocks; specifically, they ignore that labor markets are segregated on the basis of gender, and spatially fragmented. Even when education and qualifications of men and women are similar, men often work in different sectors than women (Anker, 1997). To understand this gender differentiated effect, we follow Ross (2008) and extend the classic Dutch Disease model using the fact that resource-based sectors

[2] This theory is partially based on the more complete model on the Dutch disease with gender segregation developed by Frederiksen (2007), Ross (2008).

[3] It is important to note that which sectors produce traded or non-traded goods can vary across nations (Isham et al., 2005; Frederiksen, 2007). As is common in the Dutch Disease model, the *traded sectors* include agriculture and manufacturing, while the *non-traded sectors* include services like health, education, care, household chores and retail. For Chile, mining is included as a traded sector.

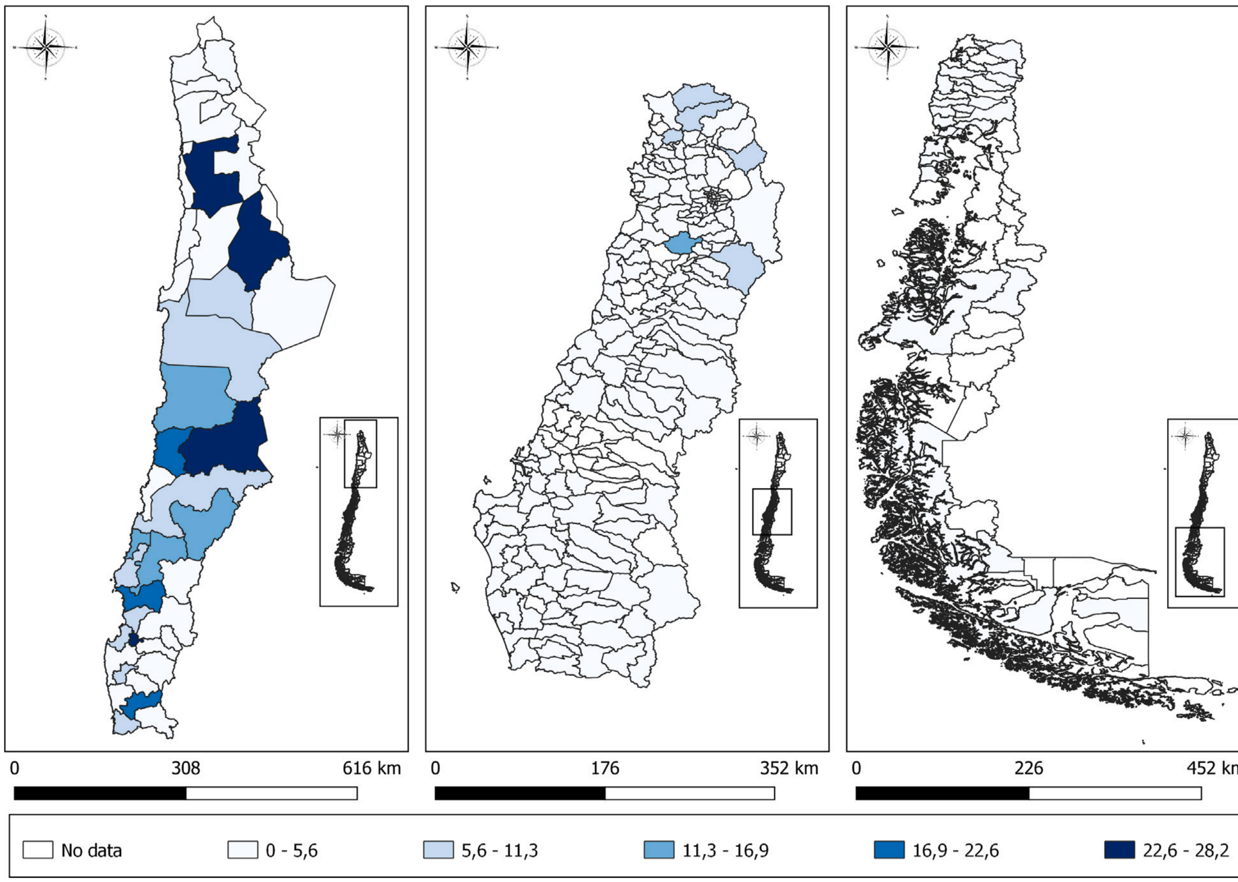

Fig. 2. Metal-Mining Employment Share, 2000.
Notes: The figure shows the average municipal employment share for the year 2000. Metal mining employment share is calculated as the relative weight of employment held in the metal mining sector with respect to total employment for each municipality in the year 2000. Employment information is from CASEN.

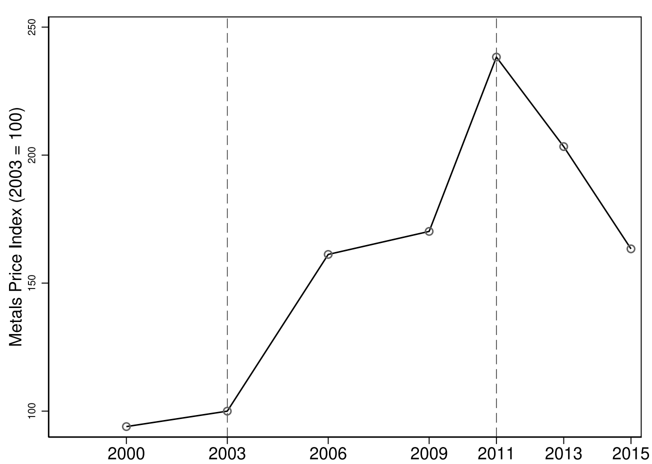

Fig. 3. Metal mining price index.
Notes: Metal mining price Index is normalized to 2003 values (2003=100). Data obtained from the Chilean Mining Yearbook or "Anuario" (AMC) provided by the National Geology and Mining Service.

in most developing countries are segregated by gender. This is the case of the mining sector in Chile, where less than 10% of workers in the sector are women, as can be seen in Fig. B.1.

Let us first address the gender-based segregation in the labor market. The argument is that socially assigned roles exclude women from participating in specific sectors, which become male-dominated, such as mining (Ross, 2008). This creates social and cultural barriers that lead to labor market immobility, and thus, to a reduction in its capacity to adjust to changes (Frederiksen, 2007). Since the ability to adjust to changes is what leads to the Dutch Disease (Frederiksen, 2007), we argue that gender-based segregation in the labor market is crucial to understand such economic condition. There are several explanations for gender-based segregation in a sector or specific occupations within a sector. For example, segregation based on segmentation, which argues that certain barriers prevent interaction between economic sectors. As a consequence, there will exist two types of sectors: one that has high wages and is male dominated, and another one that is less attractive and female dominated (Anker, 1998). Another explanation relates to the operation of households, which are mainly operated by females. This is particularly common in developing countries, where women use a large share of their labor endowment for household work or subsistence activities, causing low female participation on high-returns activities (Frederiksen, 2007).

