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The Pro-Trade Bias of Offshoring

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1 Introduction

Offshoring is an ubiquitous feature of global production and international trade. Reduction in trade barriers, technological change in information and communication and technologies have made possible the routinization of tasks and vast improvements in business-to-business coordination across long distances. These factors have contributed to a drastic reduction in the cost of trade fragmentation facilitated by the offshoring of tasks worldwide. Trade in intermediate inputs now comprises a sizeable share of global trade. According to OECD estimates, over 50% of the value of imports in OECD economies are intermediate inputs (OECD 2009). Johnson and Noguera (2012) found that as high as two-thirds of total merchandise imports for many OECD countries comprised of imported intermediate goods.[1]

The growth in offshoring relationships along the global supply chain precipitates a novel type of interdependence between offshoring partners, hitherto underappreciated in a growing literature on offshoring. To wit, developing countries export offshored labor services to developed countries, only to import final products from developed countries that contain their own countries' labor content. In this paper, we scrutinize the nature of this new form of interdependence between countries, with particular focus on the effectiveness of current rules that guide multilateral trade agreement to disincentivize trade policy violation, and to settle trade disputes.

At the beginning of the century, the domestic content of manufacturing imports, which measures the domestic value added embodied in gross imports from exporting trade partners divided by total gross imports of the exporting country, stood at less than one percent.[2] This scenario has changed in nuanced but notable ways at the country-level. To see this, we take the mean long difference in the domestic content of manufacturing import by importing country between 2005 and 2015 across trading partners, and ascertain the change against the initial log scale of manufacturing production in 2005. Figure 1 displays the resulting picture, which shows quite clearly that the more nascent a country's manufacturing industry in 2005, the larger and the more positive the change in domestic content of imports has been in the ten years between

[1] Of comparable magnitudes, between 1992 and 2008, offshored production from foreign countries contributed to 56% of China's total exports (Sheng and Yang 2017). Imported content comprised 44% of EU exports in 2000 (European Central Bank 2005). In the US, the import content of exports ranged between 12 - 13% from 2008 - 2013 based on OECD statistics on trade and value added.

[2] Based on our calculations using the OECD trade in value added data across 63 countries in 2005.

2005 and 2015.

With this rise in domestic content of imports facilitated by the global value chain, we show that the offshoring relationship has the potential to alter the incidence of commercial policies between upstream (typically emerging markets) and downstream (more often developed country) producers. Specifically, we show that a tax on imports by an upstream country can now implicitly tax the use of workers in the domestic export sector, for the services of these workers are embodied in imports through trade in intermediate goods, for example. Meanwhile, a tax on imports by a downstream country is a direct tax on the hiring of workers upstream as well in the standard way. What are the implications of this form of interdependence between developing country labor market and developed country export market on policy-making with respect to labor and trade? To what extent can the principles that have guided the multilateral trading system decades before the onset of global offshoring, such as market-access and dispute settlement reciprocity, continue to guide countries to make and sustain efficient trade agreements?

To answer these questions, we write a parsimonious model of offshoring and trade. The model features a continuum of varieties of final products, and two countries otherwise similar but for a difference in equilibrium wages that facilitates international task offshoring (Grossman and Rossi-Hansberg 2008). We perform simple comparative statics to formally demonstrate the asymmetric wage response to an import tariff levied respectively by the upstream and the downstream country. The model can be flexibly extended to demonstrate that the wage comparative statics of the parsimonious model continues to hold incorporating (i) an endogenous extensive margin of the complexity of tasks offshored, (ii) market power, (iii) an endogenous number of varieties, and (iv) cross-substitution in demand between varieities.

