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Offshore Production and Business Cycle Dynamics with Heterogeneous Firms

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Abstract

To examine the effect of offshoring through vertical FDI on the international transmission of business cycles, I propose a two-country model in which firms endogenously choose the location of their production plants over the business cycle. Firms face a sunk cost to enter the domestic market and an additional fixed cost to produce offshore. As such, the offshoring decision depends on the firm-specific productivity and on fluctuations in the relative cost of effective labor. The model generates a procyclical pattern of offshoring and dynamics along its extensive margin that are consistent with data from Mexico's maquiladora sector. The extensive margin enhances the procyclical response of the value added offshore to expansions in the home economy, as the number of offshoring firms mirrors the dynamics of firm entry at home. As a result, offshoring increases the comovement of output across economies, in line with the empirical evidence.

JEL classification: F23, F41

Keywords: offshore production; extensive margin; heterogeneous firms; firm entry; business cycle dynamics; terms of labor.

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*The views in this paper are solely the responsibility of the author and should not be interpreted as reflecting the views of the Federal Reserve Bank of Boston, the Board of Governors of the Federal Reserve System, or of any other person associated with the Federal Reserve System.

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1 Introduction

Firms often establish production affiliates at foreign locations to benefit from lower production costs, a process known in the international economics literature as offshoring through vertical foreign direct investment (FDI).[1] The offshoring output fluctuates over the business cycle, and thus affects the dynamics of output and trade for the home and foreign economies. Since offshoring through vertical FDI contributes to the output of the foreign economy but is often affected by shocks originating in the home country, it has potential implications for the comovement of output between the two economies.[2] Also, since the relocation of production is a firm-level decision, the offshoring output and trade are likely to be influenced by changes in the firms' production strategies in addition to other factors considered in the traditional literature, in which the location of production plants is usually fixed over time.[3]

To motivate the line of research proposed in this paper, I empirically document the business cycle fluctuations of offshoring through vertical FDI, including its extensive margin,[4] using the relationship between U.S. manufacturing and Mexico's *maquiladora* sector as an example. The maquiladora sector in Mexico is an appropriate empirical setup to examine the cyclicality of offshoring through vertical FDI, as it consists of manufacturing plants that import inputs mostly from U.S. firms, process them, and export the resulting output back to the U.S. firms, thus accommodating the offshoring activities of the latter. The time series and correlations in Fig. 1 show that: (a) The offshoring value added in Mexico's maquiladora sector is procyclical with the U.S. manufacturing industrial production (IP); in fact, it is more procyclical than Mexico's total manufacturing IP. (b) Like the offshoring value added, the extensive margin of offshoring (proxied by the number of maquiladora plants) is also procyclical with the U.S. manufacturing IP. (c)

[1]Unlike offshoring through horizontal FDI, under which firms relocate production abroad to gain access to the local market, the type of offshoring that I model is motivated by cross-country differences in the cost of effective labor, as foreign affiliates produce goods that are shipped back to the country of origin. Helpman, Melitz, and Yeaple (2004) model exports and horizontal FDI as alternative internationalization strategies for multinational firms. Contessi (2010) analyzes the trade-off between exporting and offshoring through horizontal FDI in a business cycle framework.

[2]"Offshoring" refers to the activity of firms that relocate certain stages of production to foreign countries. In contrast, "outsourcing" refers to firms that purchase intermediates from unaffiliated suppliers either at home or abroad, rather than producing them in-house (see Helpman, 1984, 2006).

[3]In the traditional literature, output comovement crucially depends on the elasticity of substitution between country-specific goods (Backus, Kehoe, and Kydland, 1994; Burstein, Kurz, and Tesar, 2008).

[4]The extensive margin refers to the number of firms, plants, or varieties operating in a sector. The intensive margin refers to the amount of output (or exports) per firm, plant, or variety. The model in this paper assumes a one-to-one correspondence between a firm, a plant, and a variety.

Mexico's offshoring exports are more procyclical than Mexico's regular (non-offshoring) exports with the U.S. manufacturing IP. This evidence highlights the procyclical pattern of offshoring and its extensive margin and adds to empirical studies documenting that fluctuations in the extensive margin of offshoring can have substantial macroeconomic effects for the economies involved (Bergin, Feenstra, and Hanson, 2009; Kurz, 2006; and Ramondo, Rappoport, and Ruhl, 2016).[5]

Motivated by these observations, this paper proposes a model of offshoring through vertical FDI in which firms choose the location of their production plants endogenously over the business cycle. In turn, the model allows for adjustments of offshoring along its extensive margin (the number of firms) that can potentially affect aggregate variables and the comovement of output between economies. Thus, the paper aims not to merely replicate the empirical business cycle properties of offshoring, but to explore whether the firm-level decision to produce offshore can play a role in shaping the model implications for trade and output comovement.

The model of offshoring proposed in this paper consists of two economies (the North and the South), building on the dynamic stochastic general equilibrium framework in Ghironi and Melitz (2005, henceforth GM05). As in GM05, the key model ingredients include endogenous firm entry, firm heterogeneity in labor productivity, and an endogenous export decision for firms in each economy. To this framework, I add: (1) an endogenous offshoring decision by the Northern firms, which decide whether to produce domestically (in the North) or offshore (in the South) guided by the cost advantage of offshoring every period; (2) a steady-state asymmetry in the cost of effective labor[6] across countries, which makes production cheaper in the South; and (3) a calibration that replicates the asymmetric size of the U.S. and Mexican economies, as well as the importance of offshoring for the latter. Thus, there are two types of exports in the Southern economy, namely the offshoring and the regular exports. The offshoring exports,

[5]For instance, the offshoring extensive margin accounts for about one-third to one-half of the adjustment in maquiladora employment (Bergin, Feenstra, and Hanson, 2009; Coronado, 2011). Although offshoring is undertaken by only a fraction of U.S. manufacturing firms, the offshoring firms are larger and more productive (Kurz, 2006). Since intrafirm trade is concentrated in a small group of large affiliates and large multinational corporations (Ramondo, Rappoport, and Ruhl, 2016), firms' actions can plausibly affect aggregate variables. Also, since firms' decisions to export and/or import have non-trivial effects on firm-level characteristics (see Kurz and Senses, 2016, for employment volatility), they are likely to have macro-level effects in the economies where these multinational corporations operate.

[6]The cost of effective labor is defined as the real wage normalized by aggregate productivity. Thus, the cross-country asymmetry in the cost of effective labor in steady state implies that offshoring takes place in one direction, from the North to the South.

which represent the focus of this paper, are initiated by the Northern offshoring firms that decide to produce in the South and ship the resulting output back to the North. In contrast, the regular exports are initiated by the Southern firms that export to the North, as in GM05.

In this framework, following entry in the North (subject to a sunk cost), firms can use either domestic or foreign labor in production for their home market. The use of foreign labor involves the establishment of an offshore plant and allows firms to transfer their idiosyncratic productivity abroad, but is subject to fixed and trade costs every period. Thus, the decision to produce offshore is firm-specific: Despite the lower cost of effective labor offshore, only firms with idiosyncratic productivity levels above an endogenous cutoff can afford the fixed and trade costs associated with offshoring. As a result, the extensive margin of the Southern offshoring exports depends on the terms of labor (i.e., the ratio between the cost of effective labor in the South and the North expressed in the same currency), which reflects the cost advantage of producing in the South. In contrast, the extensive margin of the Southern regular exports depends on Northern demand, which drives the Southern firms' decision to export.

The model implications are as follows. First, the model generates a procyclical pattern of the offshoring value added and the number of offshoring firms. The result reflects the link between firm entry in the North, the appreciation of the terms of labor, and the Northern firms' decision to produce offshore. Second, the model generates a higher correlation between the Southern offshoring exports and Northern output than between the Southern regular exports and Northern output, as in the data. The result is driven by the extensive margin of offshoring enhancing the procyclical pattern of offshoring exports relative to that of regular exports. In contrast, when the extensive margins are shut down, there is no longer a distinction between the offshoring and regular exports.[7] Third, the extensive margin is less consequential for the dynamics of regular exports than for those of the offshoring exports, which is consistent with Alessandria and Choi (2007) and Fattal Jaef and Lopez (2014). In contrast to offshoring exports, the impulse responses for the Southern regular exports are similar when their extensive margin

[7] To explore the role of the extensive margin of offshoring in shaping aggregate implications, I contrast the baseline model to a number of special cases. These include versions of the model in which firm entry, the offshoring and exporting cutoffs, or both firm entry and the cutoffs are held fixed. Thus, when both firm entry and the cutoffs are held fixed, the Southern offshoring and regular exports display the same correlations and impulse responses. In addition, when the extensive margin of offshoring becomes countercyclical, which happens when firm entry alone is held fixed, the countercyclical extensive margin weighs down on the Southern offshoring exports, which become less correlated with the Northern output than are the Southern regular exports.

is free to adjust or when it adjusts only slowly. Since both the extensive and intensive margins of regular exports are driven by changes in demand, keeping one margin fixed has little impact in the aggregate. Fourth, since the offshoring exports are more procyclical than the Southern regular exports with output in the North, a larger share of offshoring exports in the total Southern exports leads to more output comovement. Using alternative calibrations of the baseline model, increasing the share of offshoring in Southern exports (while keeping the share of exports in output constant) results in more output comovement between the North and the South. This result is consistent with the empirical evidence in Burstein, Kurz, and Tesar (2008, henceforth BKT08), which shows that country pairs with larger shares of offshoring exports in bilateral trade exhibit more output comovement. To illustrate the role of the extensive margin in driving my result, the positive link between offshoring and output comovement breaks down in the alternative case with fixed extensive margins: Since the Southern offshoring and regular exports behave similarly in this case, varying the share of offshoring exports in the total Southern exports has little effect on output comovement.

These model implications are robust under a number of alternative assumptions. First, in the presence of capital and endogenous labor supply, the model displays the same properties as in the baseline case, namely: (1) procyclical pattern of offshoring value added and its extensive margin; (2) higher correlation between the Southern offshoring exports and Northern output than between the Southern regular exports and Northern output; and (3) positive link between the share of offshoring in Southern exports and output comovement, which holds when the extensive margins are free to adjust but not otherwise. Second, these implications also hold when the bivariate total factor productivity (TFP) process is re-calibrated to mirror the standard symmetric case for the United States and an aggregate of European economies as in Backus, Kehoe, and Kydland (1992, henceforth BKK92), rather than the asymmetric process for the United States and Mexico estimated in this paper. Third, the results hold when key model variables and the exogenous TFP process are adjusted to take into account measurement issues that arise when comparing model implications to the data, such as the deflators for GDP and its components not reflecting changes in the number and composition of varieties (Burstein and Cravino, 2015), or the data series on investment not including expenditures related to firm entry (Fattal Jaef and Lopez, 2014).

1.1 Literature

This paper builds upon previous literature on business cycle synchronization, as it proposes a new mechanism of output comovement that hinges on the link between firm entry in the home economy and the extensive margin of offshoring in a framework with heterogeneous firms. The mechanism differs from others proposed in the literature, such as those relying on a low elasticity of substitution between country-specific goods or dependence on imported inputs under vertical specialization (BKT08; Arkolakis and Ramanarayanan, 2009). For instance, BKT08 propose a model in which offshoring enhances output comovement but the location of production is fixed over time. In their model, comovement results from a very low elasticity of substitution between the country-specific goods in the offshoring sector, which is set to be lower than in the regular exports sector. In contrast to BKT08, the positive relationship between offshoring and output comovement in my model is due to the asymmetric role of the extensive margin in driving the Southern offshoring vs. regular exports, which makes the former more procyclical than the latter, while the elasticity of substitution is the same for both sectors. Bergin, Feenstra, and Hanson (2011) also study the importance of offshoring in amplifying the transmission of shocks across countries in a model that allows for extensive margin adjustments. While they study the implications of offshoring for the transmission of shocks across countries, my paper focuses on the implications of offshoring for output comovement.

This paper also adds to literature that studies the role of the extensive margin in shaping export dynamics; however, this literature generally looks at regular exports rather than at trade flows resulting from vertical FDI. For example, GM05 model export dynamics in a framework with endogenous firm entry, heterogeneous firms, and endogenous exports that generates persistent deviations from purchasing power parity and rationalizes the Harrod-Balassa-Samuelson effect. Alessandria and Choi (2007) analyze the extensive margin of exports in a model with sunk exporting costs and fixed continuation costs that explains the "exporter hysteresis" behavior; they find that modelling firms' export decision does not alter the aggregate implications for the real exchange rate and net exports.[8] In a framework like GM05 augmented with capital and endogenous labor supply, Fattal Jaef and Lopez (2014) take into account the endogenous effect of firm entry on aggregate productivity and find that firm entry and exporting decisions

[8] "Exporter hysteresis" refers to the behavior of firms that continue to serve the foreign market even after a real exchange rate appreciation reduces their export competitiveness.

generate minimal departures from the aggregate implications in BKK92.[9] However, Liao and Santacreu (2015) propose a model with firm entry and endogenous export decisions to show that a higher level of the extensive margin of regular exports enhances output comovement between countries, as aggregate productivity shocks are propagated through exports. My paper differs from these studies in that it models the extensive margin of exports resulting from vertical FDI, which is driven by different factors than the extensive margin of regular exports: Firms' decision to relocate production offshore during booms in the home economy (or to relocate the production of varieties offshore when new varieties are created at home) is driven by the appreciation of the terms of labor. In turn, the relocation of production offshore boosts the foreign economy's offshoring exports and enhances output comovement.

