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The Rise of the Maquiladoras: A Mixed Blessing*

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RRH: THE RISE OF THE MAQUILADORAS
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Abstract

Mexico experienced a tremendous expansion of its export-processing *maquila* sector during the 1990s. Since one of the main objectives of the *maquiladora* program was to increase formal employment, we study how the rapid increase in *maquiladora* activity has affected labor market outcomes and welfare in Mexico. We develop a heterogeneous-firm model with imperfect labor markets that captures salient features of the Mexican economy such as the differences between *maquila* and non-*maquila* manufacturing plants and the existence of an informal sector. We calibrate the model's parameters to match key cross-sectional moments characterizing the Mexican economy. We find that the expansion of the *maquila* sector during the 1990s was a mixed blessing for Mexico. Our quantitative model indicates that the skill premium decreased by 2.7%, informality increased by 0.9% and overall welfare decreased by 3.7%.

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1. Introduction

Over the past three decades Mexico has undergone a dramatic transformation that has made it one of the most open developing countries in the world today. One of the key drivers behind Mexico's impressive export growth has been the *maquila* sector.

Maquila plants, or *maquiladoras* for short, are export assembly plants which are mostly located along a 20km strip along the US-Mexico border. The defining characteristic of *maquiladoras* is their exclusive focus on assembling imported intermediate inputs which are then re-exported either for further assembly or as finished goods, mostly to the US. Although the *maquiladora* program formally started in 1965, it was not until the end of the 1980s, after Mexico's first round of trade and investment liberalization reforms, that the sector started booming. With the sector's value-added growing at an average of 10% per year during the 1990s (in comparison to a 3% per year growth rate of non-*maquila* manufacturing), *maquiladoras* have come to account for 8.3% of manufacturing value-added, 47.1% of manufacturing employment and 52.9% of aggregate exports by 2004.

One of the main goals of the *maquiladora* program was to increase employment of unskilled workers. Although Mexico's unemployment rate has always been particularly low,[1] around 30 to 50% of the labor force is employed in the informal sector, an array of small-scale, low-productivity establishments, where workers earn wages substantially lower than in formal firms. The fact that such a large share of the labor force participates in this sector is regarded as undesirable, since it is widely assumed that workers only turn to informality as a last measure when they cannot find a formal sector job.[2]

We develop a quantitative model that allows us to explore the implications of an expansion in the *maquila* sector for Mexico's industrial structure and labor market outcomes, such as the skill premium, the share of the labor force employed in the informal sector and overall welfare. We calibrate our small open economy, two-sector, two-factor model of trade with firm heterogeneity and the possibility of informal employment for unskilled workers to match key cross-sectional moments of the Mexican economy.

Our model takes into account the fact that *maquiladoras* differ substantially from non-*maquiladora* manufacturing plants across several dimensions. Namely, *maquiladoras* (i) are less skill-intensive (their share of production workers in total employment tends to be higher than that of non-*maquila* manufacturing plants)[3], (ii) use a high share of imported intermediate inputs, (iii) are more likely to be foreign-owned, and (iv) are on average larger in terms of total employment than non-*maquila* manufacturing plants.

Concerning informality, our model seeks to incorporate three main stylized facts about the Mexican labor market: (i) a large share of the labor force is employed in the informal sector, (ii) the vast majority of informal workers has low educational attainment, and (iii) there is a formality premium: on average, informal workers earn lower wages than comparable individuals employed in the formal sector.[4]

We use our model to simulate an exogenous increase in the foreign demand for *maquila* output that replicates the observed increase in the sector's share of GDP during the 1990s. Our results suggest that the rise of the *maquiladoras* has been more of a mixed blessing than a panacea for Mexico. We find that despite *maquila* production being relatively intensive in unskilled labor, the expansion of the sector is accompanied by a much larger contraction in non-*maquila* manufacturing. This ultimately results in a smaller number of open vacancies and higher informality. The response of factor rewards resembles a Stolper-Samuelson effect: the increase in demand for the low-skill intensive *maquila* output induces a reduction in the skill premium. Although the reduction in the skilled wage follows directly from the contraction of the skill-intensive manufacturing sector, the increase in the unskilled wage is due to an increase in the recruitment costs of unskilled workers. This result is in turn a consequence of lower average productivity and a higher price index in Mexican manufacturing caused by the expansion of the *maquila* sector. Given the magnitude of the changes in skilled and unskilled wages as well as the increase in informality and the price index faced by Mexican consumers, our model predicts a reduction in real income, our welfare measure.

Our study of the expansion of the *maquiladoras* in an economy with an informal sector contributes to three separate strands of the literature seeking to understand how globalization shapes labor market outcomes. Despite their considerable importance to aggregate exports in several developing countries, the behavior of export processing firms like *maquiladoras* has not been explored in models of international trade that combine firm heterogeneity and labor market frictions such as those by Felbermayr et al. (2011) and Helpman and Itskhoki (2010). Similarly, models that study the causes, consequences and implications of informality in developing countries using a search and matching framework (Zenou, 2008; Satchi and Temple, 2009; Albrecht et al., 2009) have also overlooked export-processing plants. Moreover, since these models assume a very stylized view of the production side of the economy, usually considering only one-worker firms, they are unable to take into account the significant differences between *maquiladoras* and other manufacturing plants highlighted above. Finally, incorporating the informal sector and its importance in Mexico allows us to shed new light on the aggregate implications of the *maquila* phenomenon, an area of inquiry that has been studied by Feenstra and Hanson (1997) and Bergin et al. (2009).