We then consider the effects of a trade dispute between a developed and a developing nation who have a trading as well as an offshoring relationship. According GATT Article XXVIII and Article 22.4 of the Dispute Settlement Understanding, a trade agreement violation or withdrawal of concessions by any one party is to be met by an equivalent and compensatory market access re-balancing, leaving total trade unchanged for all parties concerned (Anderson 2002, WTO 2005). In a seminal paper, Bagwell and Staiger (1999) shows that market access reciprocity can guide self-interested countries to sign efficient trade agreements. Similarly, dispute settlement reciprocity negates incentives for trade agreement violations. The underlying

trade model that justified these features of a trade agreement is a trade in final goods model, where the salient features of economies engaged in offshoring relationships are not accounted for. The only exception is Antras and Staiger (2012). This paper studies a setting where a hold-up problem arises when contracts between buyers and producers are incomplete. In this setting, input trade subsidies and free trade in the final goods resolve the hold up problem. Furthermore, if governments' objective include political economy considerations, reciprocity is no longer able to guide countries to reach an efficient trade agreement.

Our paper departs from the contracting holdup issue, and focuses instead on the role of developing country labor market institutions in the offshoring story. We work with a setting where some production tasks for one of the goods is offshored by the developed nation to the developing nation. The developed nation imposes an import tariff, and the developing nation retaliates with her own import tariff. We show that while the developed nation's import tax improves the developed nation terms-of-trade in the standard way, the import tax can additionally reduce offshoring cost by depressing the developing nation wages. By sharp contrast, we show that developing nation retaliation may be rendered strictly undersirable, as imported goods from the developed country are manufactured with developing nation labor content through the offshoring linkage. An import tax by the developing nation only succeeds in damaging the terms of trade of the developing nation further.

The insight that ensues is thus that offshoring introduces interdependence between trading partners that (i) enhances the incentives on the part of the developed nation to violate a free trade agreement, while it (ii) constrains the ability of the developing nation to retaliate in response to a developed country tariff. We show this by taking up the dispute settlement reciprocity clause of the WTO (Bagwell and Staiger 2012), which provides guidance on how countries should retaliate against tariff violations. We show that in the presence of an offshoring relationship, there are situations where retaliation by the developing nation can in fact be incapable of nullifying the terms of trade consequence of the trade violation that instigated the trade dispute. Without effective retaliation that are time consistent in the punishment phase, a trade agreement with dispute settlement reciprocity cannot prevent trade wars.

A prime and recent example is the US-China trade disputes that began in 2018. The trade war began with dollar-for-dollar retailation between the two countries, in terms of both the value of market access affected, and tariff rates applied from January 2018 to August 2018.

In subsequent periods, China's match of US's new trade restrictions decelerated in market access terms. Trade weighted average U.S. tariff on Chinese products was at 3.1% in January 2018 compared to the 8.0% Chinese average. By September 2019, the U.S. average tariff and the Chinese average tariff converged at 21% (Bown 2020).[3]

In addition to the US-China trade war anecdote, we found additional suggestive evidence that the likelihood that a country confront trade policy violations by partner country indeed depends on their position along the global value chain, and the intensity of the domestic content of imports in particular. In order to assess the relationship between the domestic content of imports and trade disputes, we use the Bown-Reynolds (2014) WTO trade disputes data from to construct a trade dispute incidence matrix across 2,450 country pairs from 2005-2011. For each importer(j)-exporter(i) pair at year t, we ascertain the likelihood that an importer country j launches a WTO dispute against exporter country i as a function of the intensity of the domestic (country j's) content of imports from i. We measure this intensity in multiple ways. Including (i) a dummy variable (Domestic Content Dummy(5%)) which equals one when the domestic content of imports exceeds the value of total imports by 5% in industry sector in year t, (ii) the average domestic content of imports as a share of the value of total imports (Domestic Content Share) in year t. Table 1 summarizes the data. On average, WTO trade disputes occurred in 0.25% of the country pairs. The domestic content of imports constitutes 0.25% of total imports on average. In 5.45% of the country pair-year observations, the domestic content of import as a share of total imports exceeds 5% in at least one of the sectors. Interestingly, and just based on the raw data, a country-pair is more than three times more likely to be engaged in a trade dispute if the importer's domestic content of import exceeds 5% of total imports in at least one sector.