More generally, this paper adds to a recent stream of theoretical literature that examines the determinants of firms' decision to offshore and, in turn, the implications of offshoring for firm-level performance and macro-level characteristics. On the determinants of offshoring, Pundit (2013) highlights the role of business cycle comovement in driving the choice between foreign suppliers of inputs; Lewis (2014) examines the role of nominal volatility in foreign economies in guiding the firms' choice between exports and horizontal FDI. On the firm-level implications of offshoring, Fillat and Garetto (2015) model the link between the endogenous choice of firms' international status and financial characteristics, with firms engaging in exports and horizontal FDI displaying higher stock returns and earning yields. Fillat, Garetto, and Oldenski (2015) also examine the impact of host economy characteristics on the risk premia of multinational firms. On the macro-level implications of offshoring, Garetto (2013) highlights the welfare gains for the U.S. economy arising from the U.S. firms' vertical FDI activities, while Contessi (2015) examines the impact of horizontal FDI on the host economies' productivity and growth. Regarding the impact of offshoring on labor markets, Ottaviano, Peri, and Wright (2013) examine the joint impact of offshoring and immigration on employment in the home economy; Mandelman (2016) and Mandelman and Zlate (2016) model the impact of offshoring and low-skill labor migration on labor market polarization; Arseneau and Leduc (2012) study offshoring as an outside option in wage negotiations by multinational firms; and Arseneau and Epstein (2016) examine the role of mismatch employment in shaping the labor market impact of offshoring in the home economy. While this literature studies mostly the impact of offshoring

[9]See Farhat (2009) for the impact of labor supply assumptions on aggregate implications in a similar model.

on individual firms' and economies' performance, my paper examines the impact on output comovement between economies.

The rest of the paper is organized as follows: Section 2 introduces the baseline model with heterogeneous firms, translates it into an equivalent framework with representative firms that produce domestically and offshore, and describes the case with capital and endogenous labor supply. Section 3 presents the calibration. Section 4 discusses the results, including impulse responses, moments, and the link between offshoring and comovement. Section 5 concludes.

2 Model of offshoring with heterogeneous firms

The model consists of two economies, the North and the South. Each economy includes one representative household and a continuum of firms that are monopolistically competitive and heterogeneous in labor productivity. Each firm produces a different variety of goods, and the Northern firms can choose to produce either domestically or offshore for their home market. All Southern firms produce domestically for their home market due to the steady-state asymmetry in the cost of effective labor across countries, which is higher in the North. In parallel, some firms from both the North and the South produce domestically for the export market.

This section describes the problem of the representative household and firms from the North, for the baseline model with financial integration.[10] For simplicity, labor is the only input in production. As an extension, the model with physical capital and elastic labor supply is also considered. Full model summaries are in the Appendix online.

2.1 Household's problem

The representative household maximizes expected lifetime utility: $\max_{\{B_{t+1},\, x_{t+1}\}}\left[E_t\sum_{s=t}^{\infty}\beta^{s-t}\frac{C_s^{1-\gamma}}{1-\gamma}\right]$, where $\beta\in(0,1)$ is the subjective discount factor, C_t is aggregate consumption, and $\gamma>0$ is

[10] "Baseline" refers to the model with fixed labor supply and no capital. Also, "financial integration" refers to the presence of risk-free, country-specific bonds traded internationally. Note that the characterization of offshoring as a type of FDI, with the household investing in firms that produce abroad, could also be considered a form of financial integration.

the inverse of the inter-temporal elasticity of substitution. The budget constraint is:

$$
\begin{aligned}
&(\widetilde{v}_t + \widetilde{d}_t) N_t x_t + w_t L + (1 + r_t) B_{N,t} + (1 + r_t^*) Q_t B_{S,t} + T_t \\
&\geqslant \widetilde{v}_t (N_t + N_{E,t}) x_{t+1} + C_t + B_{N,t+1} + Q_t B_{S,t+1} + \frac{\pi}{2} (B_{N,t+1})^2 + \frac{\pi}{2} Q_t (B_{S,t+1})^2 .
\end{aligned} \tag{1}
$$

The household starts every period with share holdings x_t in a mutual fund of N_t firms whose average market value is $\widetilde{v}_t$.[11] It also holds risk-free, country-specific real bonds from the North and the South, $B_{N,t}$ and $B_{S,t}$, denominated in units of the issuing country's consumption basket. The holdings of Southern bonds are converted into units of the Northern basket through the real exchange rate Q_t.[12] The household receives dividends equal to the average firm profit $\widetilde{d}_t$ in proportion with the stock of firms N_t, the real wage w_t for $L \equiv 1$ supplied inelastically, and real rates of return r_t and r_t^* from the North and South-specific bonds.

Every period, the household purchases two types of assets. First, it purchases x_{t+1} shares in a mutual fund of Northern firms, which includes N_t incumbent firms producing either domestically or offshore at time t, and also $N_{E,t}$ new firms that enter the market in period t. (Firm entry is discussed in Section 2.2.) On average, each of these firms is worth its market value $\widetilde{v}_t$, equal to the net present value of the expected stream of future profits. The household also purchases the risk-free bonds $B_{N,t+1}$ and $B_{S,t+1}$. The budget allows for quadratic costs of adjustment for bond holdings $\frac{\pi}{2} (B_{N,t+1})^2$ and $\frac{\pi}{2} Q_t (B_{S,t+1})^2$, which are rebated to the household as T_t. Parameter π is set at a small value to ensure stationarity for net foreign assets in the presence of shocks.

The consumption basket includes varieties produced by the Northern firms either domestically ($\omega \in \Omega_t^{NN}$) or offshore ($\omega \in \Omega_t^{NS}$), as well as varieties produced by the Southern exporters ($\omega \in \Omega_t^{SS}$), with the symmetric elasticity of substitution $\theta > 1$:

$$
C_t = \left[\underbrace{\int_{z_{\min}}^{z_{V,t}} y_{D,t}(\omega)^{\frac{\theta-1}{\theta}} d\omega}_{\omega \in \Omega_t^{NN}} + \underbrace{\int_{z_{V,t}}^{\infty} y_{V,t}(\omega)^{\frac{\theta-1}{\theta}} d\omega}_{\omega \in \Omega_t^{NS}} + \underbrace{\int_{z_{X,t}^*}^{\infty} y_{X,t}^*(\omega)^{\frac{\theta-1}{\theta}} d\omega}_{\omega \in \Omega_t^{SS}} \right]^{\frac{\theta}{\theta-1}} . \tag{2}
$$

[11] Since stocks are not traded across countries, the equilibrium condition is $x_t = x_{t+1} = 1$.

[12] The real exchange rate $Q_t = P_t^* \varepsilon_t / P_t$ is the ratio between the price indexes in the South and the North expressed in the same currency, where ε_t is the nominal exchange rate.

As explained in Section 2.2 below, $[z_{\min}, \infty)$ is the support interval for the idiosyncratic productivity of Northern firms, and only the more productive firms (with productivity above the endogenous cutoff $z_{V,t}$) choose to produce offshore for the home market.[13] Since the number of firms is time-variant and firms re-optimize their offshoring and exporting strategies every period, the composition of the consumption basket changes over time. With the consumption basket C_t set as numeraire, the price index for North is $1 = \left[\int \rho_t(\omega)^{1-\theta} d\omega\right]^{\frac{1}{1-\theta}}$, in which $\rho_t(\omega)$ is the real price of each variety and $\omega \in \Omega_t^{NN} \cup \Omega_t^{NS} \cup \Omega_t^{SS}$.

The Euler equations for bonds are:

$$1 + \pi B_{N,t+1} = \beta(1 + r_{t+1}) E_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\gamma} \right], \quad 1 + \pi B_{S,t+1} = \beta(1 + r^*_{t+1}) E_t \left[\frac{Q_{t+1}}{Q_t} \left(\frac{C_{t+1}}{C_t} \right)^{-\gamma} \right], \tag{3}$$

with the market-clearing conditions $B_{N,t+1} + B^*_{N,t+1} = 0$ and $B_{S,t+1} + B^*_{S,t+1} = 0$, in which the asterisk denotes holdings by the Southern household of each type of bond. The Euler equation for stocks is below, with the rate of firm exit δ described in Section 2.2:

$$\widetilde{v}_t = \beta(1 - \delta) E_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\gamma} (\widetilde{d}_{t+1} + \widetilde{v}_{t+1}) \right] \tag{4}$$

2.2 Firm entry

Firm entry takes place every period in the North and the South, following the mechanism in GM05. In the North, firm entry requires a sunk entry cost equal to f_E units of Northern effective labor, which reflects headquarter activities in the country of origin.[14] After paying the sunk entry cost, each firm is randomly assigned an idiosyncratic labor productivity factor z, which is drawn independently from a common distribution $G(z)$ with support over the interval $[z_{min}, \infty)$, and which the firm keeps for the entire duration of its life. Thus, $N_{E,t}$ new firms are created every period t and start producing at $t + 1$. However, all existing firms, including the new entrants, are subject to a random exit shock that occurs with probability δ at the end of every period, irrespective of their idiosyncratic productivity. The law of motion for the number of active firms is: $N_{t+1} = (1 - \delta)(N_t + N_{E,t})$.

[13] In the South, $[z^*_{\min}, \infty)$ is the support interval for the idiosyncratic productivity of Southern firms, and $z^*_{X,t}$ is the endogenous productivity cutoff for Southern exporters.

[14] The sunk entry cost is equivalent to $f_E w_t / Z_t$ units of the Northern consumption basket.

The potential entrants anticipate their expected post-entry value $\widetilde{v}_t$, which depends on the expected stream of future profits $\widetilde{d}_t$, the stochastic discount factor, and the exogenous probability δ of exit every period. The forward iteration of the Euler equation for stocks from equation (4) generates the following expression for the expected post-entry value of the average firm:

$$\widetilde{v}_t = E_t \left\{ \sum_{s=t+1}^{\infty} [\beta(1-\delta)]^{s-t} \left(\frac{C_s}{C_t} \right)^{-\gamma} \widetilde{d}_s \right\}. \tag{5}$$

Thus, every period, the unbounded pool of potential entrants face a trade-off between the sunk entry cost and the expected stream of monopolistic profits. In equilibrium, firm entry takes place until the expected value of the average firm is equal to the sunk entry cost: $\widetilde{v}_t = f_E \frac{w_t}{Z_t}$.

2.3 Firms' choice of markets and production strategies

Every period, the active firms N_t choose endogenously the destination market(s) that they serve and the location of production, as follows: (1) All firms serve their home market. For this purpose, the Northern firms can produce either at home or offshore. Offshoring offers the advantage of a lower cost of production but is subject to fixed and trade costs every period. Importantly, the firms' choice between producing at home or offshore concerns output intended for the home market only, and is not guided by access to the foreign market. (2) A subset of firms from each economy also serve the foreign market. Since offshoring through horizontal FDI is beyond the scope of this paper, the firms serving the foreign market produce domestically and export subject to a fixed cost, as in GM05.[15] Each of these two problems (the offshoring decision of firms serving their home market, and the exporting decision of firms serving the foreign market) are described next.

2.3.1 Domestic vs. offshore production for the Northern market

Every period, the Northern firm with idiosyncratic productivity z chooses between the two possible production strategies to serve its home market: (a) Produce domestically, with output $y_{D,t}(z) = Z_t z l_t(z)$ as a function of aggregate productivity Z_t, the firm-specific labor productiv-

[15] One useful feature of the model is that, when offshoring is removed, the model revisits GM05, which serves as a basis of comparison for some key results.

ity z, and domestic labor $l_t(z)$. (b) Alternatively, produce offshore to obtain $y_{V,t}(z) = Z_t^* z l_t^*(z)$. Thus, the firm producing offshore uses Southern labor $l_t^*(z)$ and becomes subject to the aggregate Southern productivity Z^*, but carries its idiosyncratic labor productivity z abroad.