While this paper focuses on the case of Mexico, we believe our model can also be applied to other developing countries where export processing zones (EPZs) similar to the *maquiladora* program have been instrumental in attracting large FDI inflows. By 2006, 130 countries had established more than 3,500 EPZs accounting for 66 million employees world-wide.[5] Crucially, many of these countries are also characterized by large informal sectors as described in depth by Gasparini and Tornarolli (2009) and Jütting and de Laiglesia (2009).

2. The Model

In this section we present a model that combines the setup of Bernard et al. (2007) and Felbermayr et al. (2011) and extends these models to incorporate an informal sector arising from search frictions as well as export processing firms which can differ substantially from regular manufacturing firms along several dimensions such as size, ownership status and skill-intensity.

Our heterogeneous-firm framework features resource reallocation between and within industries in response to exogenous changes in foreign demand, which in turn result in labor market adjustments which are important determinants for evaluating the implications of the rise of the *maquiladoras* on labor market outcomes in Mexico.

We assume that Mexico is a small open economy and treat the US as the rest of world, abstracting from all other trade partners. This is not unduly restrictive, since 80% of all Mexican exports are shipped to the US.[6] Thus, we only model Mexico explicitly and take the foreign price indices, expenditure shares and prices of the imported goods as given. We assume that production in Mexico takes place in two sectors, *maquila*, $j = 1$, and non-*maquila* manufacturing, $j = 2$, both populated by firms that are heterogeneous with respect to their productivity.[7] There are two types of labor, skilled and unskilled, and we assume that Mexico is abundant in unskilled labor.

Due to the existence of search and matching frictions, not all low-skill individuals can gain employment in *maquiladoras* or manufacturing firms, which means that that a share of them has to resort to informality. We assume that the matching process between unskilled individuals and formal firms is governed by only one matching function, that is, we assume that the labor market for unskilled workers is unified. This in turn means that what determines the probability of an unskilled worker finding a formal job is the total number of vacancies open in the formal sector (i.e. in the *maquila* and manufacturing sector altogether), and that a matched unskilled worker earns the same wage working in a *maquiladora* or in a manufacturing firm. The labor market for skilled workers, on the other hand, is assumed to be perfectly competitive, which is in line with the low share of skilled informal workers observed in the data.

2.1. Consumption

Mexican households only consume goods produced in the manufacturing sector, which means that *maquila* output is exported in its entirety. Consumers maximize

$$C_2 = M_2^{\frac{1}{1-\sigma}} \left[\int_{\omega \in \Omega_{2d}} [q_{2d}(\omega)]^{\frac{\sigma-1}{\sigma}} d\omega + \int_{\omega' \in \Omega_{2f}} [q_{2f}(\omega')]^{\frac{\sigma-1}{\sigma}} d\omega' \right]^{\frac{\sigma}{\sigma-1}}, \tag{1}$$

where Ω_{2d} is the set of varieties produced in the manufacturing sector in Mexico, and Ω_{2f} the set of varieties imported from the US, $\sigma > 1$ is the elasticity of substitution and M_2 denotes the total mass of manufacturing varieties available in Mexico.[8] We follow Blanchard and Giavazzi (2003) and normalize utility by $M_2^{\frac{1}{1-\sigma}}$ in order to ensure that an increase in the size of an economy does not mechanically translate into a smaller informal sector.

Taking into account the existence of iceberg transportation costs $\tau_2 \geq 1$ for imported varieties, the price index corresponding to the composite C_2 is given by:

$$P_2 = M_2^{\frac{1}{\sigma-1}} \left[\int_{\omega \in \Omega_{2d}} [p_{2d}(\omega)]^{1-\sigma} d\omega + \int_{\omega' \in \Omega_{2f}} [\tau_2 p_{2f}(\omega')]^{1-\sigma} d\omega' \right]^{\frac{1}{1-\sigma}}. \tag{2}$$

Inverse demand for domestic and imported foreign varieties from sector 2 is then given by:

$$p_{2d}(\omega) = \left(\frac{Y}{M_2}\right)^{\frac{1}{\sigma}} P_2^{\frac{\sigma-1}{\sigma}} q_{2d}(\omega)^{-\frac{1}{\sigma}}, \quad p_{2f}(\omega) = \left(\frac{\tau_2 Y}{M_2}\right)^{\frac{1}{\sigma}} P_2^{\frac{\sigma-1}{\sigma}} q_{2f}(\omega)^{-\frac{1}{\sigma}}, \tag{3}$$

where Y denotes total expenditure in Mexico. Note that we define $p_{2f}(\omega)$ as the cif price in the US and $q_{2f}(\omega)$ is the total quantity produced, including the quantity lost in transit due to the iceberg transportation costs.

2.2. Production

Firms in both sectors are heterogeneous with respect to their idiosyncratic productivity φ as in Melitz (2003). Since each firm produces a unique variety, we index firm-level variables by φ.

Manufacturing Firms. There is an unbounded mass of potential entrants in the domestic manufacturing sector. To enter, producers pay a sunk cost f_{e2}. All costs in the model are denominated in terms of units of the manufacturing good.[9] After incurring this cost, firms draw their productivity from a Pareto distribution with density $g(\varphi) = ak^a \varphi^{-(a+1)}$ for $\varphi \geq k$. Firms that choose to operate need to pay a fixed cost f_2 per period. Having set up a plant, manufacturing firms produce their output by combining skilled labor s and unskilled labor l in a Cobb-Douglas form,

$$q_2(\varphi) = \varphi (s_2)^{\beta_{2s}} (l_2)^{1-\beta_{2s}}, \tag{4}$$

where β_{2s} is the labor cost share of skilled workers.