The main consequence of this gender-based segregation is that it reduces both female wages and the number of jobs available for women, resulting in a wider gap between men's and women's wages (Horton, 1999; Ross, 2008). This is worrying given that the Chilean mining sector is characterized by higher average salaries and other labor benefits that make mining employment more favorable than the national average, however, women's scarce participation in this sector limits their access to all these benefits (CEPAL, 2016).

With respect to classic Dutch Disease model, one of its main results is that a boom in the resource sector (metal mining) will cause a decline in the non-traded goods sector and an expansion in the traded goods sector (including mining) (Allcott and Keniston, 2018). Nevertheless, the effect of a resource shock on women's labor participation and wages using this theory is ambiguous (Ross, 2008). On the one hand, the resource boom will increase the prevailing female wage, generating incentives for women to join the labor force.[4] On the other hand, the resource boom will generate higher wages, this in turn will increase the household income, causing a raise in women's reservation wage and a reduction in the incentives to join the labor force. This second part is explained by the female unearned income factor.[5] If female unearned income is high, women would not have an incentive to become part of the labor force even if wages for women were high. But if their unearned income decreases (for example if their spouse loses their job), then females would be more inclined to join the labor force, even in the face of lower wages (Ross, 2008).

This ambiguity in the effect of the shock for women can be solved by expanding the classic Dutch Disease model, including the gender-based segregation in the labor market. By using this fact, we are able to analyze the gender differentiated effect of the shock on wages and the gender wage gap. As Frederiksen (2007), Ross (2008), we assume that women can only work in the non-traded sector, and men in the traded sector. This is common in developing countries where women are largely employed in the services sectors such as health, education and sales facing low wages and being excluded from most of the traded sector (Anker, 1997). This is the case of Chile, where women's participation in the mining sector is scarce (CEPAL, 2016). In effect, in 2013, Chile had the second lowest female labor participation rate in the mining sector of all the Andean countries: Perú had a rate of 8.4%, Chile had a rate of 8.6% and they were followed by Bolivia (9.9%), Ecuador (11.3%), Colombia (14.9%) and Venezuela (19.5%) (CEPAL, 2016).

In this sense, the differentiated effect of the shock on wages for men and women can be analyzed in two stages: first, as explained by the Dutch Disease model, the boom in metal mining will cause a relative decline in the non-traded sector and an expansion in the traded sector, with higher wages for the traded sector. Second, according to the gender-based segregation in the labor market, this expansion in the traded sector will cause an increase in the demand for male labor and male wages; also, a decline in the non-traded sector will cause a reduction in the demand for female labor and their wages, since this sector is mainly composed by female workers. Also, it must be noted that municipalities whose main activity is mining are expected to be more exposed to these effects than others.

Nevertheless, to formulate hypotheses we still need to address both phases of the resource shock: the expansion phase, characterized by a rise in the real exchange rate of the metal mining; and the contraction phase, where the real exchange rate of the metal mining decreases. Jacobsen and Parker (2016) do this division in phases and provides a model focusing on local implications of resource extraction boom and bust. The authors describe that during the boom, employment and wages will increase in the extractive sector, but later during the bust, they would decline. Based on this discussion, we can argue that, according to the Dutch Disease condition, the expansion phase of the MMPSC in Chile generated an increase in the demand for labor in the traded sector, including mining. However, given that this sector is male-dominated because of gender-based segregation, the increase affected specifically the demand for male labor and their wages. For women, since they are segregated in the non-traded sector, the effect of the boom is the opposite and the decline of this sector reduces the demand for female labor and their wages. This generates our first hypothesis,

Hypothesis 1. During the expansion phase of the resource shock, male wages grew while female wages shrank, and as a consequence the GWG increased.

In the same sense, the contraction phase of the MMPSC in Chile generated a reduction in the demand for labor in the traded sector. Given that this sector is male-dominated because of gender-based segregation, the reduction affected specifically the demand for male labor and their wages. In fact, according to the International Labour Organization, mining labor decreased 13.5% for males and only 4.0% for females in 2016 (OIT, 2018). This generates our second hypothesis, in which men would receive most of the detriment of the contraction phase,

Hypothesis 2. During the contraction phase of the resource shock, male wages shrank while female wages grew, and as a consequence the GWG decreased.

Therefore, the expected effect of the resource shock on wages and the GWG will depend on the strength of each particular phase of the natural resources shock, and this is an empirical matter to address. However, we must recognize that both the expansion and the contraction phases are opposing forces, and therefore the impacts of both phases could counteract each other: the effects of the expansion phase could be counteracted by the effect of the contraction phase. This fact leads us to our third and last hypothesis:

Hypothesis 3. The impacts of both phases counteracted each other, having as a result a small or null overall change in the GWG (either positive or negative, depending on the strength of each phase).

4. Data and descriptive evidence

The primary dataset used in this paper is the Chilean National Socioeconomic Characterization Survey (CASEN), developed by the Ministry of Social Development. We analyze the period from 2000 to 2015 and use the 2000, 2003, 2006, 2009, 2011, 2013 and 2015 CASEN surveys. The surveys include repeated cross sections of households, which are representative of Chilean population at a regional and municipality level, and are the main source for Chile's socioeconomic statistics such as well-being, poverty rate, salary and educational level (Álvarez et al., 2018; Rodríguez-Puello et al., 2021; Pérez-Trujillo and Rodríguez-Puello, 2021). These seven waves of the CASEN survey include information for about 209,958 individuals, on average.[6] We use these years because the resource boom was in 2003, allowing us to control for pre-shock trends and medium-term effects. We aggregate the data at the municipal level, same as Álvarez et al. (2018), using the sampling weights defined by the municipal expansion factor provided in the survey. This allow us to account for changes that take place between periods when the economic shock occurs and those when it does not, for the different Chilean municipalities, allowing for the creation of an unbalanced panel data, with an average of 312 municipalities per year.[7]

Following Mahajan (2017), the main dependent variables of interest in this study are the male and female monthly labor wage stated in Chilean pesos, and the female/male monthly labor wage ratio. All wages in the analysis are in real terms, adjusted for changes in price levels over time by using the Chilean inflation as the deflator. Wages in this case can be understood as the monthly labor wage obtained by men and women in their main occupation either from self-employment,

[4] The prevailing female wage is a factor that influences the number of women in the labor market; as it increases, women are more inclined to join the labor force and substitute work for leisure.

[5] The female unearned income theory refers to the household income that is not directly earned by females (it could be earned by her couple).

[6] We drop individuals with zero wage in the sample.

[7] Our dataset is an unbalanced panel data because the number of municipalities included in the CASEN survey has varied over time. Year 2000 includes information about 281 municipalities, year 2003 about 297 municipalities, and from 2006 onward the surveys include 321 municipalities. The excluded municipalities are those defined as *Difficult Access Areas* in the sampling frame provided by the National Institute of Statistics. Several tests were performed to guarantee the reliability of our data. Also, we perform estimations using balanced panel data to provide evidence that the general results are not driven by sample selection issues.

formal or informal jobs. We define these variables as the average for each municipality and period.