Under monopolistic competition, the firm with idiosyncratic productivity z solves the profit-maximization problem for the alternative scenarios of domestic and offshore production:

$$\max_{\{\rho_{D,t}(z)\}} d_{D,t}(z) = \rho_{D,t}(z) y_{D,t}(z) - \frac{w_t}{Z_t z} y_{D,t}(z), \tag{6}$$

$$\max_{\{\rho_{V,t}(z)\}} d_{V,t}(z) = \rho_{V,t}(z) y_{V,t}(z) - \tau \frac{w_t^* Q_t}{Z_t^* z} y_{V,t}(z) - f_V \frac{w_t^* Q_t}{Z_t^*}, \tag{7}$$

where $\rho_{D,t}(z)$ and $\rho_{V,t}(z)$ are the prices associated with each of the two production strategies, w_t and w_t^* are the real wages in the North and the South, and Q_t is the real exchange rate. Thus, the cost of producing one unit of output either domestically or offshore varies not only with the cost of effective labor w_t/Z_t and $w_t^* Q_t/Z_t^*$ across countries, but also with the idiosyncratic labor productivity z across firms. In addition, the Northern firms producing offshore incur a fixed cost equal to f_V units of Southern effective labor, which reflects the building and maintenance of the production facility offshore, and also an iceberg trade cost $\tau > 1$ associated with the shipping of goods produced offshore back to the country of origin.[16]

The demand for the variety of firm z produced either domestically or offshore is $y_{D,t}(z) = \rho_{D,t}(z)^{-\theta} C_t$ or $y_{V,t}(z) = \rho_{V,t}(z)^{-\theta} C_t$ respectively, where C_t is the aggregate consumption in the North. Profit maximization implies the equilibrium prices $\rho_{D,t}(z) = \frac{\theta}{\theta-1} \frac{w_t}{Z_t z}$ and $\rho_{V,t}(z) = \frac{\theta}{\theta-1} \tau \frac{w_t^* Q_t}{Z_t^* z}$ for the alternative scenarios of domestic and offshore production. The corresponding profits are $d_{D,t}(z) = \frac{1}{\theta} \rho_{D,t}(z)^{1-\theta} C_t$ and $d_{V,t}(z) = \frac{1}{\theta} \rho_{V,t}(z)^{1-\theta} C_t - f_V \frac{w_t^* Q_t}{Z_t^*}$.

When deciding upon the location of production every period, the firm with productivity z compares the profit $d_{D,t}(z)$ that it would obtain from domestic production with the profit $d_{V,t}(z)$ that it would obtain from producing the same variety offshore. As a particular case, I define the productivity cutoff level $z_{V,t}$ on the support interval $[z_{\min}, \infty)$ such that the firm at

[16] The fixed offshoring cost is equivalent to $f_V w_t^*/Z_t^*$ units of the Southern consumption basket. The iceberg trade cost implies that, for every $\tau > 1$ units produced offshore, only one unit arrives in the North, with the difference lost due to factors such as trade barriers, transportation costs, etc. (Anderson and Wincoop, 2004).

the cutoff obtains equal profits from producing domestically or offshore:

$$z_{V,t} = \{z \mid d_{D,t}(z) = d_{V,t}(z)\}. \tag{8}$$

The model implies that only the relatively more productive Northern firms find it profitable to produce their varieties offshore. Despite the lower cost of effective labor in the South, only firms with idiosyncratic productivity above the cutoff level ($z > z_{V,t}$) obtain benefits from offshoring that are large enough to cover the fixed and iceberg trade costs. This implication is consistent with the empirical evidence in Kurz (2006), who shows that the U.S. plants and firms using imported components in production are larger and more productive than their domestically-oriented counterparts, as the larger idiosyncratic productivity levels allow them to cover the fixed costs of offshoring.[17]

In addition, the productivity cutoff $z_{V,t}$ responds to fluctuations in the relative cost of effective labor across countries, and thus affects the extensive margin of offshoring over the business cycle. For any given level of firm-specific productivity, a relatively lower cost of effective labor abroad implies lower prices, higher revenues, and higher profits from offshoring, and therefore leads to a larger fraction of offshoring firms in equilibrium. This implication is consistent with the empirical evidence on the determinants of offshoring in Hanson, Mataloni, and Slaughter (2005), who show that U.S. multinationals attract larger shares of their foreign affiliates's sales when the latter benefit from lower trade costs and lower wages abroad.

In equilibrium, the existence of productivity cutoff $z_{V,t}$ requires a cross-country asymmetry in the cost of effective labor, which ensures that some of the Northern firms have an incentive to produce offshore. To illustrate this point, I re-write the per-period profits from domestic and offshore production as $d_{D,t}(z) = M_t \left(\frac{w_t}{Z_t}\right)^{1-\theta} z^{\theta-1}$ and $d_{V,t}(z) = M_t \left(\tau \frac{w_t^* Q_t}{Z_t^*}\right)^{1-\theta} z^{\theta-1} - f_V \frac{w_t^* Q_t}{Z_t^*}$, where $M_t \equiv \frac{1}{\theta}\left(\frac{\theta}{\theta-1}\right)^{1-\theta} C_t$ is a function of demand in the North. Figure 2 plots the two profits as functions of the idiosyncratic productivity parameter $z^{\theta-1}$ over the support interval $[z_{min}, \infty)$. The vertical intercept is zero for domestic production; it is equal to the negative of the fixed cost

[17] A useful implication of the Melitz (2003) model is that more productive firms have larger output and revenue. Given two firms with idiodsyncratic productivity $z_2 > z_1$, their output and profit ratios are $\frac{y(z_2)}{y(z_1)} = \left(\frac{z_2}{z_1}\right)^{\theta} > 1$ and $\frac{d(z_2)}{d(z_1)} = \left(\frac{z_2}{z_1}\right)^{\theta-1} > 1$. This is consistent with the evidence that firms using imported inputs in production are more productive, obtain larger revenues, and employ more workers (Kurz, 2006).

($-f_V \frac{w_t^* Q_t}{Z_t^*}$) for offshoring. In this framework, the productivity cutoff $z_{V,t}$ exists in equilibrium if the profit function from offshoring is steeper than the profit function from domestic production, $slope\left\{d_{V,t}(z)\right\} > slope\left\{d_{D,t}(z)\right\}$. When this condition is met, offshoring generates larger profits than domestic production for the subset of firms with idiosyncratic productivity z along the upper range of the support interval ($z > z_{V,t}$). The inequality of profit slopes is equivalent to $\tau TOL_t < 1$, with the "terms of labor" $TOL_t = \frac{Q_t w_t^*/Z_t^*}{w_t/Z_t}$ defined as the ratio between the cost of effective labor in the South and the North expressed in the same currency. The condition implies that the effective wage in the South must be sufficiently lower than in the North, so that the difference covers the fixed and iceberg trade cost ($\tau > 1$), and thus provides an incentive for some of the Northern firms to produce offshore. (Note that an appreciation of the terms of labor for the North is equivalent to a decline in TOL_t.) The model calibration and the magnitude of macroeconomic shocks ensure that this condition is satisfied every period.[18]

2.3.2 Exporting

In addition to serving their domestic market, firms from each economy can choose to serve the foreign market through exports, as in GM05. In the North, the firm with idiosyncratic productivity z would use an amount of domestic labor $l_{X,t}(z)$ to produce for the Southern market, $y_{X,t}(z) = Z_t z l_{X,t}(z)$. The Southern firms that choose to export to the North face a similar problem. Profit maximization implies the following equilibrium price: $\rho_{X,t}(z) = \frac{\theta}{\theta-1}\tau^* \frac{w_t Q_t^{-1}}{Z_t z}$ and profit function: $d_{X,t}(z) = \frac{1}{\theta}\rho_{X,t}(z)^{1-\theta} C_t^* Q_t - f_X \frac{w_t}{Z_t}$ for the Northern exporter with productivity factor z, where C_t^* is the aggregate consumption in the South. Producing for the foreign market generates additional profits, but involves a fixed exporting cost equal to f_X units of Northern effective labor, and also an iceberg trade cost τ^*. The model implies that only the subset of Northern firms with idiosyncratic labor productivity above the productivity cutoff $z_{X,t}$ find it profitable to produce in the North and export to the Southern market, as they can afford the fixed and iceberg trade costs of exporting. Thus, the time-varying productivity cutoff for exporters is: $z_{X,t} = \inf\left\{z \mid d_{X,t}(z) > 0\right\}$.

[18] A second condition necessary to avoid the corner solution when all firms would produce offshore is $d_{D,t}(z_{\min}) > d_{V,t}(z_{\min})$. It ensures that $z_{V,t} > z_{\min}$ in all periods.

2.3.3 Simultaneous offshoring and exporting

In the stylized model of vertical FDI proposed in this paper, the offshoring and exporting activities of Northern firms target different markets, namely the Northern vs. Southern markets. Since Northern firms self-select into offshoring and exporting from the higher end of the productivity distribution, there are cases in which offshoring and exporting are undertaken by firms with similar productivity, although these activities target different markets.[19] If the model were extended to allow firms to also supply the Southern market out of offshoring (in addition to the North), the new setup would preserve the implications of offshoring through vertical FDI while adding a new trade-off between exporting and horizontal FDI, as in Contessi (2010, 2015). However, this paper focusses exclusively on offshoring through vertical FDI, which is the type of offshoring that boosts trade rather than substitutes it (see Ramondo and Rodriguez-Clare, 2013) and hence is associated with the empirical relationship between offshoring and output comovement documented in BKT08.

2.4 Aggregation over heterogeneous firms

This section translates the model of offshoring into an equivalent framework with *three representative Northern firms*: one produces domestically, another produces offshore (each serving the Northern market), while a third firm produces domestically and exports to the Southern market. Since offshoring takes place one-way, there are only *two representative Southern firms*: one produces for the local market and the other exports to the North.

2.4.1 Average productivity, prices, and profits

To illustrate the average productivity levels of the two representative Northern firms that produce domestically and offshore for the Northern market, Figure 3 plots the density of the firm-specific labor productivity levels z over the support interval $[z_{min}, \infty)$. Every period, there are $N_{D,t}$ firms with idiosyncratic productivity factors below the offshoring cutoff ($z < z_{V,t}$) that produce domestically; their average productivity is $\widetilde{z}_{D,t}$. There are also $N_{V,t}$ firms with

[19] The implication is consistent with empirical evidence that both exporting and importing firms are relatively more productive (Bernard, Jensen, Redding, Schott, 2007), and also that exporting and offshoring activities may occur simultaneously within the same firm (Kurz, 2006). For instance, firms may choose globalization strategies that combine offshoring to a low-wage country with maintaining production plants for the same variety at home, such as to diversify supply chain risks and reduce inventory costs (The Economist, 2011).

productivity factors above the cutoff ($z > z_{V,t}$) that choose to produce offshore; their average productivity is $\widetilde{z}_{V,t}$. Since the firm-specific labor productivity levels z are random draws from a common distribution $G(z)$ with density $g(z)$, the two average productivity levels are:

$$\widetilde{z}_{D,t} = \left[\frac{1}{G(z_{V,t})} \int_{z_{\min}}^{z_{V,t}} z^{\theta-1} g(z) dz \right]^{\frac{1}{\theta-1}} \quad \text{and} \quad \widetilde{z}_{V,t} = \left[\frac{1}{1-G(z_{V,t})} \int_{z_{V,t}}^{\infty} z^{\theta-1} g(z) dz \right]^{\frac{1}{\theta-1}}. \tag{9}$$

Assuming that the firm-specific labor productivity draws z are Pareto-distributed, with p.d.f. $g(z) = k z_{min}^{k} / z^{k+1}$ and c.d.f. $G(z) = 1 - (z_{min}/z)^k$ over the support interval $[z_{min}, \infty)$, the average productivity levels can be written as functions of the productivity cutoff $z_{V,t}$:

$$\widetilde{z}_{D,t} = \nu z_{\min} z_{V,t} \left[\frac{z_{V,t}^{k-(\theta-1)} - z_{\min}^{k-(\theta-1)}}{z_{V,t}^{k} - z_{\min}^{k}} \right]^{\frac{1}{\theta-1}} \quad \text{and} \quad \widetilde{z}_{V,t} = \nu z_{V,t}, \tag{10}$$

where the cutoff is $z_{V,t} = z_{min}(N_t/N_{V,t})^{(1/k)}$, with parameters $\nu \equiv \left[\frac{k}{k-(\theta-1)}\right]^{\frac{1}{\theta-1}}$ and $k > \theta - 1$.[20]

The Southern firms serve their domestic market exclusively through domestic production. Their average productivity is constant, $\widetilde{z}_D^* = \nu z_{\min}^*$, as it covers the entire support interval $[z_{\min}^*, \infty)$. The average productivity levels of exporting firms are as in GM05:

$$\widetilde{z}_{X,t} = \nu z_{\min} \left(\frac{N_t}{N_{X,t}} \right)^{1/k} \quad \text{and} \quad \widetilde{z}_{X,t}^* = \nu z_{\min}^* \left(\frac{N_{D,t}^*}{N_{X,t}^*} \right)^{1/k}. \tag{11}$$

Using the average productivity levels for the domestic, offshoring, and exporting firms, the average prices and profits for each representative firm are as in Table 1. Thus, the aggregate price indexes for the North and the South are $1 = N_{D,t} \left(\widetilde{\rho}_{D,t}\right)^{1-\theta} + N_{V,t} \left(\widetilde{\rho}_{V,t}\right)^{1-\theta} + N_{X,t}^* \left(\widetilde{\rho}_{X,t}^*\right)^{1-\theta}$ and $1 = N_{D,t}^* \left(\widetilde{\rho}_{D,t}^*\right)^{1-\theta} + N_{X,t} \left(\widetilde{\rho}_{X,t}\right)^{1-\theta}$. Similarly, the total profits of firms from the North and the South are $N_t \widetilde{d}_t = N_{D,t} \widetilde{d}_{D,t} + N_{V,t} \widetilde{d}_{V,t} + N_{X,t} \widetilde{d}_{X,t}$ and $N_{D,t}^* \widetilde{d}_t^* = N_{D,t}^* \widetilde{d}_{D,t}^* + N_{X,t}^* \widetilde{d}_{X,t}^*$.