Firms sell their output domestically but can also incur an additional fixed cost f_{x2} to serve the foreign market through exports. We borrow the notion of a small open economy under monopolistic competition from Flam and Helpman (1987), and the extension to a heterogeneous-firm environment proposed by Demidova and Rodríguez-Clare (2009). This assumption implies that, despite the fact that firms located in Mexico face a downward-sloping demand schedule for their exports, their pricing decisions do not affect the price index, expenditure nor the mass of firms operating abroad. Demidova and Rodríguez-Clare (2011) show that this small country setup is the limit case of a large two-country model in which the labor endowment share of the small country tends to zero. However, the subset of firms exporting to Mexico, M^f_{2x}, is endogenous.[10] Thus, inverse demand for Mexican manufacturing exports abroad is given by

$$p_{2x}(\varphi) = A_{2x}^{1/\sigma}\left(\frac{q_{2x}(\varphi)}{\tau_2}\right)^{-\frac{1}{\sigma}}, \tag{5}$$

where A_{2x} is a demand-shifter parameter that is taken as given by Mexican manufacturing firms. Hence, we define total revenue for a Mexican manufacturing firm with productivity φ as:

$$\begin{aligned} r_2(\varphi) &= r_{2d}(\varphi) + \mathbb{I}_x(\varphi) r_{2x}(\varphi) \\ &= \left(\frac{Y}{M_2}\right)^{\frac{1}{\sigma}} P_2^{\frac{\sigma-1}{\sigma}} q_{2d}(\varphi)^{\frac{\sigma-1}{\sigma}} + \mathbb{I}_x(\varphi) A_{2x}^{1/\sigma}\left(\frac{q_{2x}(\varphi)}{\tau_2}\right)^{\frac{\sigma-1}{\sigma}}, \end{aligned} \tag{6}$$

where $\mathbb{I}_x(\varphi)$ is an indicator function that takes the value one if a manufacturing firm with productivity φ exports and zero otherwise.

***Maquiladora* Firms.** We model *maquiladoras* in a similar fashion to manufacturing firms, therefore in this section we just highlight the differences between the two sectors, namely that (i) *maquila* plants are foreign-owned, (ii) export all their output and (iii) use foreign manufacturing goods as intermediate inputs for production.

A foreign investor pays a sunk entry cost in Mexico to set up a *maquiladora* plant.[11] *Maquiladoras* draw their productivity from the same Pareto distribution as Mexican manufacturing firms. Since *maquiladoras* export all their output, there is no meaningful distinction between domestic and exporting fixed costs. We assume that *maquiladoras* use foreign manufacturing goods as intermediate inputs for production, denoted by i, as well as skilled and unskilled labor. Thus, production of *maquiladora* with productivity φ takes the form

$$q_1(\varphi) = \varphi(s_1)^{\beta_{1s}}(l_1)^{\beta_{1l}}(i_1)^{1-\beta_{1s}-\beta_{1l}}, \tag{7}$$

where β_{1s} and β_{1l} are the skilled and unskilled labor cost shares for *maquiladoras*, respectively. Inverse demand for *maquila* variety φ abroad is given by

$$p_{1x}(\varphi) = A_{1x}^{1/\sigma}\left(\frac{q_{1x}(\varphi)}{\tau_1}\right)^{-\frac{1}{\sigma}}, \tag{8}$$

where A_{1x} is a foreign demand shifter that *maquiladora* plants take as given and which has a similar interpretation to A_{2x} defined above. $\tau_1 > 1$ are the iceberg transportation costs to ship a *maquila* variety to the US. Total revenues for a *maquiladora* with productivity φ are given by

$$r_1(\varphi) = r_{1x}(\varphi) = A_{1x}^{1/\sigma}\left(\frac{q_{1x}(\varphi)}{\tau_1}\right)^{\frac{\sigma-1}{\sigma}}. \tag{9}$$

Unlike Mexican-owned firms in the manufacturing sector, profits derived from the operation of *maquiladoras* are repatriated abroad.

2.3. Labor Market

Since most individuals employed in the informal sector are unskilled, we assume that search and matching frictions only affect these workers, whereas skilled workers face a perfectly competitive labor market. Thus in our model only unskilled workers are employed in the informal sector. Although we recognize that there are several ways in which informality can be incorporated into a search and matching framework,[12] there is empirical evidence that suggests that informational frictions play a prominent role in the labor market for low-skill and informal occupations.[13]

Following Satchi and Temple (2009), unskilled individuals that are unable to get matched with neither a firm in the formal manufacturing sector nor in the formal *maquiladora* sector become informal workers. These individuals earn income bw_l, with $b \in (0,1)$, financed by lump-sum transfers from employed individuals, so we can interpret $1-b$ as the formality wage premium for unskilled workers.[14]

In order to hire unskilled workers, firms need to post vacancies v at a cost c per vacancy. As is common in the search and matching literature, we assume that the matching technology is a constant returns to scale Cobb-Douglas function, $m(\theta) = \overline{m}\theta^{-\gamma}$, with $\gamma \in (0,1)$ and where $\theta \equiv v/u$ is the vacancy-informality ratio, and $\overline{m}$ determines the overall efficiency of the matching process in the economy. The probability that a vacancy is filled is given by $m(\theta)$, which is decreasing in θ, and the probability that an unskilled individual in the informal sector finds a job in a formal firm is $\theta m(\theta)$ which is increasing in θ. We follow Keuschnigg and Ribi (2009) and consider a one-shot, static version of the search and matching framework in which the entire population of unskilled workers has just one opportunity to get matched with firms.