Then, we define a measure of the intensity of the shock on the Chilean economy during its duration. We follow the procedure of Álvarez et al. (2018) and construct a price index, that considers the five principal metals in the overall Chilean production, which are copper, silver, gold, molybdenum, and iron ore. As explained in Section 2, the index considers the price effect of all relevant metals in the Chilean economy for the period analyzed and measures the intensity of the shock on the economy. Unlike Álvarez et al. (2018), we were able to construct the index by region, gaining variability. The detailed procedure for the construction of the price index is on Appendix A.

Additionally, given that the intensity of the shock was differentiated by municipalities, we expect those that are metal mining producers to be more affected than those that are not. To account for this difference, we compute a measure to identify the municipalities of interest (the most affected by the shock). Due to the inexistence of an official classification for mining and non-mining municipalities in Chile, we use the relative weight of employment held in the metal mining sector with respect to the total employment for each municipality in the year 2000, as a measure of exposure to changes in the price index, as Álvarez et al. (2018), Pérez-Trujillo and Rodríguez-Puello (2021).[8] This variable allows us to categorize municipalities as those more exposed to the shock (treated) and those less exposed. By using the interaction between these two variables (price index and metal mining employment share) we account for the overall effect of the metal mining shock on Chilean municipalities. Fig. 2 shows the average municipal employment share for the year 2000 in each municipality. As can be seen, metal mining municipalities tend to be located mostly in the North of Chile. But more importantly, the Figure highlights the heterogeneity in the exposure distribution. In addition to the main variables previously described, we use other control variables: (i) average years of schooling, and (ii) average household size (number of people living in the household). Table B.1 shows the descriptive statistics for all the variables used in the study.

The literature has largely addressed differences in labor conditions for men and women. Even though the study of gender wage differentials has become common for researchers, most research focuses on how it varies across countries and over time, and the causes of this variation (Weichselbaumer and Winter-Ebmer, 2005; Mandel et al., 2005; Blau and Kahn, 2017; Cha and Weeden, 2014). In Chile, results differ depending on the methodology used to compute the gap, as well as the focus and database used (Montenegro, 2001; Ñopo, 2006; Perticará and Bueno, 2009). It is interesting to analyze the Chilean gender wage gap because of its behavior compared to the rest of countries of the Latin American region. Fig. 4 shows the Economic Commission for Latin America and the Caribbean (ECLAC) gender wage ratio indicator for Chile and for the Latin America region from 2000 to 2017. We can observe at least two interesting facts regarding the dynamic of the Chilean gender wage ratio. First, the Chilean gender wage gap is higher than the Latin American average for every year. This is interesting considering that Chile is one of the most developed countries of the region, yet, inequality in different contexts persists. Second, the gender wage ratio decreased around 16% from 2000 to 2017. Women went from earning around 75% in 2000 to around 87% of men's wages in 2017, meaning that the gender wage gap decreased between these years.

Additionally, before performing any empirical exercise, it is important to make a descriptive analysis of the Chilean mining labor market behavior. For this purpose, we have classified as metal mining municipalities those with a metal mining employment share above the upper quartile of the distribution in year 2000 (70 municipalities). Fig. 5

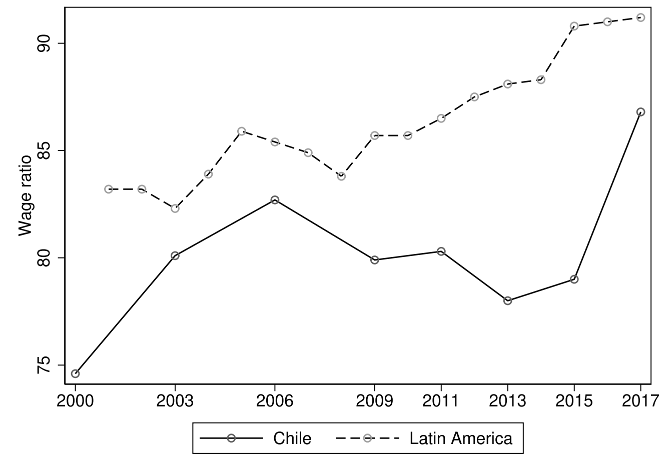

Fig. 4. Gender wage ratio, 2000–2017.
Notes: Data according to ECLAC. The wage ratio measure refers to the proportion of the average salary of women between 20 and 49 years of age, who work 35 h and more per week, with respect to the salary of men with the same characteristics. The indicator is obtained by ECLAC by dividing the average salary of salaried women and the average salary of salaried men, multiplied by 100.

shows the average municipal real labor wage for females and males expressed in thousands Chilean pesos by metal and non-metal mining municipalities. It also shows the female/male wage ratio by metal and non-metal mining municipalities. The figure reveals a positive trend for both female and male labor wages from 2000 to 2015. Also, the average wages for both males and females are higher in mining than in non-mining municipalities. For the case of the female/male wage ratio, Fig. 5 presents the trajectory of the gender wage gap for mining and non-mining municipalities, showing a negative trend for both of them during the period analyzed. Note that the decline in the wage gap was more pronounced for mining municipalities from 2006 to 2011, while for non-mining municipalities the decline was smoother. Finally, Fig. B.1 in the appendix shows the dynamic of the Chilean female labor participation rate in mining, it is important to highlight the positive trend during the period analyzed. Nevertheless, the female labor participation rate in mining is still very low (under 10%).

5. Empirical strategy

We now empirically evaluate the effects of the events that occurred in the Chilean municipalities during the metal mining price shock on the GWG, and we test the three hypotheses presented in Section 3. We expect the MMPSC to modify the wages and the GWG for higher metal mining producer municipalities. The heterogeneity in the exposure to the shock and the fact that it was externally originated, allows us to use it as a quasi-experiment to estimate the impact of metal mining price changes on the gender wage gap. We use a *difference-in-differences* (DID) approach (Heckman et al., 1999; Bertrand et al., 2004), which allows us to estimate the overall effect of the shock by using a treatment group (municipalities that are more dependent on the metal mining production and were more exposed to the shock) and a control group (municipalities that are less dependent on the metal mining production and were less exposed to the shock), both before and after the shock. The following equations estimate the effect of the metal mining shock on wages and the GWG:

$$W^i_{mjt} = \alpha_m + \alpha_t + \delta X_{mt} + \lambda_1 (ln[P_{jt}] \times z_{mt}) + \epsilon_{mt} \quad (1)$$

$$W^F_{mjt}/W^M_{mjt} = \alpha_m + \alpha_t + \delta X_{mt} + \lambda_2 (ln[P_{jt}] \times z_{mt}) + \epsilon_{mt} \quad (2)$$

Eq. (1) estimates the effect of the metal mining shock on wages differentiating by gender. The dependent variable W^i_{mjt} corresponds to

[8] The first year of the sample is taken to avoid subsequent simultaneous causality problems in the estimates.