[20] I use the Pareto c.d.f. $G(z_{V,t}) = 1 - (z_{min}/z_{V,t})^k$ and the share of Northern firms producing offshore $N_{V,t}/N_t = 1 - G(z_{V,t})$ to write the productivity cutoff as $z_{V,t} = z_{min}(N_t/N_{V,t})^{(1/k)}$. The share of Northern firms producing domestically is $N_{D,t}/N_t = G(z_{V,t})$.

2.4.2 Indifference conditions for offshoring and exporting

Using the property that the Northern firm at the productivity cutoff $z_{V,t}$ is indifferent between the two production strategies, the following equation links the average profits of the two representative firms that produce domestically and offshore for the home market:[21]

$$\widetilde{d}_{V,t} = \frac{k}{k-(\theta-1)} \left(\frac{z_{V,t}}{\widetilde{z}_{D,t}}\right)^{\theta-1} \widetilde{d}_{D,t} + \frac{\theta-1}{k-(\theta-1)} f_V \frac{w_t^* Q_t}{Z_t^*}. \tag{12}$$

In addition, using the property that the firm at the productivity cutoff $z_{X,t}$ obtains zero profits from exporting, the average profits from exports are as in GM05:

$$\widetilde{d}_{X,t} = \frac{\theta-1}{k-(\theta-1)} f_X \frac{w_t}{Z_t} \quad \text{and} \quad \widetilde{d}_{X,t}^* = \frac{\theta-1}{k-(\theta-1)} f_X^* \frac{w_t^*}{Z_t^*}. \tag{13}$$

2.5 Aggregate accounting

Under financial integration, aggregate accounting implies that households spend their income from labor, stock, and bond holdings on consumption and investment in new firms:

$$C_t + N_{E,t}\widetilde{v}_t + B_{N,t+1} + Q_t B_{S,t+1} = w_t L + N_t \widetilde{d}_t + (1+r_t) B_{N,t} + (1+r_t^*) Q_t B_{S,t}, \tag{14}$$

$$C_t^* + N_{E,t}^*\widetilde{v}_t^* + Q_t^{-1} B_{N,t+1}^* + B_{S,t+1}^* = w_t^* L^* + N_{D,t}^* \widetilde{d}_t^* + (1+r_t) Q_t^{-1} B_{N,t}^* + (1+r_t^*) B_{S,t}^*. \tag{15}$$

The balance of international payments requires that the current account balance (i.e., the trade balance, repatriated profits of offshore affiliates, and income from investments) equals the change in bond holdings:

$$TB_t + \underbrace{N_{V,t}\widetilde{d}_{V,t}}_{\text{Repatriated profits}} + \underbrace{r_t B_{N,t} + r_t^* Q_t B_{S,t}}_{\text{Income from bonds}} = \underbrace{(B_{N,t+1} - B_{N,t}) + Q_t (B_{S,t+1} - B_{S,t})}_{\text{Change in bond holdings}}, \tag{16}$$

where the trade balance is given by:

$$TB_t = \underbrace{N_{X,t} (\widetilde{\rho}_{X,t})^{1-\theta} C_t^* Q_t}_{\text{Exports}} - \underbrace{N_{V,t} (\widetilde{\rho}_{V,t})^{1-\theta} C_t}_{\text{Offshoring imports}} - \underbrace{N_{X,t}^* \left(\widetilde{\rho}_{X,t}^*\right)^{1-\theta} C_t}_{\text{Regular imports}}. \tag{17}$$

[21] The derivation of average productivity levels and the offshoring profit link are in the Appendix.

Thus, the baseline model with financial integration for the Northern economy is characterized by 18 equations in 18 endogenous variables: N_t, $N_{D,t}$, $N_{V,t}$, $N_{X,t}$, $N_{E,t}$, $\widetilde{d}_t$, $\widetilde{d}_{D,t}$, $\widetilde{d}_{V,t}$, $\widetilde{d}_{X,t}$, $\widetilde{z}_{D,t}$, $\widetilde{z}_{V,t}$, $\widetilde{z}_{X,t}$, $\widetilde{v}_t$, r_t, w_t, C_t, $B_{N,t+1}$, and $B_{S,t+1}$. Since the Southern firms do not produce in the high-cost North, the Southern economy is described by only 13 equations in 13 endogenous variables; there are no Southern counterparts for N_t, $N_{V,t}$, $\widetilde{d}_{V,t}$, $\widetilde{z}_{D,t}$ and $\widetilde{z}_{V,t}$. Finally, the real exchange rate Q_t and the balance of international payments close the model.[22]

In this framework, aggregate output in the North and the South are: $Y_t = C_t + N_{E,t}\widetilde{v}_t + TB_t$ and $Y_t^* = C_t^* + N_{E,t}^*\widetilde{v}_t^* + TB_t^*$, respectively. The value added offshore is defined as the wage income of Southern workers employed for the production activities (but not the fixed cost activities) in the offshoring sector: $VA_t = N_{V,t}\frac{\theta-1}{\theta\tau}\left(\widetilde{\rho}_{V,t}\right)^{1-\theta} C_t/Q_t$.

2.6 Capital and elastic labor supply

In the model augmented with capital and elastic labor supply, production of variety z takes the form $y_{D,t}(z) = Z_t z\left[l_t(z)\right]^{1-\alpha}\left[k_t(z)\right]^{\alpha}$ for domestic production and $y_{V,t}(z) = Z_t^* z\left[l_t^*(z)\right]^{1-\alpha}\left[k_t^*(z)\right]^{\alpha}$ for offshoring. The prices are $\rho_{D,t}(z) = \frac{\theta}{\theta-1}\frac{1}{Z_t z}\left(\frac{w_t}{1-\alpha}\right)^{1-\alpha}\left(\frac{r_t^k}{\alpha}\right)^{\alpha}$ and $\rho_{V,t}(z) = \frac{\theta}{\theta-1}\frac{\tau Q_t}{Z_t^* z}\left(\frac{w_t^*}{1-\alpha}\right)^{1-\alpha}\left(\frac{r_t^{*k}}{\alpha}\right)^{\alpha}$. Firm entry in the North implies a sunk cost activity that requires f_E effective units of domestic labor and capital, and thus is equal to $\frac{f_E}{Z_t}\left(\frac{w_t}{1-\alpha}\right)^{1-\alpha}\left(\frac{r_t^k}{\alpha}\right)^{\alpha}$ units of the Northern consumption basket. Similarly, offshoring implies a fixed cost of f_V effective units of foreign labor and capital, equal to $\frac{f_V}{Z_t^*}\left(\frac{w_t^*}{1-\alpha}\right)^{1-\alpha}\left(\frac{r_t^{*k}}{\alpha}\right)^{\alpha}$ units of the Southern consumption basket.

In the aggregate, the equation for capital accumulation is: $K_{t+1} = (1-\delta^k)K_t + I_t - \frac{\pi_k}{2}I_{t-1}\left(\frac{I_t}{I_{t-1}} - 1\right)^2$, where K_t is the stock of capital, I_t is investment in capital, δ^k is the rate of depreciation, and π_k denotes an investment adjustment cost. The aggregate stock of capital in the North incorporates capital used by the firms producing domestically for the home and foreign market, as well as capital used for the sunk entry cost and fixed exporting cost activities: $K_t = N_{D,t}\widetilde{k}_{D,t} + N_{X,t}\widetilde{k}_{X,t} + \left(N_{E,t}\frac{f_E}{Z_t} + N_{X,t}\frac{f_X}{Z_t}\right)\left[\frac{\alpha w_t}{(1-\alpha)r_t^k}\right]^{1-\alpha}$. The market clearing condition for capital in the South is similar, but also includes capital used by the Northern offshoring firms for production and fixed cost activities in the South.

Elastic labor supply implies that the Northern household maximizes the expected lifetime utility $\max_{\{L_t,\, x_t,\, B_t\}}\left[E_t\sum_{s=t}^{\infty}\beta^{s-t}U(C_s, L_s)\right]$, with discount factor $\beta \in (0,1)$. The period utility func-

[22] The model summary and the asymmetric steady-state solution are in the Appendix.

tion takes the form: $U_t(C_t, L_t) = \ln C_t - \chi \frac{L_t^{1+\psi}}{1+\psi}$, in which L_t is the variable labor supply, $\psi > 0$ is the inverse elasticity of labor supply, and $\chi > 0$ is the weight on the disutility from labor. The resulting equation for labor supply is: $L_t = \left(\frac{w_t}{\chi C_t}\right)^{1/\psi}$.

Like in the baseline model, the Northern firms serving their home market choose the location of production every period by comparing the profits from home vs. offshore production, with the firm at the productivity cutoff being indifferent between the two options. Importantly, with capital, the terms of labor $TOL_t = \frac{Q_t w_t^*/Z_t^*}{w_t/Z_t}$ are no longer an adequate measure of the relative cost of production across countries. Instead, I define the "terms of production" as the ratio between the marginal cost of production in the South and the North expressed in units of the same currency: $TOP_t = \frac{Q_t (w_t^*)^{1-\alpha}\left(r_t^{*k}\right)^{\alpha}/Z_t^*}{(w_t)^{1-\alpha}\left(r_t^{k}\right)^{\alpha}/Z_t}$.

3 Calibration

3.1 Calibration for baseline model

I use a standard quarterly calibration by setting the subjective rate of time discount $\beta = 0.99$ to match an average annualized interest rate of 4 percent. The coefficient of relative risk aversion is $\gamma = 2$. Following GM05, the intra-temporal elasticity of substitution is $\theta = 3.8$ and the probability of firm exit is $\delta = 0.025$. The quadratic adjustment cost parameter for bond holdings is $\pi = 0.0025$. The Pareto distribution parameter k, the iceberg trade cost τ, and the fixed costs of offshoring (f_V) and exporting (f_X and f_X^*) are calibrated so that the model in steady state matches the importance of offshoring for the Mexican economy, as illustrated by three empirical moments: (1) The maquiladora value added represents about 20 percent of Mexico's manufacturing GDP (Bergin, Feenstra, and Hanson, 2009) compared to 15 percent in the model in steady state. (2) The maquiladora sector provided about 55 percent of Mexico's manufacturing exports on average from 2000 to 2006 (INEGI, 2008) compared to about 61 percent in the model. (3) The maquiladora sector accounts for about 25 percent of Mexico's manufacturing employment (Bergin, Feenstra, and Hanson, 2009) and 20 percent in the model. To this end, I set $k = 4.2$, $\tau = 1.2$, $f_V = 0.095$, $f_X = 0.040$, and $f_X^* = 0.025$.[23] Without loss of

[23]The resulting exports-to-GDP ratios in steady state are 27 perecent for the North and 41 percent for the South. In the South, offshoring exports represent 61 percent of total exports and 25 percent of GDP.

generality, the lower bound of the support interval for firm-specific productivity in the North and the South is $z_{min} = z^*_{min} = 1$.

To obtain an asymmetric cost of effective labor across countries in steady state, the sunk entry cost, which reflects headquarter costs sensitive to the regulation of starting a business in the firms' country of origin, is set to be larger in the South than in the North ($f^*_E = 4f_E$ and $f_E = 1$). As a result, the steady-state output, the number of firms, the labor demand, and the effective wage are relatively lower in the South. The calibration reflects the considerable variation in the monetary cost of starting a business across economies, which was 2.8 times higher in Mexico than in the United States in purchasing power parity terms in 2010 (World Bank, 2011). The asymmetric sunk entry costs, along with the values for k, τ, f_V, f_X, and f^*_X discussed above, generate a steady-state value for the terms of labor that is less than unit ($TOL = \frac{Qw^*/Z^*}{w/Z} = 0.75$). In other words, the steady-state cost of effective labor in the South is 75 percent of the cost of effective labor in the North. Thus, the calibration provides an incentive for some of the Northern firms to produce offshore in steady state.[24]

3.2 Calibration with capital and elastic labor supply

In the model augmented with capital and elastic labor supply, the coefficient on capital in production and sunk/fixed cost activities is set at $\alpha = 0.37$ in both economies. The fixed costs of offshoring and exporting are re-set at $f_V = 0.44$, $f_X = 0.032$, and $f^*_X = 0.027$, so that the importance of offshoring for the Southern economy is similar to the baseline model (i.e., 27 percent of GDP, 56 percent of exports, and 20 percent of employment). Since investment in physical capital and firm entry are substitutes, their relative volatility has a non-trivial effect on model implications (see Fattal Jaef and Lopez, 2014). Therefore, the adjustment cost of investment in capital is set at $\pi_k = \pi^*_k = 0.335$, so that the volatility of firm entry matches that of investment, as in the data. The elasticity of labor supply is $1/\psi = 1$ in both the North and the South, as in Farhat (2009), and the weight on the disutility from labor is set at $\chi = 0.835$

[24]The resulting steady-state fraction of Northern firms that produce offshore (N_V/N) is 1 percent; the fraction of exporting firms (N_X/N) is 9 percent. Since offshoring is modelled in an asymmetric two-country framework that abstracts from the trade of U.S. firms with the rest of the world other than Mexico, these steady-state values are less than their empirical counterparts. In the data, 14 percent of the U.S. firms (other than domestic wholesalers) used imported inputs in 1997 (Bernard, Jensen, Redding, and Schott, 2007); 21 percent of the U.S. manufacturing plants were exporters in 1992 (Bernard, Eaton, Jensen, and Kortum, 2003).

in the North and $\chi^* =$ 0.855 in the South, so that labor supply in state state matches that in the baseline model, $L = L^* = 1$.