The optimal labor demand decision for a manufacturing firm solves the following program:

$$\pi_2(\varphi) = \max_{l_2, s_2} \left\{ r_2(\varphi) - w_l l_2 - w_s s_2 - cP_2\left(\frac{l_2}{m(\theta)}\right) - f_2 P_2 - f_{x2} P_2 \mathbb{I}_x(\varphi) \right\}, \tag{10}$$

where we have also made use of the fact that a manufacturing firm wishing to hire l_2 unskilled workers needs to post $l_2/m(\theta)$ vacancies.[15]

The solution to program (10) yields two policy rules, one for skilled labor demand, which is the usual condition that the marginal revenue product of skilled labor has to be equal to the skilled wage, w_s, and a second one for unskilled employment, which shows that firms have monopsony power and take into account that their vacancy posting has an impact on the wage rate for unskilled workers:

$$\frac{\partial r_2(\varphi)}{\partial l_2} = w_l + \frac{\partial w_l}{\partial l_2} l_2 + \frac{cP_2}{m(\theta)}. \tag{11}$$

As in Stole and Zwiebel (1996) we assume that unskilled workers bargain individually with their employers about their wage and are all treated as the marginal worker. Total surplus of a worker-employer match is split according to a generalized Nash bargaining solution in each sector j, i.e. $(1-\mu)[E(\varphi) - U] = \mu \partial \pi_j(\varphi)/\partial l_j$ where $E(\varphi)$ denotes the income of an unskilled worker being employed at a firm with productivity φ, U is the income of a worker in the informal sector, and $\mu \in (0,1)$ measures the bargaining power of a worker.

Following the same procedure as in Felbermayr et al. (2011) and Larch and Lechthaler (2011) (i.e. combining the first-order conditions for unskilled employment by plants in both sectors together with the surplus-splitting rule), yields a set of two job-creation conditions (one for each sector):

$$w_l + \frac{cP_2}{m(\theta)} = \left[\frac{\beta_{1l}(\sigma-1)}{\sigma-\beta_{1l}\mu+\beta_{1l}\sigma\mu-\sigma\mu}\right]\varphi p_{1x}(\varphi)s_1(\varphi)^{\beta_{1s}}l_1(\varphi)^{\beta_{1l}-1}i_1(\varphi)^{1-\beta_{1s}-\beta_{1l}}, \quad (12)$$

$$w_l + \frac{cP_2}{m(\theta)} = \left[\frac{(1-\beta_{2s})(\sigma-1)}{\sigma+\beta_{2s}\mu-\mu-\beta_{2s}\sigma\mu}\right]\varphi p_{2d}(\varphi)\left(\frac{s_2(\varphi)}{l_2(\varphi)}\right)^{\beta_{2s}}, \quad (13)$$

and the wage curve is given by:

$$w_l = \frac{\mu c P_2}{(1-\mu)(1-b)}\left[\theta+\frac{1}{m(\theta)}\right]. \quad (14)$$

Note that since we assume that the labor market for unskilled workers is unified, this implies that wages for unskilled formal workers are the same in both manufacturing and *maquiladora* firms. The same holds for skilled workers.

2.4. Productivity Cutoffs and Entry

As described in Section 2.2, the production side in our model closely follows Melitz (2003) and Bernard et al. (2007). Because $\pi_j(\varphi)$ is a strictly increasing function of φ, only firms with high enough productivity to earn non-negative profits will start production. Thus the usual productivity cutoff for production in sector j is defined implicitly by $\pi_j(\varphi_j^*) = 0$. In the manufacturing sector, where firms need to incur a fixed cost to serve the foreign market, an export cutoff is similarly defined as $\pi_{2x}(\varphi_{2x}^*) = 0$. We follow Melitz (2003) and define average productivity in sector j as:

$$\tilde{\varphi}_j \equiv \left[\frac{1}{1-G(\varphi_j^*)}\int_{\varphi_j^*}^{\infty}\varphi^{\sigma-1}g(\varphi)d\varphi\right]^{\frac{1}{\sigma-1}}, \quad j=1,2. \quad (15)$$

Using the cutoff productivity of the least productive exporting manufacturing firm φ^*_{2x}, we can define the average productivity for manufacturing exporters analogously. Finally, let $\chi_2 \equiv [1-G(\varphi^*_{2x})]/[1-G(\varphi^*_2)]$ denote the ex-ante probability that a manufacturing firm exports, conditional on successful entry. Using these definitions we can write the free-entry condition for firms in sector j as $[1-G(\varphi^*_j)]\overline{\pi}_j = f_{ej}P_2$.[16]

2.5. Aggregate Variables

The equilibrium share of informal workers in the labor force follows from the one-period equivalent of the Beveridge curve and is given by $u = 1/[1+\theta m(\theta)]$. The mass of firms operating in sector j in Mexico, M_{jd}, is pinned down by the labor market clearing condition for unskilled workers:

$$M_{1d} = \frac{L_1}{l_1(\tilde{\varphi}_1)}; \qquad M_{2d} = \frac{L_2}{l_{2d}(\tilde{\varphi}_2) + \chi_2 l_{2x}(\tilde{\varphi}_{2x})}, \tag{16}$$

with $L_1 + L_2 = (1-u)\overline{L}$, where L_j denotes total unskilled employment in sector j and $\overline{L}$ is the total endowment of unskilled labor in the economy. Market clearing for skilled labor is given by $M_{1d}s_1(\tilde{\varphi}_1) + M_{2d}\left[s_{2d}(\tilde{\varphi}_2) + \chi_2 s_{2x}(\tilde{\varphi}_{2x})\right] = \overline{S}$. Finally, the trade balance condition reads:

$$\underbrace{M_{1d}r_1(\tilde{\varphi}_1)}_{\text{value of } \textit{maquila} \text{ exports}} + \underbrace{\chi_2 M_{2d} r_{2x}(\tilde{\varphi}_{2x})}_{\text{value of manufacturing exports}} = \underbrace{\tau_2^{1-\sigma}\left(\frac{Y}{M_2}\right)\left(\frac{P_2}{P_2^f}\right)^{\sigma-1}}_{\text{value of manufacturing imports}} + \underbrace{\tau_2 P_2^f M_{1d} i_1(\tilde{\varphi}_1)}_{\text{value of intermediate imports}} + \underbrace{M_{1d}\pi_1(\tilde{\varphi}_1)}_{\text{aggregate } \textit{maquila} \text{ profits}}. \tag{17}$$