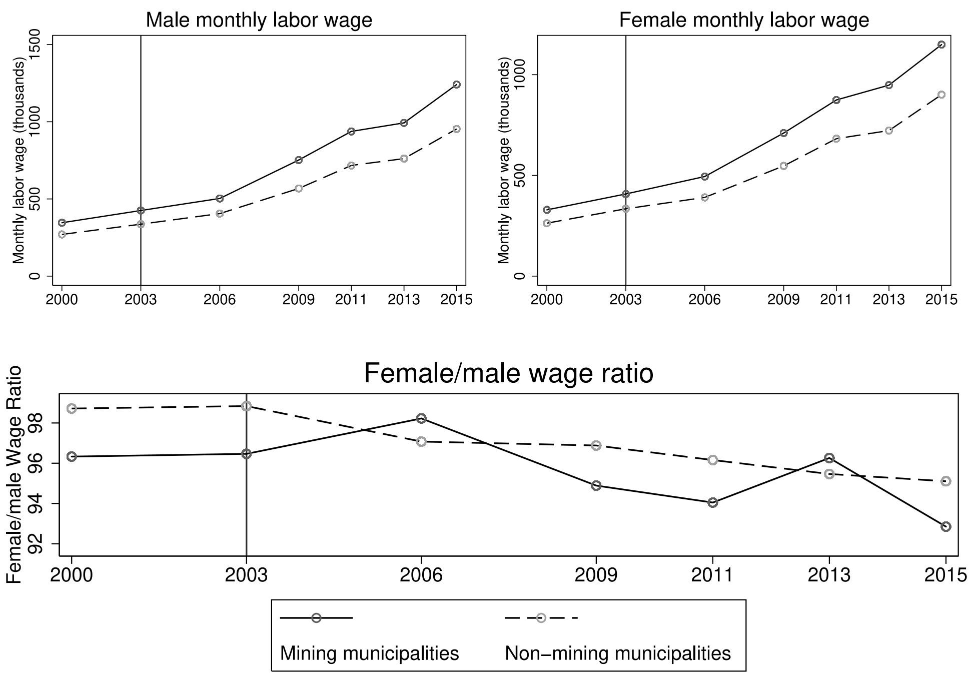

Fig. 5. Dynamic of wages and female/male wage ratio in Chile.
Notes: The figure shows the average municipal real labor wage for females and males expressed in Chilean pesos by metal and non-metal mining municipalities. It also shows the female/male wage ratio by metal and non-metal mining municipalities. Municipal expansion factors provided in CASEN were used. Wages in real terms, adjusted for inflation.

the log of female and male monthly labor wage for each municipality m in region j and the period t, where $i = F, M$. F and M serve as indexes for females and males respectively. In Eq. (2) the dependent variable is the log of female/male wage ratio for each municipality m in region j and the period t. α_m and α_t are municipality and time fixed effects to control for all the time-invariant municipal-specific heterogeneity correlated with changes in the wage ratio, X_{mt} is a vector of other control variables that are important in explaining the changes in the wage ratio across municipalities. The three main variables of interest for the DID approach are $ln[P_{jt}]$, z_{mt}, and the interaction between them.

The $ln[P_{jt}]$ represents the metal mining price index at the regional level that varies over time, this variable controls for the conditions that change over time for all the municipalities. z_{mt} identifies the exposure of municipalities to the shock, specifically, the metal mining employment share described in Section 4. This variable controls for fixed differences between treated (more exposed) and non-treated (less exposed) municipalities. Finally, the interaction between the intensity of the shock $ln[P_{jt}]$ and the exposition z_{mt} gives us the parameters of interest (λ_1, λ_2). These coefficients identify the differential local impact of the resource shock on the municipality's female/male wage ratio and other dependent variables of interest.

According to Bertrand et al. (2004) the causal inference in DID models need to correct the serial correlation in the error term. To deal with this concern, we allow for clustering of standard errors at the municipal level.[9] The identification of the parameters of interest is based on the variation on wages and the heterogeneous distribution of the shock exposure in municipalities over time; under the identifying assumption that, in absence of the shock, the wage gap would have followed a similar trend in mining and non-mining municipalities. This assumption of parallel trends is important in identifying causal effects with the DID approach, therefore, it is necessary to present preliminary (and unconditional) results from our design and data.

As a first approximation we can observe the temporal dynamic of the main variables of interest (Fig. 5). We compare the trajectory of the wage gap (female/male wage ratio) in mining and non-mining municipalities before and after the resources shock that started in 2003. In this preliminary analysis we would expect that, if the resource shock affected the wage gap, these trajectories would diverge after the beginning of the shock in 2003, with a more pronounced reduction or increase in the wage gap in mining relative to non-mining municipalities. Note that the increase in the wage gap was more pronounced for mining municipalities from 2006 to 2011, while for non-mining municipalities the decline was smoother.

Nevertheless, we need to further test and explore the parallel trends assumption. As is common in the literature, we estimate a regression model that includes treatment leads and lags (Miller et al., 2019; Cunningham, 2020). To do this, we follow Cerulli and Ventura (2019) and use a binary time-varying treatment to classify municipalities as metal and non-metal mining (same as Fig. 5). We perform two tests. The first one, using time leads, indirectly tests whether the assumption holds or not, while the second one uses an additional time trend variable. Rejecting the null hypothesis for these tests only imply a necessary condition for the parallel trends assumption to hold.[10] Our results for both tests (available upon request from the authors) confirm that the parallel trends assumption holds. Therefore, we continue our empirical analysis using the DID approach to identify the causal effects of the resource shock on the GWG.

6. Results

6.1. Effect of the commodity price boom: baseline specifications

Table 1 presents results for specifications (1) and (2) using the relative weight of the employment held in the metal-mining sector with respect to the total for each municipality in 2000, as a measure of

[9] There is also the alternative of using the wild bootstrap technique to correct the standard errors, suggested mainly for small number of clusters (Cameron et al., 2008). However, our estimations have a reasonable large number of clusters (MacKinnon and Webb, 2017).

[10] For more technical information on these tests check Cerulli and Ventura (2019).

municipality exposure to the natural resource shock; and the metal's price index as a measure of intensity of the shock (similar to Álvarez et al. (2018)). Column 1 shows results for the MMPSC impact on wages in general, column 2 does it for female wages, column 3 for male wages, column 4 does the same for the female/male wage ratio, and column 5 shows results for the female/male wage ratio using balanced panel data. We have included year and municipality fixed effects in all models, as well as household-based variables to control for differences in the composition of the average household across municipalities, such as average years of schooling and household size.[11]

According to our theoretical review, the metal-mining expansion phase would cause male wages to increase, widening the gender wage gap; while the contraction phase, due to gender-based segregation in the labor market in the mining sector, would generate the opposite effect. Therefore, the effect of the resource shock on wages and the GWG depends on the strength of each particular phase of the MMPSC. The main variable of analysis is represented by the interaction $ln[P_{jt}]$ x z_{mt}. A positive sign on this coefficient for wages, would mean that wages increased, while a positive sign for the ratio would mean that the GWG decreased (that is, the difference between female and male wages shrank).

We observe in the three first columns that the sign of the interaction $ln[P_{jt}]$ x z_{mt} is positive and statistically significant at the 95% confidence level. Thus, we find consistent and robust evidence that the MMPSC is associated with an increase in wages in highly exposed municipalities.[12] Also, we can observe in column 2 and 3 that the coefficient for female is greater than male wages (0.005 versus 0.003). However, the effect of the shock on female wages differs in significance with a 99% confidence level for female wages and a 90% confidence level for male wages. We run a test on these to compare whether the effect of the shock is significantly different for each coefficient or not, we obtained that it is indeed different and significant at the 5% level.