3.3 Shutting down the extensive margins

The results section discusses several special cases in which firm entry, the offshoring and exporting cutoffs, or both firm entry and the cutoffs are held fixed. Holding the cutoffs fixed implies that the fraction of offshoring and exporting firms is constant over time. Therefore, when the cutoffs are fixed but firm entry is active, the number of offshoring and exporting firms (and hence their extensive margins) still vary over the cycle due to firm entry and the evolving stock of incumbent firms. Thus, shutting down the extensive margins requires fixing both firm entry and the cutoffs.

To hold firm entry fixed, I use a sunk cost that is convex in the deviation of firm entry from its steady-state level, as in Fattal Jaef and Lopez (2014): $f_{E,t} = f_E + \pi_f \left[\exp(N_{E,t} - \overline{N}_E) - 1\right]$. As such, the sunk cost increases rapidly if firm entry rises above its steady state and, conversely, decreases if firm entry falls below it. By setting parameter π_f to be very high (i.e., $\pi_f = 10,000$), the number of new firms is virtually fixed and matches the number of firms that exit every period; thus, the stock of firms is constant. Similarly, to fix the offshoring and exporting cutoffs, the fixed cost is convex in deviations of the cutoff from its steady-state value. For offshoring, the fixed cost is: $f_{V,t} = f_V + \pi_f \left[\exp\left(z_{V,t}^{cutoff} - \overline{z_V^{cutoff}}\right) - 1\right]$.

4 Results

4.1 Impulse responses

To illustrate the mechanism of offshoring and its aggregate implications, I log-linearize the model around the steady state and compute impulse responses for key variables to a transitory one-percent increase in aggregate productivity in the North. Aggregate productivity follows the autoregressive process $\log Z_{t+1} = \rho \log Z_t + \xi_t$, with persistence $\rho = 0.9$.

4.1.1 Baseline model

In the baseline model (solid lines in Fig. 4), the increase in aggregate productivity in the North (Z) generates a proportional increase in the domestic real wage (w) on impact. In the quarters after the shock, as aggregate productivity persists above its steady state, firm entry leads to a gradual increase in the stock of firms (N).[25] In turn, higher demand for labor boosts the cost of effective labor in the North, as shown by the real wage declining more slowly than aggregate productivity after the initial increase.[26] As a result, the terms of labor (TOL) appreciate (fall) over time relative to their steady-state level, reflecting the increase in the cost of effective labor in the North relative to the South. The number of offshoring firms (N_V) rises on impact and continues to increase gradually over time, in line with the gradual buildup in the stock of firms in the North. The number of offshoring firms rises for two reasons. First, entry in the North results in some of the new firms producing directly offshore (i.e., those with idiosyncratic productivity above the cutoff). Second, as the terms of labor appreciate, the offshoring cutoff shifts down, prompting some of the existing Northern firms to relocate production offshore. The increase in the number of offshoring firms (the extensive margin) more than offsets the decline in the value added per offshoring firm (VA/N_V, the intensive margin). Thus, the extensive margin shapes the procyclical pattern of the value added offshore, the total Southern exports, and the Southern output.

To better illustrate the mechanism of offshoring, it is useful to highlight the difference in the dynamics of Southern offshoring and regular exports, which mirror the different behaviors of their extensive margins. (The offshoring exports are initiated by the Northern firms producing offshore; they are described by the same impulse response as the value added offshore; the regular exports are initiated by Southern firms.) As shown in Fig. 4 (solid lines), both the offshoring and the regular Southern exports rise on impact. However, in the quarters after the shock, the offshoring exports persist above their steady state, whereas the regular exports fall below it. The difference reflects the firms' offshoring and exporting decisions that are driven by

[25] Sunk entry costs and the time-to-build mechanism explain the gradual increase in the stock of firms. With higher aggregate productivity, the home market becomes a more attractive location for potential entrants. As productivity persists above its steady state but the stock of operating firms is slow to adjust, firm entry also persists above its steady state. Eventually, firm entry returns to the steady state as the terms of labor appreciate and the temporary boost to productivity fades away.

[26] In the South, the upward pressure on the real wage (w^*) from the increase in Northern demand is dampened by the decline in Southern firm entry.

different factors, although both are subject to fixed costs. As the positive shock to productivity encourages firm entry in the North and the terms of labor appreciate, more of the Northern firms start producing in the South in the quarters after the shock; their action is driven by the cost advantage of producing offshore, rather than by changes in demand. In contrast, as firm entry increases the number of varieties available in the North, the Northern demand shifts away from Southern exports, which causes some of the Southern firms to stop exporting.

Compared with the extreme case with no offshoring (dashed lines in Fig. 4), which revisits the model in GM05, the offshoring exports boost the Southern total exports and output. Following the positive shock to productivity in the North, the Southern total exports and output in the baseline model persist above those from GM05 in the quarters after the shock.[27]

4.1.2 Fixed cutoffs

In the case with fixed offshoring and exporting cutoffs (dashed lines in Fig. 5), the extensive margin still shapes the pattern of the Southern offshoring exports. Following firm entry in the North, the new firms with idiosyncratic productivity above the cutoff start by producing directly offshore. Thus, the number of offshoring firms increases gradually in the quarters after the shock, mirroring the build-up in the stock of firms in the North, even though less than in the baseline case. The value added per offshoring firm (the intensive margin) spikes on impact, then declines below its steady state, but not enough to offset the boost to offshoring exports provided by the extensive margin. Hence, the offshoring exports persist above their steady state, unlike the Southern regular exports that dip below.[28]

Turning to the Southern regular exports, the case with fixed cutoffs results in a smaller adjustment in the number of Southern exporters (the extensive margin), which mirrors the slow-moving stock of Southern firms, but to a larger adjustment in the regular exports per firm (the intensive margin) than in the baseline case. In fact, the intensive margin in the case with fixed cutoffs (dashed lines in Fig. 5) resembles the extensive margin from the baseline case

[27] In the alternative model with no offshoring, $f_X = 0.005$ and $f_X^* = 0.016$ are set so that the exports-to-GDP ratios in the North and the South match those from the baseline model (27 and 41 percent).

[28] The alternative case with a fixed offshoring cutoff provides a lens to abstract from changes in average productivity when assessing the intensive margin dynamics. With a fixed offshoring cutoff, the average productivity of firms above and below the cutoff is constant. In this case, the intensive margin of offshoring rises on impact in response to higher demand, unlike in the baseline case (in which the offshoring cutoff shifts down, the average productivity of offshoring firms declines, and hence the intensive margin changes little on impact).

(solid lines). As the Northern demand for Southern varieties rises on impact but declines in the quarters after the shock, some of the Southern firms would choose to stop exporting. Instead, if exit from exporting is not an option, exporters reduce the volume of exports per firm, since both the extensive and intensive margins of regular exports are driven by demand. Thus, unlike for offshoring exports, the Southern regular exports behave similarly with or without a flexible extensive margin. The result is consistent with the findings in Alessandria and Choi (2007) and Fattal Jaef and Lopez (2014).

4.1.3 Fixed extensive margins

To entirely shut down the extensive margins, I fix both firm entry and the cutoffs for offshoring and exporting (dashed lines in Fig. 6). When the extensive margins are held fixed, the Southern offshoring and regular exports display identical impulse responses, since differences in the behavior of their extensive margins no longer affect the volume of each type of exports. Also, the offshoring exports rise by less on impact and persist below their path from the baseline case, which highlights the role of the extensive margin in enhancing the procylical response of the Southern offshoring exports relative to that of regular exports.

4.1.4 Fixed entry

The alternative model in which firm entry is fixed (but the cutoffs are free to adjust) provides another illustration of the role of the extensive margin in shaping the pattern of offshoring exports (thin lines in Fig. 6). Since the positive shock to productivity in the North is not followed by firm entry, the terms of labor depreciate (rise) on impact; while the cost of effective labor is unchanged in the North, it rises in the South due to the higher Northern demand for Southern varieties. Therefore, the number of offshoring firms drops on impact and persists below its steady state. In turn, the countercyclical extensive margin of offshoring weighs down on the value added offshore, the total Southern exports, and the Southern output, which fall in the quarters after the shock, instead of rising as in the baseline model.

4.1.5 Capital and endogenous labor supply

The model augmented with capital and endogenous labor supply generates dynamics that are largely similar to those from the baseline model. Although investment in capital partially substitutes firm entry, as in Fattal Jaef and Lopez (2014), firm entry is still followed (with a lag) by the appreciation of the terms of production and an increase in the number of offshoring firms (see the Appendix, Fig. E1). Like in the baseline case, shutting down the extensive margins results in identical impulse responses for the Southern offshoring and regular exports, which illustrates the role of the extensive margin in enhancing the procyclical response of the Southern offshoring exports relative to regular exports (Fig. E2).

4.2 Moments

Table 2 presents the moments from model simulations and compares them to the data, for the baseline model and a number of alternative cases.[29] To obtain these moments, I assume that aggregate productivities Z_t and Z_t^* follow the bivariate autoregressive process:

$$\begin{bmatrix} \log Z_t \\ \log Z_t^* \end{bmatrix} = \begin{bmatrix} \rho_Z & \rho_{ZZ^*} \\ \rho_{Z^*Z} & \rho_{Z^*} \end{bmatrix} \begin{bmatrix} \log Z_{t-1} \\ \log Z_{t-1}^* \end{bmatrix} + \begin{bmatrix} \xi_t \\ \xi_t^* \end{bmatrix}, \tag{18}$$

with the persistence parameters ρ_Z and $\rho_{Z^*} < 1$, spillovers ρ_{ZZ^*} and $\rho_{Z^*Z} \geqslant 0$, and normally-distributed, zero-mean technology shocks ξ_t and ξ_t^*.

4.2.1 TFP calibration

The bivariate productivity process is calibrated for the United States and Mexico, based on the Solow residual estimates for the two economies at quarterly frequency over the interval 1987:Q1 to 2003:Q2. For each economy, the natural logarithm of the Solow residual is computed as $\ln \lambda = \ln y - (1-\alpha_\lambda) \ln k - \alpha_\lambda \ln n$, using seasonally-adjusted aggregate data on output (y), the capital stock (k) and employment (n) obtained from Silos (2007) for the United States,

[29] The moments for output, value added offshore, consumption, investment, exports, and imports are based on variables deflated by the average price index $\widetilde{P}_t$ rather than the welfare-based price index P_t, as in GM05. For instance, variable X_t in the North is deflated as $X_{R,t} = P_t X_t / \widetilde{P}_t = \left(N_{D,t} + N_{V,t} + N_{X,t}^*\right)^{\frac{1}{1-\theta}} X_t$, using the decomposition of the price index into its variety and average price components: $P_t = \left(N_{D,t} + N_{V,t} + N_{X,t}^*\right)^{\frac{1}{1-\theta}} \widetilde{P}_t$.

and Aguiar and Gopinath (2007) for Mexico.[30] Following Heathcote and Perri (2002), I use the seemingly unrelated regression procedure to estimate the persistence and spillover parameters from the Solow residuals, as well as the variance-covariance matrix of the shocks.[31] As such, the productivity process is calibrated to be more persistent in the United States than in Mexico ($\rho_Z = 0.996 > \rho_{Z^*} = 0.951$), and the spillovers from Mexico to the United States to be close to zero ($\rho_{ZZ^*} = 0.003$), in contrast with the positive U.S.-to-Mexico spillovers ($\rho_{Z^*Z} = 0.049$). I also set the variance of shocks equal across countries by taking the average standard deviations for the two economies (at 0.00953^2), and the covariance (at 0.242172×10^{-4}) to match the empirical correlation of shocks, as in BKK92 and Heathcote and Perri (2002).

4.2.2 Moments for aggregate variables

The model generates volatilities for output, consumption, and firm entry that are close to the data, although the volatilities of exports and imports are generally less than in the data (Table 2, column 2). Firm entry becomes less volatile in the presence of capital, when the volatility of firm entry and investment are calibrated to match each other, as in the data (see the Appendix, Table E1, column 2). The domestic correlations show that consumption, firm entry, hours worked, investment, and trade flows are all procyclical, while the trade balance is countercyclical as in the data.