We define the foreign price index for manufacturing goods, P_2^f, as the *numéraire*. Note that aggregate profits in the manufacturing sector remain in Mexico, since firms in this sector are domestically owned.

3. Bringing the Model to the Data

We calibrate parameters in order to match observations both at the aggregate and at the cross-sectional level for the Mexican economy.[17] Table 1 presents the parameters used in the benchmark solution of the model.

Table 1 about here

We normalize the endowment of unskilled labor $\overline{L}$ to 1,500, and choose the endowment of skilled labor to match an employment share of production workers in Mexican manufacturing of 0.825. Factor shares in each sector $\{\beta_{jk}\}_{j=1,2}^{k=s,l}$ are calibrated using national accounts data. In order to be consistent with our model, we take the gross value of production in the *maquila* sector to be composed of wage payments and consumption of foreign intermediate goods, which yields $\beta_{1l} = 0.089$, $\beta_{1s} = 0.028$ and $\beta_{1i} = 1 - \beta_{1l} - \beta_{1s} = 0.884$. In the manufacturing sector, the gross value of production is entirely accounted for by wage payments, resulting in $\beta_{2l} = 1 - \beta_{2s} = 0.571$ and $\beta_{2s} = 0.429$. Thus, $\beta_{2s}/\beta_{2l} > \beta_{1s}/\beta_{1l}$, implying that the manufacturing sector's production is more skill-intensive than that of *maquiladoras*.

Since, as Satchi and Temple (2009) note, there are no studies that estimate search and matching models for Mexico, we choose to set both the elasticity of the matching function, γ, and the bargaining power of unskilled workers, μ, to 0.5, a common parametrization used in the calibration of search and matching models as exemplified by Petrongolo and Pissarides (2001), Albrecht et al. (2009) or Felbermayr et al. (2011). The parameter b that determines the income that unskilled workers earn in the informal sector is pinned down by the estimate of Binelli and Attanasio (2010) of a 29% formality premium for male employees in Mexico.[18]

The parameters characterizing the distribution from which both *maquiladoras* and manufacturing firms draw their productivity, the shape parameter a and the lower bound of the support k, as well as the elasticity of substitution σ, are chosen following Bernard et al. (2007). Thus, $a = 3.4$, $k = 0.2$ and $\sigma = 3.8$, satisfying the condition that $a > \sigma - 1$, which insures that the variance of the sales distribution is finite. Note that we normalize the fixed entry costs of manufacturing plants f_{e2} to 1. This allows us to interpret the matched magnitudes of the remaining fixed costs as multiples of f_{e2}.

We set the iceberg transportation costs in both sectors $\{\tau_j\}_{j=1,2}$ to 1, reflecting the fact that by 2001, after several rounds of unilateral trade liberalization and NAFTA provisions coming into place, both the average tariff faced by Mexican exporters selling in the US and the average import tariff for manufacturing imports coming from the US into Mexico were below 1.3% as documented by Kose et al. (2004). Due to the proximity of Mexico and the US, we abstract from additional transportation costs. Table 2 presents the set of moments that we use to calibrate the remaining parameters of the model which appear in boldface in Table 1.

Table 2 about here

To provide a better sense of how our model fits the data, we present equilibrium variables produced by our model that have not been used as targets in the calibration. Since our model features a direct relationship between size (measured in terms of employment) and productivity, this implies that *maquiladoras* are the most productive firms in Mexico, being 15% more productive than local manufacturing exporters and 52 % more productive than domestic producers. Unfortunately, since INEGI records plant-level variables for *maquiladoras* and non-*maquiladora* manufacturing plants in different surveys, to the best of our knowledge no study has yet compared the performance of these two types of firms in terms of productivity. Focusing on the manufacturing sector, our model predicts an exporter size premium of 43.5%, which is very close to the 47.4% average reported by Verhoogen (2008) for Mexican manufacturing plants for the period 1993-2001.

To compare the fixed costs of setting up and operating a plant in each sector, we scale them by average sales, thus facilitating the comparison with other studies. Using this metric, our results indicate that the fixed cost of opening a *maquiladora* and the fixed costs of operation account for 21.7% and 33.0% of average sales respectively. The fixed costs paid by Mexican manufacturing firms are substantially smaller. This result is in line with theoretical models in which firms choose whether to serve foreign markets by exporting or through a subsidiary as in Helpman et al. (2004), which assume that the fixed costs associated with FDI are larger than those of exporting. Entry and operation costs for firms operating only in the domestic market amount to

6.8% of total sales. Fixed costs of serving the foreign market by exporting amount to 1.6% of average export sales. The low estimates for the fixed cost of exporting are in line with structural estimates for Colombia reported by Das et al. (2007). Using a structural estimation technique, Riaño (2009) finds the fixed costs of production and exporting for Mexican manufacturing firms to be around 33% of average labor costs and 5% of export sales revenues respectively.[19] Finally, recruitment costs for the average Mexican manufacturing firm are 1.4% of its wage-bill (or 1.2% of its sales), a very close figure to that used by Satchi and Temple (2009) who report vacancy costs of 1.2% of formal sector output in their calibrated model with homogeneous one-worker firms.