When analyzing the female/male wage ratio in columns 4 and 5, we can observe that the sign of the interaction between the log of the metals' price index and the index of municipal exposure is positive and significant at the 95% confidence level, meaning that the shock is associated with a decrease of the GWG in municipalities more exposed to the shock. In this sense, we could infer that the effects of the contraction phase were stronger than the effects of the expansion phase; and, as discussed in the theoretical review, in absolute values, male wages grew less than female wages and therefore the GWG decreased as a consequence of the MMPSC in more exposed municipalities. Nevertheless, according to our third hypothesis, the overall change in the GWG was relatively small, with a coefficient of only 0.002.

It is important to note that because our coefficient of interest is an interaction between the municipal exposure and the temporal intensity of the price index, we need to evaluate this coefficient for municipalities with different levels of exposure to the shock. We evaluate the effect of the shock on the GWG for municipalities in four levels of exposure: none exposure (a value of 0 on the metal mining employment share), low exposure (a value of 0.14, which is the lowest non-zero value of the share), median exposure (a value of 1.59) and the highest exposure (a value of 29.27). We find that a 100% increase in the metal mining price index increases the GWG by about 0.025%, 0.024% and 0.022% points in municipalities with none, low and median exposure, respectively. However, as we move towards the upper tail of the distribution to the higher exposure, we find the opposite effect: for municipalities with very high exposure, the impact of the shock decreases the GWG by about 0.121% points. Thus, we confirm our finding that municipalities that were highly exposed to the shock experienced a decline in the GWG, in comparison to those that were not or were very weakly exposed to the shock.

These results do not necessarily mean that women are earning much more than men; it only shows that, given the opposing forces that counteract each other, male wages were more negatively affected by the MMPSC and therefore grew less than female wages. Therefore, even though we can conclude that the shock generated a decrease in the GWG in more exposed municipalities, there is still an unresolved and urgent task regarding the attraction and retention of female workers in the mining sector, so that women can also enjoy the benefits of expansion phases; at the same time that market labor conditions for both male and female are protected during contraction phases of the business cycle.

It must be noted that the effect of the shock in our results is small compared to others in the literature; however, we expected a small effect given the already mentioned counteracting effect between the expansion and contraction phases. Mahajan (2017) is the only study we know of that has addressed the impact of a shock in wages and gender wage gap in a developing country. The author uses data from 1993 to 2007 to study how rainfall shocks affect the gender wage gap in India. The article finds that both female and male wages were positively affected (3.6% and 2.4% respectively), and that the female to male wage ratio increases by 5% with an increase in a rainfall shock by one unit, although this last result is not statistically significant.

Finally, a main concern in our analysis in the potential measurement error bias, as Pérez-Trujillo and Rodríguez-Puello (2021). According to Modrego and Berdegué (2015) the sampling carried out by the CASEN for municipalities with small population might not be representative of the variables in the estimations, this can introduce bias into the parameters. In our case, the lower the population size of the municipalities, the greater the measurement error bias, and the estimates will converge in probability to a value close to 0 (Greene, 2012). A common correction is the use of instrumental variables; however, this is not possible for us because the source of measurement error is in the sample itself and any variable used as instrument would also have this error (Angrist and Krueger, 2001). In order to address this, we estimate three different versions of Eq. (2): (i) using the complete sample, (ii) using only the municipalities with at least 25,000 inhabitants, and (iii) using only the municipalities with at least 50,000 inhabitants. As can be seen in Table 2 the main result of the impact of the shock on the wage gap holds unchanged.

6.2. Dealing with spatial spillovers

An important concern in the Chilean context is the long-distance commuting, that happens because of the nature and spatial distribution of mining and construction activities in the country (Rowe, 2014). Considering that mineral deposits are spatially concentrated, mining workers usually work in municipalities that own the deposits, but live in municipalities far from the mineral deposits (Aroca and Atienza, 2011). This phenomenon could be affecting our results given that most of commuters spent their wage where they and their families live and not where they work. This is especially important for the Chilean context, where a significant percentage of workers, especially in the mining sector, do not reside in the place of work (Storey, 2001; Aroca and Atienza, 2008; Atienza et al., 2021).

To address this issue, we change the level of aggregation of the data using functional territories instead of municipalities. These functional territories correspond to a socially-constructed economic space, bounded by regular flows of resources, such as labor (Karlsson et al., 2010). Therefore, we consider that they could be a good level of aggregation to evaluate conditions of labor market, as it considers the

[11] As we claim the exogeneity of the commodity shock and use the DID approach for the estimations, it is not necessary to include additional controls. Table B.2 presents results for the impact of the shock on female–male wage ratio without and with additional controls. The main coefficient of interest, $ln[P_{jt}]$ x z_{mt}, remains unchanged.

[12] An important concern is the possible existence of a national link between metal mining prices and wages. However, note that the coefficient for the metal's price index, $ln[P_{tj}]$, is not statistically significant, confirming the existence of a differentiated effect by municipalities.

Table 1
Impact on wages.

	(1) Wages β/SE	(2) Female wage β/SE	(3) Male wage β/SE	(4) Wage ratio β/SE	(5) Wage ratio β/SE
z_{mt}	0.075***	0.063**	0.096***	−0.033**	−0.041***
	(0.029)	(0.029)	(0.029)	(0.017)	(0.015)
$\text{Ln}(P_{jt})$	0.011	−0.003	0.024	−0.027*	−0.025*
	(0.024)	(0.025)	(0.025)	(0.014)	(0.014)
$\text{Ln}(P_{jt}) \times z_{mt}$	0.004**	0.005***	0.003*	0.002**	0.002*
	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)
Average years of schooling	0.186***	0.192***	0.179***	0.014*	0.017***
	(0.012)	(0.012)	(0.013)	(0.007)	(0.007)
Household size	0.084***	0.085***	0.082***	0.003	0.004
	(0.016)	(0.017)	(0.016)	(0.010)	(0.009)
Constant	10.206***	10.202***	10.206***	4.601***	4.578***
	(0.140)	(0.144)	(0.144)	(0.079)	(0.075)
Year Fixed-Effects	Yes	Yes	Yes	Yes	Yes
Municipality Fixed-Effects	Yes	Yes	Yes	Yes	Yes
Sample	Unbalanced	Unbalanced	Unbalanced	Unbalanced	Balanced
Observations	1959	1959	1959	1959	1911
R-squared	0.935	0.930	0.933	0.172	0.171

Notes: Ordinary Least Squares regression. This table shows the effect of metal prices changes on wages in a panel of municipalities over the period 2000–2015. All dependent variables are in logarithm. All regressions controls for municipality and year fixed effects. Standard errors (in parenthesis) are clustered at the municipal level. Wages are expressed in Chilean pesos and in real terms, adjusted for inflation. The general effect on the wage ratio using the balanced panel can be observed in column 5. As it can be seen, the result is also positive and significant.

*$p < 0.1$.

**$p < 0.05$.

***$p < 0.01$.

Table 2
Impact on wage ratio by population size.