The model does not solve some of the well-known puzzles in the international business cycle literature, such as those in BKK92. The cross-country correlation of consumption exceeds that of output, and the correlation between relative consumption spending and the real exchange rate is zero, rather than negative as in the data. Also, in the model with capital and elastic labor supply, labor is negatively correlated across countries, rather than positively like in the data, while investment is positively correlated but less than in the data.

4.2.3 Moments for offshoring

Regarding the cyclicality of offshoring and its implications for output comovement (Table 2, column 2), first, the correlation between the Northern output and the value added offshore

[30] Silos (2007) uses $\alpha_\lambda = 0.64$ for the United States; Aguiar and Gopinath (2007) use $\alpha_\lambda = 0.68$ for Mexico.

[31] The estimates of persistence and spillover parameters are $A = \begin{bmatrix} 0.996\ (0.014) & 0.003\ (0.015) \\ 0.049\ (0.040) & 0.951\ (0.040) \end{bmatrix}$; standard errors are reported in parentheses. Also, $\text{var}(\xi_t) = 0.0051^2$, $\text{var}(\xi_t^*) = 0.0140^2$ and $\text{corr}(\xi_t, \xi_t^*) = 0.267$.

is larger than the correlation between the Northern and Southern output, $Corr(Y, VA) > Corr(Y, Y^*)$. The ranking of correlations is consistent with the data in Fig. 1, which shows that the maquiladora value added is more procyclical than Mexico's total manufacturing IP with the U.S. manufacturing IP. Second, the correlation between the Northern output and the number of offshoring firms is positive, $Corr(Y, N_V) > 0$, as in the data. Third, the Southern offshoring exports are more correlated with the Northern output than is the case for the Southern regular exports, $Corr(Y, EX^*_{VFDI}) > Corr(Y, EX^*_{REG})$. Fourth, since the Southern offshoring exports are more procyclical than the Southern regular exports with the Northern output, varying the share of offshoring exports in the total Southern exports (while keeping the share of total exports in output fixed) should affect the comovement of output between the North and the South. Indeed, as the share of offshoring is lowered from 61 percent in the baseline calibration (column 2) to 42 percent (column 3) and eventually to zero (column 4, which is the limit case of GM05), the correlation of output declines from 0.38 to 0.32 and 0.22.[32] Also, since offshoring enhances the procyclicality of Southern exports, the trade balance in the North becomes less countercyclical when the share of offshoring in Southern exports is lowered across columns 2-4.

In the special case with fixed cutoffs (Table 2, column 5), the number of offshoring firms is still positively correlated with the Northern output, although less than in the baseline case. The Southern offshoring exports are still more procyclical than the Southern regular exports with output in the North, $Corr(Y, EX^*_{VFDI}) > Corr(Y, EX^*_{REG})$. In contrast, when the extensive margins are shut down by fixing both firm entry and the cutoffs (Table 2, column 6), the Southern offshoring and regular exports are equally procyclical with output in the North, $Corr(Y, EX^*_{VFDI}) = Corr(Y, EX^*_{REG})$. In this case, the link between the share of offshoring in Southern exports and output comovement breaks down.

In the special case with fixed firm entry but adjustable cutoffs (Table 2, column 7), the number of offshoring firms becomes negatively correlated with the Northern output, $Corr(Y, N_V) < 0$. The result is consistent with the impulse responses showing that, following a positive shock to productivity in the North, the terms of labor depreciate on impact (rather than appreciating

[32] In the case with a low share of offshoring in the Southern exports ("Low VFDI"), I set $f_V = 0.365$, $f_X = 0.017$, and $f^*_X = 0.02$ so that the exports-to-GDP ratios in the North and South match the corresponding moments from the baseline model in steady state (27 and 41 percent), while offshoring accounts for only 42 percent of the Southern exports (down from 61 percent in the baseline case). In the limit case with no offshoring ("GM05"), $f_X = 0.005$ and $f^*_X = 0.016$ are set so that the exports-to-GDP ratios in the North and the South match those from the baseline model (27 and 41 percent).

as in the baseline case), which prompts some of the Northern firms to bring production back home. With a countercyclical extensive margin, the correlation between output in the North and the value added offshore declines relative to the baseline case (to 0.16 from 0.99). Also, the Southern offshoring exports become less procyclical than the Southern regular exports relative to output in the North, $Corr(Y, EX^*_{VFDI}) < Corr(Y, EX^*_{REG})$, as the countercyclical extensive margin weighs down on the offshoring exports.

4.2.4 Robustness

The model implications are robust under a number of alternative assumptions and calibrations. First, in the model augmented with capital and endogenous labor supply, the moments are similar to those from the baseline model: (1) the offshoring value added and its extensive margin are procyclical with the Northern output; (2) the correlation between the Southern offshoring exports and Northern output exceeds the correlation between the Southern regular exports and Northern output; and (3) a larger share of offshoring exports in the total Southern exports is associated with more output comovement between the North and the South. In contrast, when the extensive margins are held fixed, the Southern offshoring and regular exports are equally correlated with the Northern output, and varying the share of offshoring in Southern exports has little impact on output comovement (see the Appendix, Table E1, columns 2-5).

Second, the model implications hold when the cross-country bivariate TFP process is recalibrated to reflect the standard symmetric case from BKK92 for the United States and Europe, rather than the asymmetric process for the United States and Mexico estimated in this paper.[33] With the TFP process from BKK92, implications (1)-(3) above hold both in the baseline model with labor only and in the model with capital and endogenous labor supply (see the Appendix, Table F1, columns 2-5). In addition, with the BKK92 calibration, the volatility of firm entry over-predicts the data like in GM05, instead of under-predicting it. Firm entry and investment become less procyclical, given the lower persistence of aggregate productivity and lower standard deviation of shocks than in the U.S.-Mexico calibration. As a result, the offshoring value and its extensive margin also become less procyclical, given their link with firm entry in the North.

Third, the results are robust when real model variables and the TFP calibration are adjusted

[33] With the BKK92 calibration, the symmetric persistence and spillovers are $\rho_Z = 0.906$ and $\rho_{ZZ^*} = 0.088$, the variance of innovations is $\text{var}(\xi_t) = var(\xi_t^*) = 0.00852^2$, and the correlation of innovations is $\text{corr}(\xi_t, \xi_t^*) = 0.258$.

to take into account some of the measurement issues that arise when comparing the model to data from statistical agencies, namely the deflators for GDP and its components not reflecting changes in the number and composition of varieties (Burstein and Cravino, 2015), and the data series on investment excluding expenditures related to firm entry (Fattal Jaef and Lopez, 2014). For this purpose, the model with capital and endogenous labor supply is adjusted as follows: (1) Real GDP is computed by deflating each expenditure component separately using its own deflator (consumption, investment, exports, and the offshoring and regular imports), as in Burstein and Cravino (2015), while excluding the expenditures with firm entry (see the Appendix, section F2). (2) The exogenous TFP process is re-calibrated to allow for lower persistence of aggregate productivity and a higher standard deviation of shocks than in the benchmark BKK92 calibration, thus taking into account the endogenous effect of firm entry on the model-based TFP discussed in Fattal Jaef and Lopez (2014).[34] In each case, the calibration ensures that the volatilities of firm entry and investment match each other, as in the data. Using the new definition of real GDP and deflators specific to each component boosts the volatility of output relative to other variables, but leaves the correlations largely unchanged (in the Appendix, see Table F2, columns 2-3). In addition, adjusting the exogenous TFP process enhances the volatility of output, firm entry, labor, and investment, given the higher standard deviation of shocks, but leaves the correlations mostly unchanged (columns 4-5). Thus, the baseline model predictions are not driven by changes in the composition of varieties affecting the model-based measures of output and price indices when new firms enter the home economy and/or production is relocated offshore. Rather, the model predictions are robust when these measures are computed in a manner consistent with the data series on which the observed link between offshoring and output comovement is based.

[34]To illustrate this case, I adjust the BKK92 process to use $\rho_Z = 0.85$, $\rho_{ZZ^*} = 0.088$, $\text{var}(\xi_t) = var(\xi_t^*) = 0.0120^2$, and $\text{corr}(\xi_t, \xi_t^*) = 0.1$. As shown in Fattal Jaef and Lopez (2014), following a positive shock to the exogenous aggregate productivity, the rise in firm entry poses a drag on the model-based endogenous TFP on impact, since the creation of new firms triggers a reallocation of labor from production toward entry-related activities. The pattern is subsequently reversed as the stock of incumbent firms rises over time. Therefore, by setting lower persistence parameters and higher standard deviation of innovations, the endogenous model-based TFP process is more closely aligned to the data.

4.3 Offshoring and output comovement

This section examines the relationship between offshoring and output comovement generated by my model, and compares it to the empirical evidence in BKT08: Namely, while controlling for the share of exports in output, a higher share of offshoring-related trade in bilateral trade is associated with more output comovement. Using annual data on manufacturing value added and trade for the United States and 34 trading partners, BKT08 estimate the cross-sectional regressions shown at the top of Table 3. First, in the equation at the top of Panel 1, the dependent variable is the correlation between manufacturing output in the United States and output in each of its trading partners over 1983-2005, while the explanatory variables are a proxy for the share of offshoring-related trade in bilateral trade (with coefficient β_1), and the share of exports to the United States in each trading partner's manufacturing output (with coefficient β_2). The BKT08 empirical results (row 1) indicate a positive link between output comovement and the share of offshoring in bilateral trade: $\beta_1 = 0.746$ is statistically significant at the 5 percent level, whereas $\beta_2 = 0.140$ is not statistically significant. Second, the univariate regression at the top of Panel 2 shows that a higher share of offshoring-related exports in the foreign economy's output is also associated with more output comovement, as $\beta = 0.940$ is statistically significant at the 5 percent level.

To compare my model results to the empirical evidence, I run similar regressions using artificial data generated by the baseline model of offshoring and, alternatively, by the model with fixed extensive margins. The comovement of output (the dependent variable) is computed for alternative calibrations that vary the steady-state shares of offshoring and regular exports in output. To obtain the alternative calibrations, I iterate the fixed costs of offshoring and exporting to take values from the intervals $f_V \in [0.045, 0.405]$, $f_X \in [0.005, 0.071]$, and $f_X^* \in [0.016, 0.038]$. For each alternative calibration, $Corr(Y, Y^*)$ is computed using the bivariate TFP process for the United States and Mexico.

To visualize the model-generated data, Fig. 7 shows the relationship between the share of offshoring exports in the total Southern exports (on the horizontal axis) and the correlation of output (on the vertical axis). The chart shows the values generated by the baseline model (full dots) and by the alternative model with fixed extensive margins (empty dots) for the set of calibrations that keep the exports-to-GDP ratios in the North and the South close to their original calibration values (i.e., ± 0.0015 around 0.27 and 0.41). Thus, while controlling for the share of exports in output, the baseline model generates a positive relationship between the share of offshoring in Southern exports and output comovement, in line with the empirical evidence in BKT08. In contrast, when the extensive margins are held fixed, the slope between the share of offshoring in exports and output comovement is almost zero.

To quantify the relationship between offshoring and output comovement generated by my model, Table 3 also shows results from regressions similar to those in BKT08 ran with the model-generated data described earlier. For the baseline case (Table 3, row 2), in Panel 1, the coefficient on the share of offshoring in Southern exports is positive and statistically significant ($\beta_1 = 0.345$); it is about half the value of its empirical counterpart. While controlling for the share of offshoring, the same regression generates a negative coefficient on the ratio of total exports to output (β_2), like in the model with no offshoring (row 6), while the empirical coefficient in BKT08 is positive but not statistically significant. In Panel 2, the coefficient on the share of offshoring in Southern output is also positive and statistically significant ($\beta = 0.616$); it is about two-thirds the value of its empirical counterpart.

In the alternative model with fixed extensive margins (row 3), the relationship between the share of offshoring in Southern exports (or output) and output comovement breaks down. The corresponding coefficients are one order of magnitude smaller than in the baseline case ($\beta_1 = 0.032$ and $\beta = 0.089$). As discussed in Sections 4.1 and 4.2, when the extensive margins are shut down, there is no longer a distinction between the Southern offshoring and regular exports, and hence varying the share of offshoring exports in total exports (while keeping the share of exports in output fixed) has little impact on output comovement.

The positive relationship between offshoring and output comovement is robust when the model is augmented with capital and elastic labor supply (row 4); the corresponding coefficients are about one-half to two-thirds of their empirical counterparts ($\beta_1 = 0.482$ and $\beta = 0.430$). The relationship also holds when, in the baseline model, the productivity spillovers and the correlations of shocks in the bivariate TFP are set to zero, while the persistence and variance of shocks are kept at their original values for the United States and Mexico (row 5).

While the relationship between offshoring and output comovement implied by the model proposed in this paper is consistent with the empirical evidence in BKT08, it is generated by a different mechanism than in their model. In BKT08, the model holds the location of plants fixed over time, and the link between offshoring and output comovement arises due to the asymmetric elasticity of substitution between country-specific goods, which is set to be lower in the offshoring sector than in the regular exports sector. In contrast, in my model, the elasticity of substitution is the same across the two sectors; the link between offshoring and output comovement arises from the asymmetric impact of Northern firm entry on the Southern offshoring and regular exports through their extensive margins.