Our model is less successful at matching aggregate labor outcomes. The skill premium implied by our model, which is the wage of skilled workers relative to unskilled workers employed in the formal sector, is 1.7, whereas in the data, Robertson (2007) finds the average wage of non-production workers relative to production workers in the Mexican manufacturing sector to be close to 2.7 in 2000. Our model also underestimates the *maquila* sector's share of manufacturing employment (3.5% in our model versus 20% in the data), although this result could easily be overcome if we allowed the manufacturing sector to use intermediate inputs as well. Finally, the informal sector accounts for 22% of GDP in our model, an estimate that falls between INEGI's own conservative estimate of 13% and estimates from Buehn and Schneider (2012) of 30%.

4. The Rise of the *Maquiladoras* during the Nineties

We use our quantitative model to evaluate the impact that the extraordinary expansion of *maquiladoras* had on the size of the informal sector, the skill premium and welfare. To do so, we present an experiment in which we increase the exogenous foreign demand shifter for *maquila* goods so as to reproduce the observed increase in the *maquila* sector's share of GDP from 4.2% to 9.9% during the 1990s. This entails increasing A_{1x} from 0.6 to 1.4 times the value used in our benchmark calibration. Table 3 summarizes the response of the main endogenous variables to the increase in demand for *maquila* output.

Table 3 about here

To evaluate the welfare implications of the expansion of the *maquila* sector for Mexico, we use real wage income as our welfare measure. Because we allow for free entry of firms in both sectors, there are no aggregate profits in equilibrium, as in Melitz (2003). In the *maquila* sector, variable profits are transferred abroad and cover the fixed entry costs of setting up *maquila* plants paid by US investors. Variable profits in the domestically-owned manufacturing sector do not leave Mexico but are also used to pay for entry costs. Informal sector wages are completely financed by the wage income of formal sector workers via lump sum transfers. Due to our assumption of homothetic preferences, consumption patterns of informal sector workers do not differ from those of formal workers. Hence, welfare, stated in terms of the indirect utility function, is simply real wage income:

$$W = \frac{(1-u)w_l\bar{L} + w_s\bar{S}}{P_2}. \tag{18}$$

Because by definition *maquiladoras* export all their output, the decision whether to operate or not is characterized by just one productivity cutoff, above which it is profitable for a firm to produce and export, instead of the usual two (one for domestic production, another for exporting) featured in trade models with firm heterogeneity. Moreover, because of our assumption that firms' productivity is drawn from a Pareto distribution, it is easily shown that both the production cutoff and average productivity for *maquiladoras* are independent of A_{1x}. Thus, the increase in demand for *maquila* output leads to an adjustment on the extensive margin (the mass of firms), but not on the intensive margin (firm size) in the *maquila* sector.[20] Thus, our model produces a one-to-one increase in both the mass of *maquiladora* firms and the value of *maquila* exports, both increasing by a factor of 2.3.

How does the expansion of the *maquila* sector affect non-*maquila* manufacturing and labor market outcomes? Since the *maquila* sector always presents a trade surplus, it follows that its expansion needs to be balanced by an increase in the manufacturing sector's trade deficit in order to maintain equilibrium in the balance of payments. This adjustment occurs on two fronts: the share of US-based manufacturing firms exporting to Mexico increases by 6.9%, while at the same time the share of Mexican manufacturing exporters falls by 2.1%. In contrast to the *maquila* sector, there is a within-sector reallocation of market shares in manufacturing. Lower expected profits in the foreign market for Mexican manufacturing firms are compensated by higher domestic profits, which are reflected in a lower cutoff of production for the domestic market, inducing entry of firms in the lower end of the productivity distribution.

As foreign demand for Mexican manufacturing goods weakens following the expansion of the *maquila* sector, the mass of manufacturing firms and average productivity in this sector fall by 5.8% and 0.1% respectively, resulting in an increase in the manufacturing price index of 3.1%. From the labor market perspective, because the manufacturing sector is relatively skill-intensive, we observe that it sheds 1.1% of its skilled employment, while reducing its unskilled employment by 3.9%. Some of the unskilled workers that leave manufacturing will find a job in the *maquila* sector, whereas the unlucky ones that are unable get matched will join the informal sector.

As we mention in the previous section, because of the high cost share of foreign intermediates in the production of *maquila* output, this sector only accounts for 4.1% of total unskilled employment in our model. This means that in aggregate, the contraction of the manufacturing sector dominates the increase in demand for unskilled workers in the *maquila* sector, resulting in a reduction in the number of vacancies opened for unskilled workers and an increase in informality of 0.9%. This effect is reinforced by the fact that the higher manufacturing price index increases the cost of recruiting unskilled workers.

In terms of wages, the reduction in the demand for skilled labor caused by the contraction in manufacturing leads to a reduction in the skilled workers' wage of 2.1%. For the wage of unskilled workers, there are two effects at work that operate in opposite directions. On the one hand, the reduction in the total number of vacancies decreases the vacancy/informality ratio, θ, curtailing the bargaining power of unskilled workers. A lower θ means unskilled workers find it more difficult to get matched with firms in the formal sector, which reduces the share of the match's surplus that they can retain when negotiating their wage. On the other hand, a higher recruitment cost cP_2 means that matched workers are rewarded for reducing firms' recruitment costs as noted by Pissarides (2000). In our quantitative model, the second effect dominates, and wages of unskilled workers increase by 0.6%. These predictions are in line with Waldkirch (2010), who finds that a 10% increase in *maquila* FDI reduces wages of skilled workers by 0.19% without having any significant effect on the wages of unskilled workers. In our model, a 10% increase in the foreign demand for *maquila* output decreases the wage of skilled workers by 0.27%, increasing the wage of unskilled workers by just 0.08%.