	(1) Wage Ratio (Full sample) β/SE	(2) Wage Ratio (> 25000) β/SE	(3) Wage Ratio (> 50000) β/SE
z_{mt}	−0.033**	−0.006	−0.003
	(0.017)	(0.006)	(0.008)
$\text{Ln}(P_{jt})$	−0.027*	−0.034*	−0.061**
	(0.014)	(0.019)	(0.029)
$\text{Ln}(P_{jt}) \times z_{mt}$	0.002**	0.002***	0.003***
	(0.001)	(0.001)	(0.001)
Average years of schooling	0.014*	0.002	−0.003
	(0.007)	(0.010)	(0.014)
Household size	0.003	−0.015	−0.019
	(0.010)	(0.013)	(0.015)
Constant	4.601***	4.765***	4.938***
	(0.079)	(0.167)	(0.260)
Year Fixed-Effects	Yes	Yes	Yes
Municipality Fixed-Effects	Yes	Yes	Yes
Observations	1959	818	511
R-squared	0.172	0.253	0.237

Notes: Ordinary Least Squares regression. This table shows the effect of the shock on the wage ratio depending on the municipality size in a panel of municipalities over the period 2000 2015. All dependent variables are in logarithm. All regressions controls for municipality and year fixed effects. Standard errors (in parenthesis) are clustered at the municipal level. Wages are expressed in Chilean pesos and in real terms, adjusted for inflation.

*$p < 0.1$.

**$p < 0.05$.

***$p < 0.01$.

Table 3
Impact on wages at a functional territories level.

	(1) Wages β/SE	(2) Female wage β/SE	(3) Male wage β/SE	(4) Wage ratio β/SE
z_{mt}	−0.011	−0.016*	−0.007	−0.009**
	(0.009)	(0.009)	(0.010)	(0.004)
$\text{Ln}(P_{jt})$	0.017	0.005	0.028	−0.022
	(0.032)	(0.034)	(0.031)	(0.019)
$\text{Ln}(P_{jt}) \times z_{mt}$	0.003*	0.004**	0.002	0.002***
	(0.002)	(0.002)	(0.002)	(0.001)
Average years of schooling	0.179***	0.192***	0.162***	0.030**
	(0.022)	(0.021)	(0.023)	(0.014)
Household size	0.087***	0.093***	0.081***	0.011
	(0.024)	(0.026)	(0.025)	(0.018)
Constant	10.425***	10.314***	10.570***	4.349***
	(0.300)	(0.290)	(0.325)	(0.195)
Year Fixed-Effects	Yes	Yes	Yes	Yes
Funct. territories Fixed-Effects	Yes	Yes	Yes	Yes
Observations	795	795	795	795
R-squared	0.939	0.939	0.932	0.189

Notes: Ordinary Least Squares regression. This table shows the effect of metal prices changes on wages in a panel of 114 functional territories over the period 2000 2015. All dependent variables are in logarithm. All regressions controls for functional territories and year fixed effects. Standard errors (in parenthesis) are clustered at the functional territories level. Wages are expressed in Chilean pesos and in real terms, adjusted for inflation.
*$p < 0.1$.
**$p < 0.05$.
***$p < 0.01$.

flows of people caused by the commuting phenomenon. As can be seen in Table 3, we estimate the model using functional territories level data. This allows us also to use a wider definition of local labor market, removing the potential concerns related to the fact that people may live in one municipality, but work in another municipality within the same functional territory. These functional territories were constructed by Berdegué et al. (2019) combining stable satellite night lights and commuting flows.

Results in Table 3 are in line with those using municipality level data. The shock is associated with an increase in wages in general, a result that is statically significant at the 90% confidence level. Also, same as at the municipal level, female wages present an increment greater than male wages; although the effect on male wages is not statistically significant. Regarding the female/male wage ratio, is positive and significant at the 99% confidence level, which is interpreted as a decrease in the GWG in more exposed municipalities, same results than at the municipal level.

A second concern are the spatial spillovers and heterogeneity. Given that mineral deposits are not uniformly distributed around space, mining is highly concentrated in some municipalities (Aroca and Atienza, 2011). This fact can be evidenced in Fig. 2, where mining municipalities (relatively exposed) tend to be located close to mining deposits, which are concentrated in the North of Chile. To further explore this spatial aspect, we use exploratory spatial data analysis (ESDA) techniques to analyze the distribution of mining employment at both global and local contexts. According to Anselin et al. (2007), ESDA is a collection of techniques that focus mainly on spatial autocorrelation and heterogeneity, and are used to study the spatially varying patterns of variables of interest. The first step is to define a spatial weight matrix that describes the neighborhood structure, after experimenting with various spatial weights, the normalized inverse distance weight matrix was selected, see for example Getis and Aldstadt (2004).

An important advantage of the inverse distance matrix is that reflects proximity in the distance sense, as it is not represented in a contiguity matrix (Crociata et al., 2020). The inverse distance matrix uses latitudes and longitudes and is based on Haversine's formula for computing distances.[13] In our case we use the geographic coordinates of the municipalities m and j to compute the distance d_{mj}. This matrix has zeros on the main diagonal and the corresponding elements in the rest of entries, and is row-standardized and normalized to be used.

Then, Global spatial autocorrelation is determined by the Moran's I statistic (Anselin, 1995), which null hypothesis is that there exists spatial randomness. Rejecting this null hypothesis indicates the existence of spatial association in mining employment. The Moran's I value varies between −1 and +1, the closer it is to −1, the greater the spatial dissimilarity, indicating the presence of potential outliers. In contrast, if it is close to +1, the greater the spatial similarity, indicating clustering (Manesh et al., 2020). Table 4 presents the results of the estimated Moran's I with its respective pseudo p-values for each year of our sample. The results suggest that there is enough evidence to reject the null hypothesis at a 1% significance level.[14] Therefore, we can conclude that there exists global spatial autocorrelation in mining employment in the Chilean municipalities; that is, the spatial distribution of the mining sector is not random (there are clusters or hotspots).

Furthermore, to provide information about the geographic location of these clusters, we perform a local-level analysis to detect local spatial distribution patterns. We use the Local indicators of spatial association (LISA) to determine the locations and significance level of clusters, which cannot be found through a global spatial autocorrelation test (Anselin, 1995). The maps generated by LISA show the locations with significant local Moran statistics and their types, where the outliers are classified as low–high and high–low; and clusters are classified as low–low and high–high. LISA maps for the local clusters

[13] See Aldieri and Cincera (2009) for more information.
[14] The number of permutations is set at 999, indicating precision of 0.001.

Table 4
Moran's I statistic for global spatial autocorrelation in mining employment.

Year	Moran's I statistic	Pseudo p-value
2000	0.304	0.001
2003	0.390	0.001
2006	0.394	0.001
2009	0.189	0.001
2011	0.390	0.001
2013	0.400	0.001
2015	0.359	0.001

among municipal level neighbors at a 5% significance level for mining employment for 2000 can be found in Fig. B.2. We can observe the distribution and specific location of the clusters. As expected, the high-high cluster is located in the northern part of Chile. This cluster is composed by municipalities with high rates of mining employment (higher than the average of all municipalities), surrounded by municipalities with high rates of mining employment. These results confirm that mineral deposits are not uniformly distributed around space and that mining is highly concentrated in some municipalities.