5 Conclusion

This paper examines the effect of offshoring motivated by lower production costs on the cross-country transmission of business cycles in a model with endogenous firm entry, heterogeneous firms, and endogenous offshoring. The model generates a procyclical pattern of offshoring output and its extensive margin relative to output in the home economy, offshoring exports that are more procyclical than the regular exports, and a positive relationship between the share of offshoring in exports and output comovement, as in the data. The mechanism of comovement arises from the link between firm entry in the home economy, the appreciation of the terms of labor, and firms' decision to produce offshore.

The model proposed here allows for the study of a number of additional implications of offshoring, including the effect on labor market outcomes in the home and foreign economies, and the behavior of real exchange rates when offshoring transfers upward pressure on foreign wages and prices. Nonetheless, the interaction between offshore production and international labor mobility in a framework that distinguishes between tradable and non-tradable sectors represents a topic with rich policy implications.

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Table 1: Average prices and profits

Firm	Origin	Production	Market	Average prices	Average profits
1.	North	North	North	$\widetilde{\rho}_{D,t}=\frac{\theta}{\theta-1}\frac{w_t}{Z_t\widetilde{z}_{D,t}}$	$\widetilde{d}_{D,t}=\frac{1}{\theta}\left(\widetilde{\rho}_{D,t}\right)^{1-\theta}C_t$
2.	South	South	South	$\widetilde{\rho}^*_{D,t}=\frac{\theta}{\theta-1}\frac{w^*_t}{Z^*_t\widetilde{z}^*_{D,t}}$	$\widetilde{d}^*_{D,t}=\frac{1}{\theta}\left(\widetilde{\rho}^*_{D,t}\right)^{1-\theta}C^*_t$
3.	North	South	North	$\widetilde{\rho}_{V,t}=\frac{\theta}{\theta-1}\tau\frac{w^*_tQ_t}{Z^*_t\widetilde{z}_{V,t}}$	$\widetilde{d}_{V,t}=\frac{1}{\theta}\left(\widetilde{\rho}_{V,t}\right)^{1-\theta}C_t-f_V\frac{w^*_tQ_t}{Z^*_t}$
4.	North	North	South	$\widetilde{\rho}_{X,t}=\frac{\theta}{\theta-1}\tau^*\frac{w_tQ_t^{-1}}{Z_t\widetilde{z}_{H,t}}$	$\widetilde{d}_{X,t}=\frac{1}{\theta}\left(\widetilde{\rho}_{X,t}\right)^{1-\theta}C^*_tQ_t-f_X\frac{w_t}{Z_t}$
5.	South	South	North	$\widetilde{\rho}^*_{X,t}=\frac{\theta}{\theta-1}\tau\frac{w^*_tQ_t}{Z^*_t\widetilde{z}^*_{H,t}}$	$\widetilde{d}^*_{X,t}=\frac{1}{\theta}\left(\widetilde{\rho}^*_{X,t}\right)^{1-\theta}C_tQ_t^{-1}-f^*_X\frac{w^*_t}{Z^*_t}$

Table 2: Moments

	Data	Baseline	Low VFDI	GM05	Fixed cutoffs	Fixed ext. margins (entry & cutoffs)	Fixed entry
St. dev.	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Y (abs, %)	1.67	1.14	1.12	1.08	1.17	1.16	1.17
C	0.81	0.82	0.82	0.81	0.82	0.91	0.89
N_E	2.89	2.62	2.72	2.91	2.36	n/a	n/a
EX	2.36	1.02	0.99	0.95	0.81	0.97	1.10
IM	3.25	1.12	1.09	1.04	0.81	0.90	1.23
Dom. corr.							
Y, C	0.86	0.99	0.99	0.99	0.99	0.98	0.97
Y, N_E	0.52	0.89	0.88	0.87	0.90	n/a	n/a
$Y, TB/Y$	−0.49	−0.35	−0.31	−0.23	−0.19	0.52	0.53
Y, EX	0.28	0.82	0.82	0.83	0.78	0.99	0.94
Y, IM	0.61	0.97	0.96	0.92	0.97	0.63	0.43
Int'l. corr.							
Y, Y^*	0.58	0.38	0.32	0.22	0.41	0.47	0.31
Y, VA	0.69	0.99	0.99	n/a	0.99	0.57	0.16
Y, N_V	0.33	0.97	0.98	n/a	0.15	n/a	−0.29
Y, EX^*_{VFDI}	0.42	0.99	0.99	n/a	0.99	0.57	0.16
Y, EX^*_{REG}	0.36	0.84	0.84	0.87	0.81	0.57	0.75
C, C^*	0.36	0.85	0.83	0.80	0.84	0.84	0.81
N_E, N^*_E		−0.67	−0.66	−0.65	−0.63	n/a	n/a
$C/C^*, Q$	−0.35	0.00	0.24	0.37	−0.30	0.98	0.68

Sources: For international correlations, empirical moments use the U.S. manufacturing IP (for Y), Mexico's manufacturing IP (for Y^*), the maquiladora real value added (for VA), and the number of maquiladora establishments (for N_V) provided by the Federal Reserve Board and INEGI, as well as Mexico's merchandise exports (total and maquiladoras) from 1990:Q1 to 2006:Q4 in dollars, deflated by Mexico's PPI, provided by the International Financial Statistics via Haver Analytics. For firm entry, empirical moments are based on the series for net firm entry (for N_E) from 1975:Q1 to 1998:Q4, from Bilbiie, Ghironi, and Melitz (2007, 2012). The data are seasonally adjusted, converted in natural logs, and expressed in deviations from the HP trend. The remaining empirical moments are from

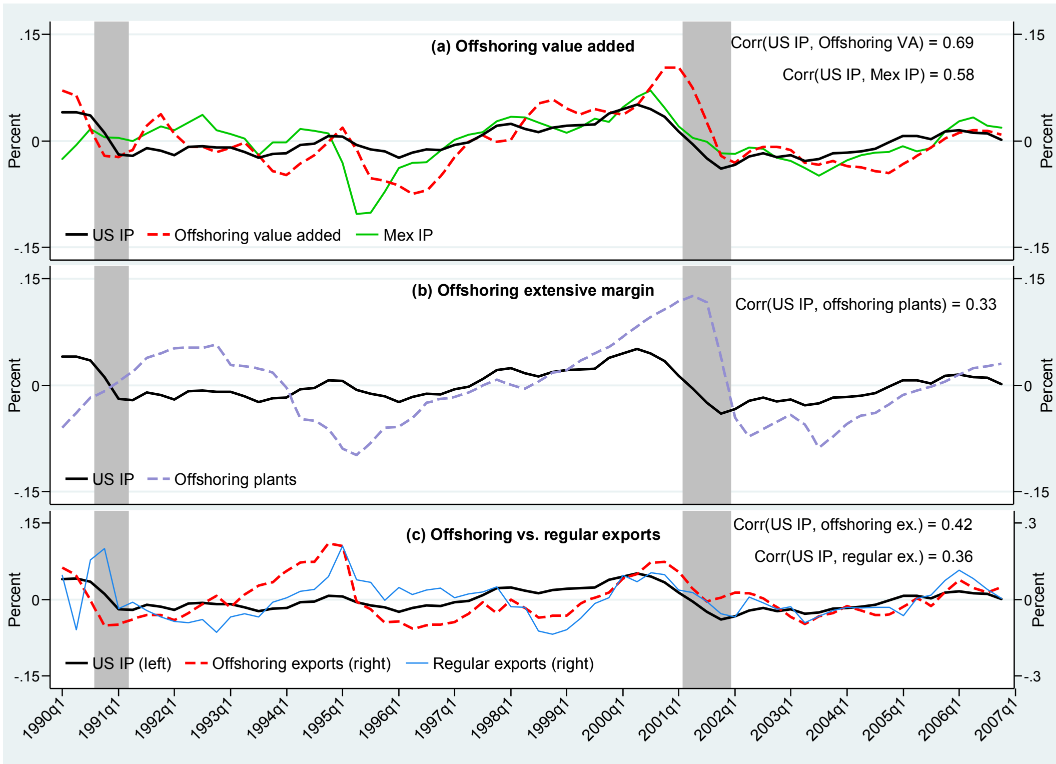
Heathcote and Perri (2002) and Chari, Kehoe, and McGrattan (2002).

Table 3: Offshoring and output comovement

Regression:	Panel 1: $Corr(Y,Y^*) = \alpha + \beta_1 \left(\frac{EX^*_{Offsh}}{EX^*_{Total}}\right) + \beta_2 \left(\frac{EX^*_{Total}}{Y^*}\right) + \varepsilon$				Panel 2: $Corr(Y,Y^*) = \alpha + \beta \left(\frac{EX^*_{Offsh}}{Y^*}\right) + \varepsilon$			
	α	$\boldsymbol{\beta}_1$	$\boldsymbol{\beta}_2$	R^2	α	$\boldsymbol{\beta}$	R^2	*Obs*
1. Data (BKT08)	0.069	**0.746****	0.140	0.25	0.177***	**0.940****	0.18	33
Model:								
2. Baseline	1.013	**0.345**	−2.041	0.99	0.211	**0.616**	0.34	274
3. Fixed ext. margins	0.369	**0.032**	0.192	0.98	0.446	**0.089**	0.74	274
4. Capital & elastic labor	0.971	**0.482**	−1.542	0.98	0.132	**0.430**	0.46	194
5. Zero spill. & corr.	0.244	**0.174**	−0.544	0.99	0.032	**0.352**	0.63	274
6. No offshoring	0.834	–	−1.808	0.97	–	–	–	32

Notes: For the empirical evidence (row 1), the results are from BKT08, with ** and *** showing statistical significance at the 5 percent and 1 percent levels. For the regressions with moment-generated data (rows 2-6), all coefficients are statistically significant at the 1 percent level. The results in row 3 correspond to a version of the baseline model with fixed entry and fixed cutoffs for offshoring and exporting; those in row 4 correspond to the model with capital and elastic labor supply; those in row 5 correspond to the baseline model with the bivariate TFP process estimated for the United States and Mexico, but with zero productivity spillovers and zero correlation of shocks; and those in row 6 correspond to the limit case with no offshoring (GM05).

Figure 1: Business cycle properties of offshoring to Mexico.



Note: The data series are from Federal Reserve Board (for the U.S. manufacturing IP and U.S. real GDP), INEGI (for Mexico's manufacturing IP, real GDP, the maquiladora real value added, and the number of establishments), and the International Financial Statistics via Haver Analytics (for Mexico's maquiladora and non-maquiladora exports in dollars, deflated by PPI). The series are seasonally adjusted, converted in natural logs, and expressed in deviations from a Hodrick-Prescott trend. The shaded areas represent the U.S. recessions during 1990:Q3-1991:Q1 and 2001:Q1-2001:Q4, as defined by the NBER. If the U.S. and Mexico's real GDP are used instead of manufacturing IP, the correlations are largely similar: 0.54 and 0.45 for the U.S. GDP with the maquiladora value added and Mexico's GDP; 0.34 for the U.S. GDP with and the number of maquiladora establishments; 0.55 and 0.34 for the U.S. GDP with Mexico's maquiladora and non-maquiladora real exports, respectively.

Figure 2: The offshoring productivity cutoff.

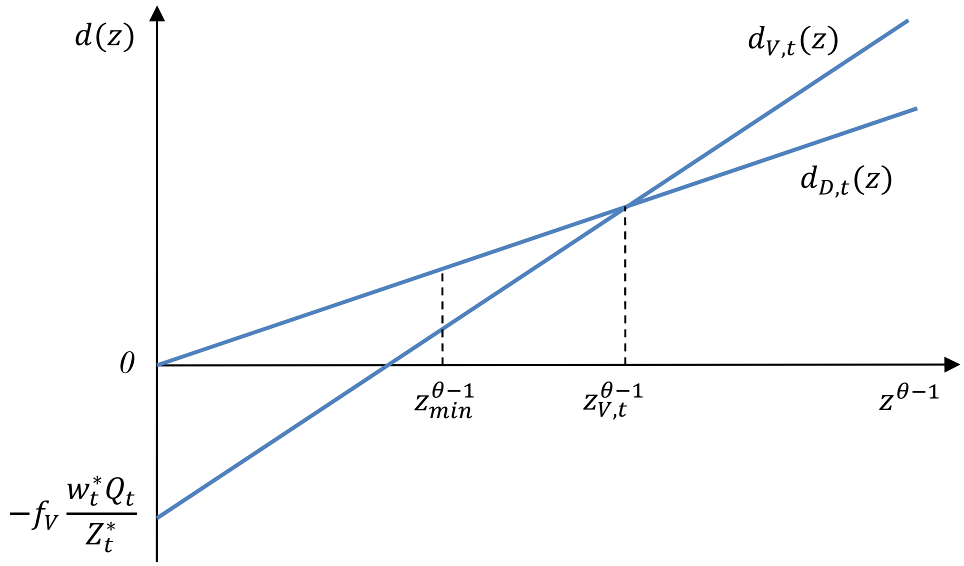


Figure 3: Average productivity of firms producing at home vs. offshore.