The movements in absolute wages imply a 2.7% reduction in the skill premium. This is consistent with the observed pattern of the average relative wage of non-production workers in Mexican manufacturing documented by Robertson (2007).[21] The skill premium started to fall gradually after 1994, following the tremendously rapid increase of more than 30% that characterized the second half of the 1980s and early 1990s, when most of Mexico's unilateral trade and investment liberalization reforms took place. Robertson suggests that the steady rise in the price of *maquila* output relative to that of non-*maquila* manufacturing observed after 1995 could explain the fall in the skill premium via a Stolper-Samuelson mechanism. Our quantitative model suggests that although the expansion of the *maquila* sector might not have been large enough to reduce informality, it could have contributed to the fall in the skill premium.

Finally, since the rise of the *maquiladoras* increases both the price index faced by consumers and the share of unskilled workers in informality, while at the same time reducing the wage of skilled workers and, to a lesser extent, increasing the wage of unskilled workers, we find that real income, our welfare measure for the Mexican economy, falls by 3.7%.

5. Conclusion

This paper investigates how the rise of the *maquila* sector during the 1990s affected informality, the skill premium, and welfare in Mexico. Using a quantitative model with heterogeneous firms and imperfect labor markets calibrated to match key stylized facts of the Mexican economy, we find that the expansion of the *maquila* sector during the 1990s increased the size of the informal sector and reduced overall welfare in Mexico by 0.9% and 3.7% respectively, while at the same time reducing the skill premium by 2.7%. Thus, our quantitative model suggests that the expansion of the *maquila* sector may have been a mixed blessing for Mexico.

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Notes

[1]At the height of the Tequila crisis in 1995, the unemployment rate reached a peak of 7%.

[2]For a different view see Maloney (2004) who stresses the positive entrepreneurial aspects of the informal sector.

[3]Robertson (2007) using data from Mexico's Monthly Industrial Survey for 1994 and 2004, shows that the non-production/production (N/P) employment ratio for *maquiladoras* is lower than for non-*maquila* plants in almost all industries where *maquiladoras* operate. This fact seems at odds with Feenstra and Hanson's (1997) finding that during the 1980's the relative demand for non-production workers was higher in regions where *maquiladoras* expanded most rapidly. However, Bernard et al. (2010) find that controlling for industry, *maquiladora* plants do employ a higher N/P ratio than non-*maquila* manufacturing plants. The reason behind these seemingly contradictory facts is that *maquiladoras* are concentrated in low-skill intensive industries. Since in our model we treat *maquila* as a completely separate industry from non-*maquila* manufacturing, we assume that the *maquila* sector is relatively low-skill intensive.

[4]For a more detailed description of the stylized facts about *maquiladoras* and the informal sector in Mexico, please refer to the working paper version of this article.

[5]China alone accounts for 40 million employees, Latin America for 5.5 million employees, the transition economies in Eastern Europe for 1.4 million employees; for further details, see Boyenge (2007).

[6]In 1991, 79.4% of all exports were shipped to the US; in 2009, 80.5%.

[7]Hereafter we will refer to the non-*maquila* manufacturing as manufacturing sector for short.

[8]The total number of manufacturing varieties available for consumption in Mexico is $M_2 = M_{2d} + M^f_{2x}$ where M^f_{2x} denotes the mass of imported varieties.

[9]Note that this implies that not all output produced can be used for consumption.

[10]Demidova and Rodríguez-Clare (2009)'s framework needs an endogenous variable to clear the trade balance. There, the price index and expenditure abroad are unaffected by Mexican firms but the share of US firms exporting to Mexico is endogenous.

[11]The fixed costs of entry, operation and vacancy posting for unskilled workers are incurred in Mexico and are denominated in units of the Mexican manufacturing good.

[12]For instance, Zenou (2008) assumes that search and matching frictions only affect the formal labor market, while the informal labor market is assumed to be fully competitive and accessible for everybody. Satchi and Temple (2009) assume that unmatched urban workers become informal as in our model, but they assume the existence of an outside agricultural sector along the lines of the traditional Harris-Todaro model.

[13]Assaad (1993) provides evidence of the importance of kinship and social networking in regulating informal employment in Egypt. Similarly, Wahba and Zenou (2005) find that information sharing through friends and relatives relative to other methods of finding a job is more important for uneducated individuals.

[14]See `http://alejandroriano.weebly.com/research.html` for a variant of the model where workers in the informal sector produce non-traded manufacturing varieties to earn their wage.

[15]The labor demand program for *maquila* plants is almost identical to equation (10), the only difference being that *maquiladoras* also need to choose how much foreign intermediate inputs to use for production.

[16]For *maquiladoras* $\overline{\pi}_1 = \pi_1(\tilde{\varphi}_1)$ and for manufacturing firms $\overline{\pi}_2 = \pi_{2d}(\tilde{\varphi}_2) + \chi_2 \pi_{2x}(\tilde{\varphi}_{2x})$.

[17]Unless otherwise noted, all figures correspond to the year 2000.