To a further understanding of the spatial spillover effects, we use spatial econometric techniques allowing for spatial interdependence between neighboring municipalities. Therefore, we estimate Eq. (2) using spatial models. There are some previous literature that add spatial effects on DID methods (Heckert and Mennis, 2012; Dubé et al., 2014). We specify Spatial Autoregressive (SAR) and Spatial Durbin (SDM) models, using normalized inverse distance weight matrices at the municipal level. The municipality panel data has been strongly balanced for the purpose of spatial estimations. Table 5 show results for both spatial models using the log of the female/male wage ratio for each municipality as our dependent variable. The spatial lagged dependent variables are not statistically significant for both SAR and SDM, however, the spatial lagged independent variable of interest (the interaction that reflects the shock effect) is positive and significant in the SDM. This suggests that the commodity shock impacts indirectly to neighboring municipalities, confirming the existence of spatial interdependence between municipalities.

Table 5
Spatial Autoregressive Model (SAR) and Spatial Durbin Model (SDM).

	(1) SAR β/SE	(2) SDM β/SE
z_{mt}	−0.035***	−0.110***
	(0.008)	(0.027)
$\text{Ln}(P_{jt})$	−0.026**	−0.055***
	(0.013)	(0.016)
$\text{Ln}(P_{jt}) \times z_{mt}$	0.002**	0.001*
	(0.001)	(0.001)
Average years of schooling	0.017***	0.017***
	(0.006)	(0.006)
Household size	0.004	0.005
	(0.009)	(0.009)
Constant	4.652***	5.046***
	(0.600)	(0.623)
Spatially lagged dep. variable	−0.020	−0.082
	(0.129)	(0.133)
Spatially lagged $\text{Ln}(P\_tj) \times z\_ct$		0.012***
		(0.004)
Year Fixed-Effects	Yes	Yes
Municipality Fixed-Effects	Yes	Yes
Sample	Balanced	Balanced
Observations	1911	1911
R-squared	0.181	0.183

Notes: This table estimates spatial autoregressive (SAR) and Spatial Durbin models (SDM), using normalized inverse distance weighting matrices at the municipal level for the 2000 2015 period. All dependent variables are in logarithm. Sample has been balanced and all regressions control for the same set of variables considered before. Standard errors (in parenthesis) are clustered at the municipal level. Wages are expressed in Chilean pesos and in real terms.
$^{*}p < 0.1$.
$^{**}p < 0.05$.
$^{***}p < 0.01$.

7. Conclusions and discussion

It is not until recently that some studies have started to analyze the economic effects of natural resources shocks within the same country to understand the potential curses or blessings related to natural resource endowments (Atienza and Modrego, 2019). In this paper, we use disaggregated Chilean municipality-level information to analyze the impact that natural resources shocks have on the gender wage gap. Understanding the effect of such a shock can provide insights for policymakers who are deciding to implement policies that either attenuate or intensify resource shocks. We have analyzed Chile's case, a country whose economy was affected by the Metal Mining Prices Super-Cycle (MMPSC), which comprises the expansion phase (increase in the mineral price since 2003 to 2011) and the contraction phase (progressive drop in the mineral price since 2012). This shock allowed us to address the performance of the Chilean labor market, in terms of wages for both men and women; as well as to address the effect on the gender wage gap. With this in mind, we have developed a theoretical review expanding the classic Dutch Disease model with the theory of gender-based segregation in the labor market, in which the effect of the shock on wages is differentiated for men and women.

The results show a positive and significant impact of the MMPSC on wages in general, as well as on female and male wages. It also reflects a small but positive and significant positive effect on the female/male wage ratio, which translates in a decrease of the gender wage gap. This reduction, does not necessarily means that females are closer to equality regarding labor conditions, in fact, it only reflects what the theory tells us: men were more affected than females by the MMPSC due to existent gender-based segregation in the labor market in the mining sector. Given that the wage gap was reduced, and in line with the discussion presented in our theoretical framework, we can infer that the effects of the contraction phase were stronger than the effects of the expansion phase, and therefore male wages were more affected and increased less. Also, given that the reduction was small, we can also infer that the benefits of the expansion phase were dampened by the damages of the contraction phase, having as a result a relatively small overall reduction in the GWG. These results hold robust through a variety of robustness checks, as well as specifications allowing for spatial interdependence between neighboring municipalities. Results using different level of aggregation of data and spatial econometric techniques are in line with the general findings just discussed.

Implications and insights deriving from this study are manifold. From the policy perspective, these results provide insights for the implementation of specific policies that attempt to protect labor conditions for women, as well as to create more gender sensitive mining policies. Due to gender-based segregation in the mining sector, the relationship between the gender wage gap and resources shocks will depend on whether the expansion or contraction phase dominates, then policy efforts should have two purposes: First, to attract and retain female workers to the mining sector, so that during the expansion phase women can also enjoy its benefits. Second, to protect labor conditions for both male and female during the contraction phase, to mitigate its negative effect and as a result have an overall improvement in the labor market conditions for both males and females. From the empirical perspective, we have provided evidence about the positive effect that natural resources shocks may have on different economic welfare dimensions, in this case the gender wage gap. Furthermore, based on our results, we argue that studies about gender wage gaps in resources-based countries must take into account the variation of resource's prices, otherwise results could be biased. With the adequate

Table B.1
Summary statistics.

	2000		2003		2011		2015	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Male wage	288820.4	204960.1	380067.9	320783.3	795767.0	491458.3	1059446.0	606081.0
Female wage	279205.5	174478.5	371948.6	315697.1	751526.6	432058.6	994535.1	559393.8
Female/Male wage ratio	98.1	11.1	98.1	9.0	95.7	10.4	94.6	7.4
Metal mining emp. share	1.6	4.4	1.6	4.4	2.9	6.3	2.7	6.1
Price index	94.0	8.1	100.0	0.0	238.3	236.9	163.4	74.0
Av. years of schooling	8.8	1.4	9.1	1.5	9.7	1.2	10.1	1.3
Household size	4.9	0.3	4.8	0.3	4.3	0.4	4.1	0.4
N	281		297		321		321	

Notes: municipal expansion factors provided in CASEN were used. Wages are expressed in Chilean pesos and in real terms, adjusted for inflation. Metal mining employment share is calculated as the relative weight of employment held in the metal mining sector with respect to total employment for each municipality.

data at hand, further research could develop more specific analyses and look at the specific impact of each phase, in different economic sectors, as well as in different population sectors (by age, skills, etc.).