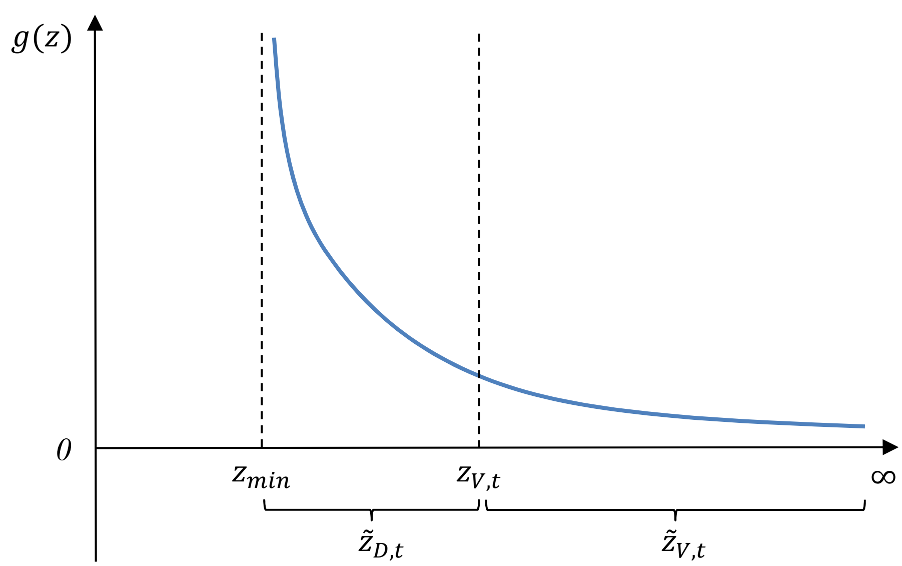


Figure 4. Impulse responses, (1) baseline model vs. (2) model with no offshoring (GM05).

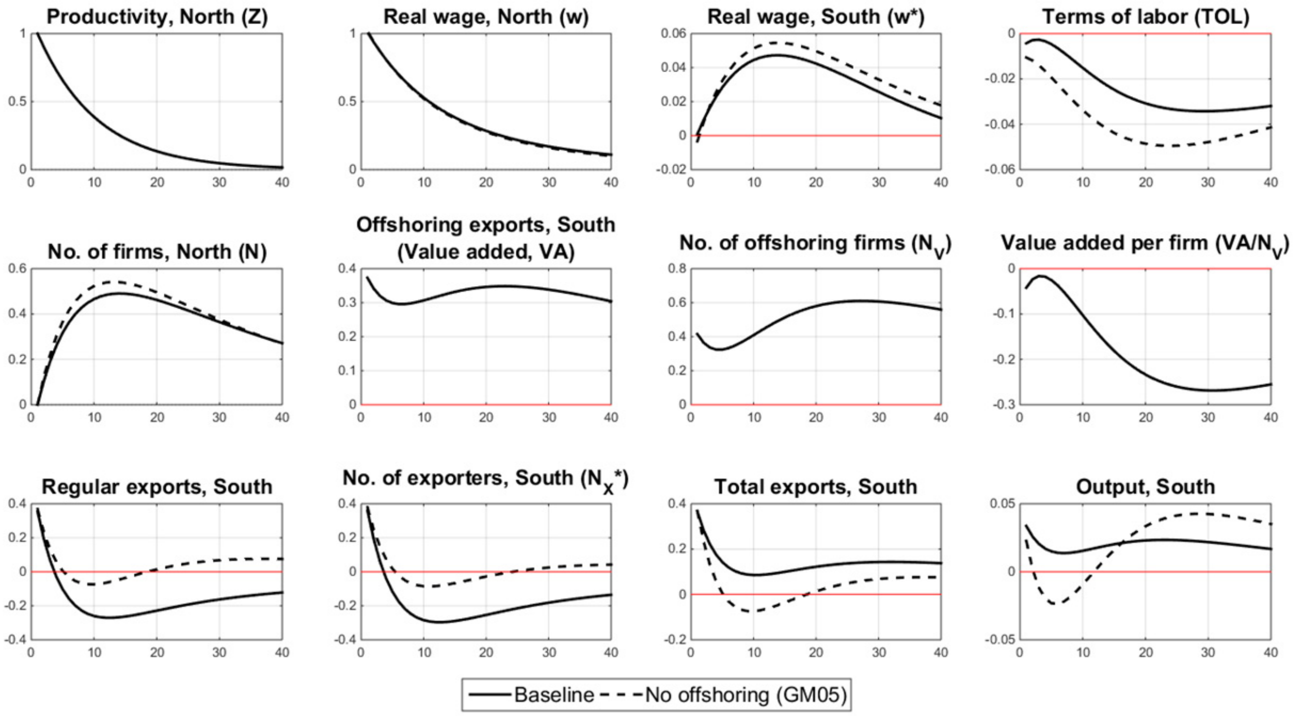


Figure 5. Impulse responses, (1) baseline model vs. (2) model with fixed cutoffs.

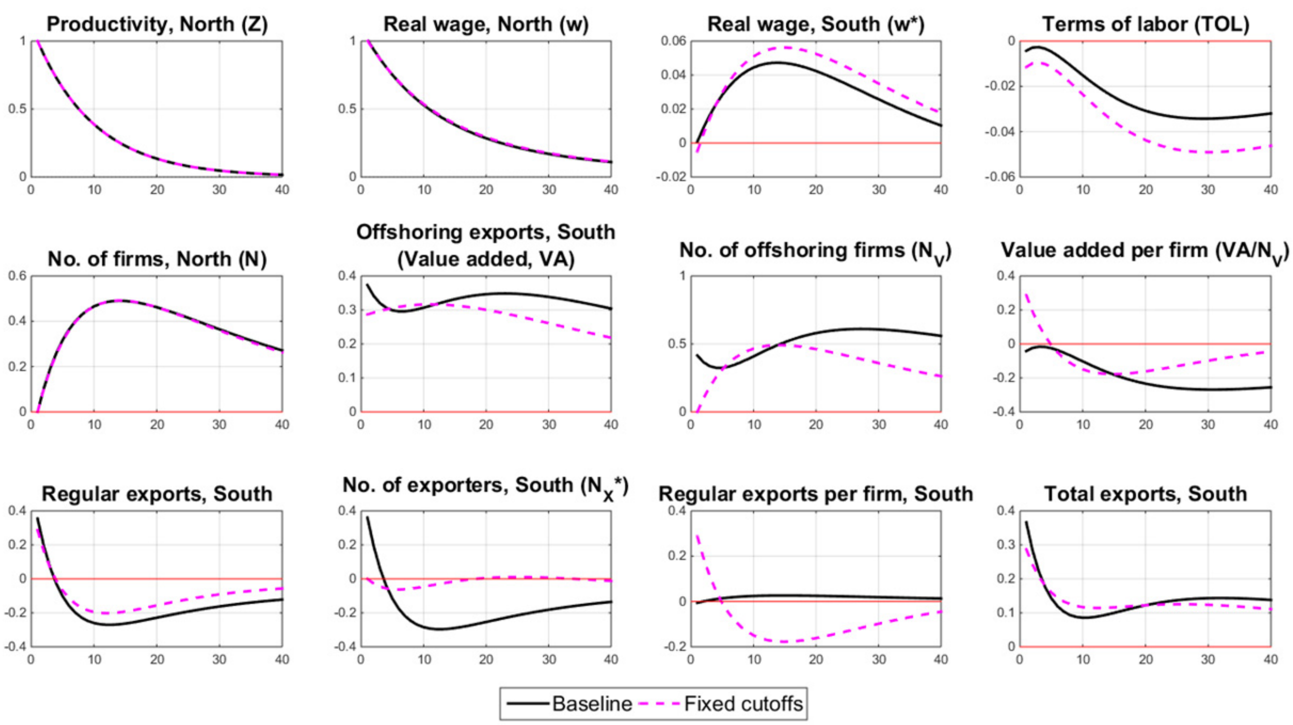


Figure 6. Impulse responses, (1) baseline model; (2) fixed entry and cutoffs; (3) fixed entry.

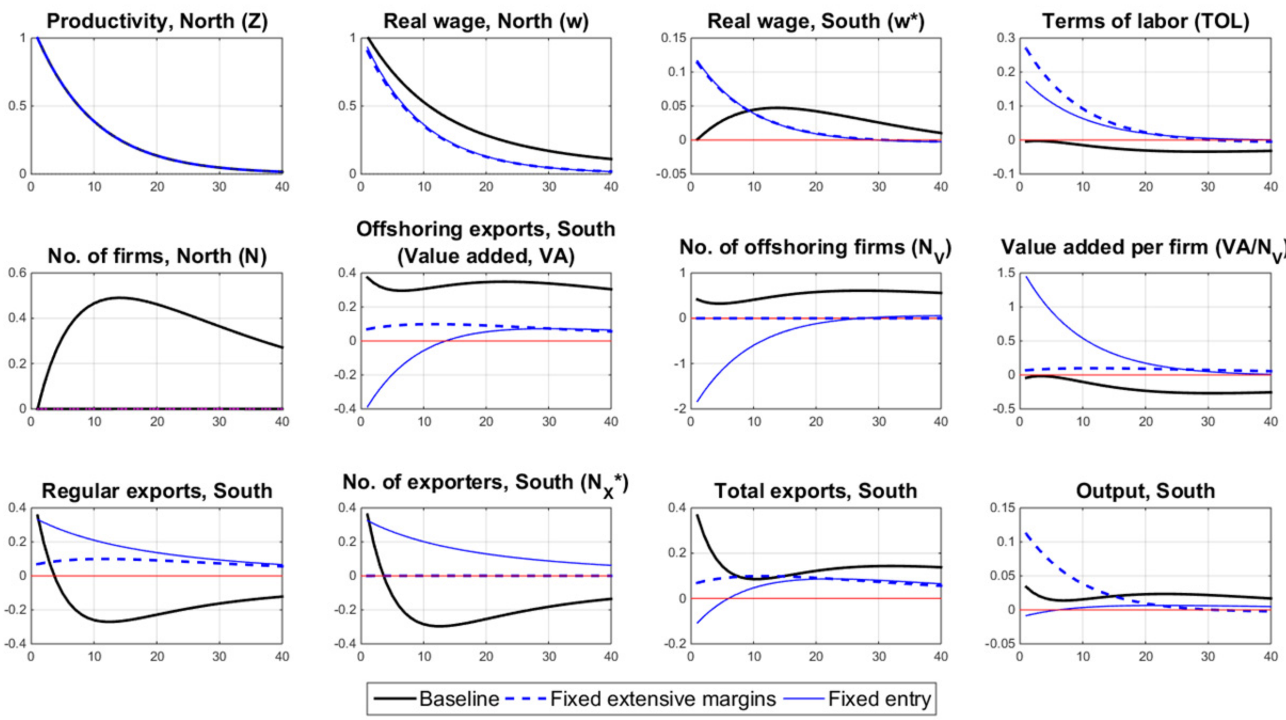
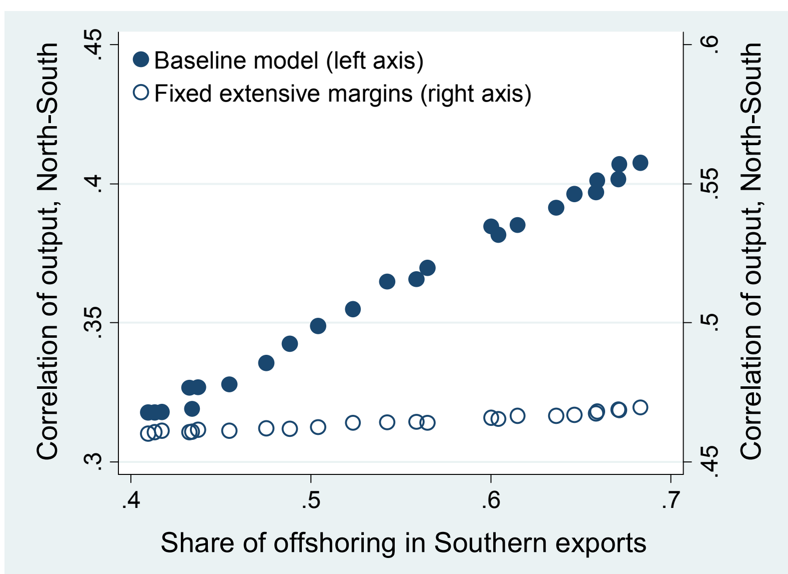


Figure 7: Offshoring and output comovement



Note: "Fixed extensive margins" refers to the model with fixed firm entry and fixed cutoffs for offshoring and exporting. The alternative calibrations vary the share of offshoring in Southern exports (on the horizontal axis) while keeping the ratios of exports to GDP in the North and the South close to their steady-state levels from the baseline model.