[18]Binelli and Attanasio (2010) calculate the formality premium as the ratio of mean formal to informal wages for male employees aged between 25 and 60. A worker is considered informal if she does not pay any social security contribution in either the private or public sector. Based on their productive definition of informality, Gasparini and Tornarolli (2009) report a formality premium of 21.9% in Mexico for males with primary education, controlling for age and region, and a 30% premium based on their legalistic definition.

[19]In our model, fixed costs of domestic production correspond to 8% of the total wage-bill for the average domestic manufacturing firm.

[20]This contrasts with the usual result in heterogeneous-firm models, in which increasing the profitability of exporting, by reducing iceberg transportation costs, for instance, produces a within-industry reallocation of resources from low to high-productivity firms.

[21]Similarly, Airola (2008) finds only weak evidence that growth in *maquila* employment has increased the skill premium using Mexican household survey data.

Parameter	Description	Value
σ	Elasticity of substitution	3.800
Foreign market		
P_2^f	Price index manufacturing abroad (*numéraire*)	1.000
$\mathbf{p_{1x}(\tilde{\varphi}_1)}$	**Variety price of the average *maquila* exporter**	2.858
$\mathbf{p_{2f}(\varphi_2^{*f})}$	**Variety price of the marginal US mfg. exporter**	16.680
$\mathbf{A_{1x}}$	**Foreign demand shifter *maquila***	33,527.635
$\mathbf{A_{2x}}$	**Foreign demand shifter manufacturing**	1,691.753
Labor market		
$\overline{L}$	Unskilled labor endowment	1,500.000
$\overline{S}$	Skilled labor endowment	318.864
μ	Bargaining power unskilled workers	0.500
γ	Matching function elasticity	0.500
$1-b$	Formality premium	0.290
$\mathbf{c}$	**Vacancy posting fixed cost**	0.001
$\overline{\mathbf{m}}$	**Efficiency of matching function**	0.603
Factor shares		
β_{1l}	Unskilled labor share *maquila*	0.089
β_{1s}	Skilled labor share *maquila*	0.028
β_{1i}	Foreign intermediates share *maquila*	0.884
β_{2l}	Unskilled labor share manufacturing	0.571
β_{2s}	Skilled labor share manufacturing	0.429
Productivity distribution		
a	Pareto distribution shape parameter	3.400
k	Pareto distribution lower bound	0.200
Transport costs		
$\{\tau_j\}_{j=1,2}$	Iceberg transportation costs in sector j	1.000
Fixed costs		
f_{e2}	Fixed entry cost manufacturing	1.000
$\mathbf{f_{e1}}$	**Fixed entry cost *maquila***	42.266
$\mathbf{f_1}$	**Fixed cost of production *maquila***	64.264
$\mathbf{f_2}$	**Fixed cost of production manufacturing**	0.311
$\mathbf{f_{x2}}$	**Fixed cost of exporting manufacturing**	0.135

Table 1. Parameters for the Baseline Economy

Note: Parameters in bold are chosen to match calibration targets defined in Table 2.

#	**Statistic to match**	**Target**
1	Share of exporters, manufacturing	0.389
2	Mean plant size, *maquila*	371
3	Mean plant size, manufacturing	214
4	Aggregate trade openness	0.600
5	Share of *maquila* exports in total exports	0.549
6	Yearly transition rate informal $\rightarrow$ formal	0.210
7	Share of informal workers	0.366
8	*Maquila* value added to GDP ratio	0.093
9	Intermediate imports to GDP ratio	0.106
10	Mexican to US GDP ratio	0.091

Table 2. Calibration Targets

Note: The share of exporting plants (1) comes from Iacovone and Javorcik (2010). Mean size of *maquila* plants (2) comes from CNIME (*Consejo Nacional de la Industria Maquiladora y Manufacturera de Exportación*, National Council of Maquiladora Industries). Mean plant size for manufacturing (3) is from INEGI, EIA (*Encuesta Industrial Anual*, Annual Manufacturing Survey). Aggregate trade openness (4) is calculated from the World Bank's World Development Indicators. The share of *maquila* exports in total exports (5) comes from CNIME. Both the yearly transition rate from informal to formal employment (6) and the share of informal workers (7) come from Gong et al. (2004). The *maquila* value added to GDP ratio (8) is from INEGI, *Sistema de Cuentas Nacionales de México* (Mexican National Income and Production accounts). The share of intermediate imports for *maquiladoras* in Mexican GDP (9) is from *Banco de México* Balance of Payments statistics. The ratio of Mexican to US GDP (10) is measured in PPP in current US dollars from the World Bank's World Development Indicators.

Variable	% Change
***Maquila* sector**	
Average productivity	0
Mass of firms	133.3
Exports	133.3
Unskilled employment	131.7
Skilled employment	138.5
Manufacturing sector	
Average productivity	-0.1
Mass of firms	-5.8
Exports	-5.0
Unskilled employment	-3.9
Skilled employment	-1.1
Share of Mexican exporters	-2.1
Share of US exporters	6.9
Consumer price index in Mexico	3.1
Labor market	
Vacancy-informality ratio	-2.9
Unskilled wage	0.6
Skilled wage	-2.1
Skill premium	-2.7
Share of labor force in informality	0.9
Welfare	-3.7

Table 3. Change in Endogenous Variables Due to an Increase in *Maquila* Goods Demand

Note: Table depicts percentage changes in endogenous variables due to an exogenous increase in the foreign demand parameter for *maquila* goods, A_{1x}, by 130%, i.e. from 0.6 to 1.4 times the value used for the benchmark calibration. This increase resembles the rapid expansion of the *maquila* sector during the 1990s, roughly an increase in the *maquila* sector's share of GDP from 4.2 to 9.9%. All other parameters remain at the values from the benchmark calibration.