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Metal mining price index

As a measure of the intensity of the shock on the economy we follow the procedure of Álvarez et al. (2018). The authors define a price index that considers the five principal metals in the overall Chilean production, which are copper, silver, gold, molybdenum, and iron ore. The first step in the construction of the price index is to calculate the average percentage change in metal's price for each period t, as:

$$\tilde{P}_{jt} = \sum_{l=1}^{5} \theta_{l,j}^{2000} \times \frac{\Delta p_t}{p_t} \tag{A.1}$$

Where l represents each of the five metals, $\theta_{l,j}^{2000}$ is the production value share of each metal l for the year 2000 in every j Chilean region. We use regions, since there is no disaggregated data at the municipality level (this parameter is scaled by the production value of the five metals, so $\sum_{l=1}^{5} \theta_{l,j}^{2000} = 1$), and p_t is the nominal price of each one of the five metals in the period t. Price and production data for the primary metals produced in Chile were taken from the Chilean Mining Yearbook or "Anuario" (AMC) provided by the National Geology and Mining Service, allowing us to have production values that are disaggregated at a regional level.

The final step is to compute the metal's price index as:

$$P_{jt} = (1 + \tilde{P}_{jt}) \times P_{j,t-1}; \text{ with } P_{j,2003} = 100 \tag{A.2}$$

Thus, we obtain a metal mining price index, normalized to 2003 values (2003=200). This index has a minimum value of 93.969, a maximum of 238.297 and a mean of 161.489. Fig. 3 in Section 2 depicts the dynamic of the index throughout the years under analysis.

Appendix B. Additional tables and figures

See Tables B.1 and B.2.

Table B.2
Impact on female–male wage ratio without and with controls.

	(1) Wage ratio β/SE	(2) Wage ratio β/SE
z_{mt}	−0.003	−0.033**
	(0.003)	(0.017)
$\text{Ln}(P_{jt})$	−0.027*	−0.027*
	(0.014)	(0.014)
$\text{Ln}(P_{jt}) \times z_{mt}$	0.002**	0.002**
	(0.001)	(0.001)
Average years of schooling		0.014*
		(0.007)
Household size		0.003
		(0.010)
Constant	4.670***	4.601***
	(0.060)	(0.079)
Year Fixed-Effects	Yes	Yes
Municipality Fixed-Effects	Yes	Yes
Observations	1959	1959
R-squared	0.169	0.172

Notes: Ordinary Least Squares regression. This table shows the effect of metal prices changes on the female–male wage ratio without and with control variables. All dependent variables are in logarithm. All regressions controls for municipality and year fixed effects. Standard errors (in parenthesis) are clustered at the municipal level. Wages are expressed in Chilean pesos and in real terms, adjusted for inflation.
*$p < 0.1$.
**$p < 0.05$.
***$p < 0.01$.

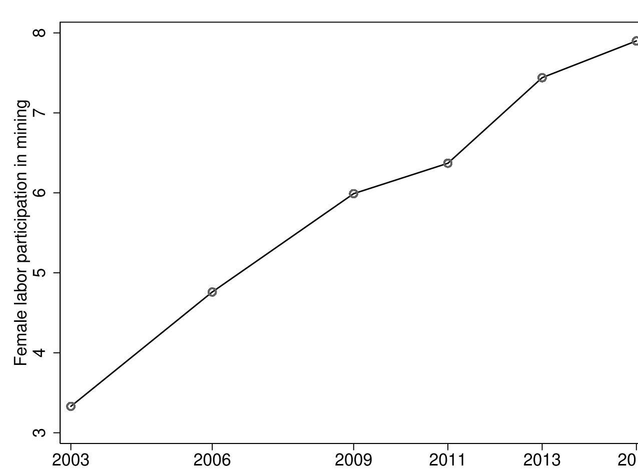

Fig. B.1. Dynamic of female labor participation rate in mining in Chile.
Notes: The figure shows the female labor participation share in mining. Women represent between 3,3% and 7,6% of the total employment in mining. Information from the Chilean copper commission (COCHILCO).

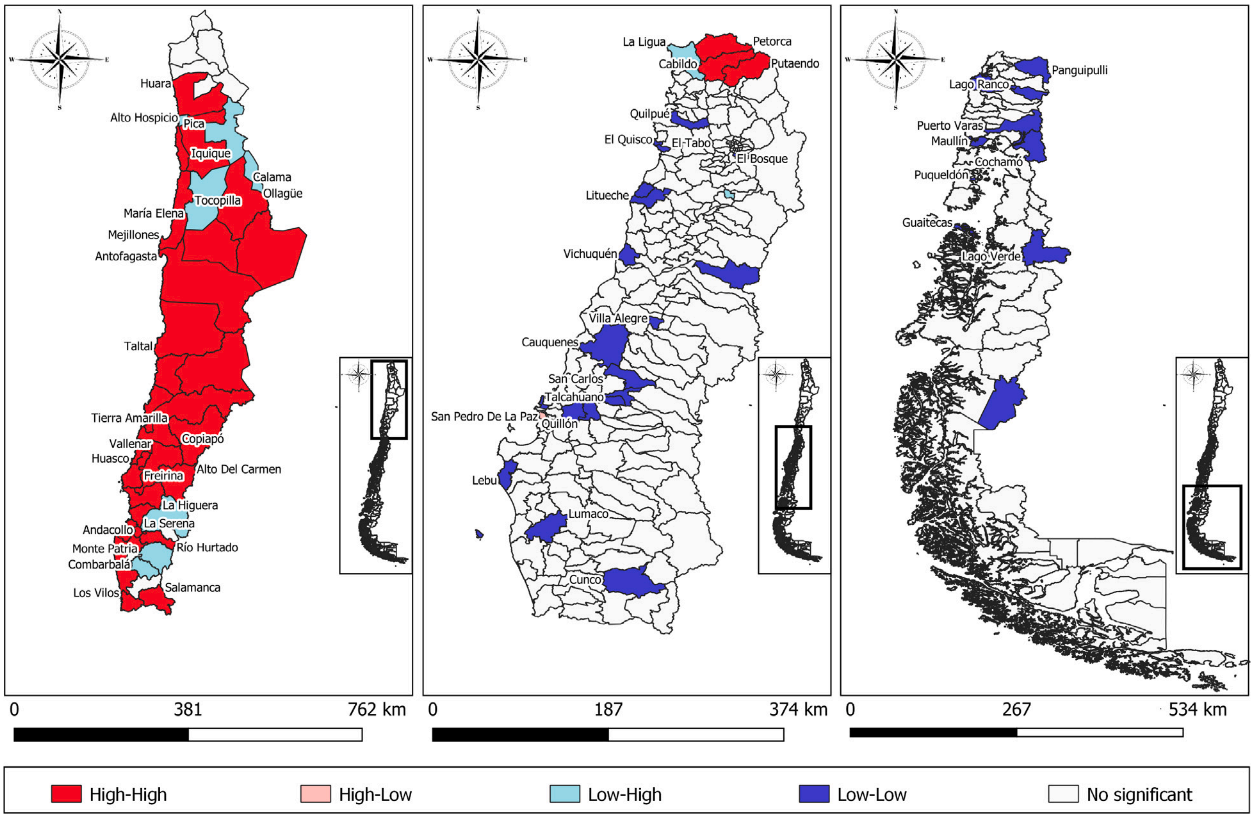

Fig. B.2. Local indicators of spatial association (LISA) for metal mining employment share in 2000. Clusters at 10% significance level.
Notes: Employment information from CASEN 2000.

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