Table 2 displays the results of logit regressions with year fixed effects that assess likelihood of a trade dispute between an importer-exporter pair in year t as function of the intensity of the domestic-content of import. The first two columns measures the intensity of the domestic content of import using the domestic content dummy, and the domestic content share variable

[3]The list of tariff proposed also reflect the different stages of production by the US and China along the global supply chain. For example, the first list of tariffs proposed by the US included 1,333 products, of which intermediate inputs and capital equipment comprised close to 85% of the $50 billion of imports subject to proposed import tariff (Lovely and Liang 2018, Bown 2018). Subsequently, China retaliated by announcing a list of US exports facing Chinese tariffs, including not just food and materials imports, but also electronics including televisions, cell phones, machinery, vehicles, medical instruments, plastic products for example that worth $75 billion.

respectively. The last specification accounts for scale effects by separately entering the value of the domestic content of imports of an importer-exporter pair, and the total value of production of the importer. In all three regressions, an increase in the intensity of the domestic content of imports increases the likelihood of a trade dispute between an importer-exporter pair.

In view of such asymmetries between upstream and downstream countries, we propose a potential remedy. The idea is to set up labor market institutions and policy measures ensure a stable level of factor market terms of trade, in order to (i) tame the incentives on the part of developed countries to violate trade agreements in order to reap developing country wage benefits, and (ii) to restore the benefits associated with retaliation in response violation of trade agreement beneficial. We demonstrate these ideas using a well-enforced, and binding minimum wage as a potential candidate. Naturally, perfect enforcement is a tall order. Likewise, a two-country world is a far cry from reality. We turn to a series of extension of the basic model where we examine the scope for labor standards to contribute, rather than deter, offshoring relationships between countries.

2 Related Literature

This paper is related to a growing volume of studies on offshoring that has so far been concerned primarily with the wage and employment consequences of offshoring. The benefits of offshoring in terms of employment generation and wage increases in the offshoring country have been shown in a number of studies. Mankiw and Swagel (2006) examines employment levels in the overseas affiliates of US multinational firms and the US parent. Harrison and McMillan (2011) points to the need for a more nuanced look at the offshoring and employment relationships, by pointing out the need to distinguish between horizontal and vertical foreign investment, while Ottaviano, Peri and Wright (2013) additionally shows that along the spectrum of tasks organized by degree of complexity, offshoring competes with both immigrant workers as wellas native workers in the United States. Mitra and Ranjan (2010) introduces search friction into the Grossman and Rossi-Hansberg setting, and Ranjan (2013) demonstrates the importance of labor market institutions such as the employer-employee bargaining relationship. Hummels, Munch and Xiang (2016) is an excellent survey of the literature. In this paper, we contribute to this line of studies by adding the impact of offshoring relationship to trade policy setting as an additional wage consequence associated with offshoring.

Most of this literature has been focussed on developed countries. Two exceptions are Feenstra and Hanson (1996, 1997), where examine the impact of offshoring on wage inequality between developed and developing countries, and show that the skill intensities of the tasks offshored play a critical role. Davidson, Matusz and Shevchenko (2008) presents a two country model of offshoring with search friction. A reduction in the cost of posting a vacancy in the developed country is shown to increase offshoring, and raise wages. Bergin, Feenstra and Hanson (2011) shows interestingly that offshoring stabilizes wages in the developed country, while adding volatility to developing country wages as offshoring activities respond to business cycle effects. Bandyopadhyay et al. (2019) formulates a basic model of tasks offshoring as in Grossman and Rossi-Hansberg (2008), and show that even in this simplest setting, a developing country wage increase when offshoring cost declines is not a guaranteed prosposition, and depends instead on general equilibrium labor demand elasiticities in the two countries. This paper contributes this literature by pointing out that wages in the developing country in the presence of offshoring is ultimately the outcome of labor market institutions and trade policy interactions between developed and developing country. Furthermore, we show that labor market policies can in fact alter governments' ability to abide by the terms of a free trade agreement.[4]

Finally, this paper is also related to the globalization and labor standards literature, where the predominant focus is that globalization leads to a cut-throat race in developing countries' effort to outcompete one another in terms of wages. Some argued that strict regulations regarding labor standards deters free participation and competition in the global economy (Collier and Dollar 2002), while other studies have shown it is globalization that unleashes a race to manipulate labor standards (Chau and Kanbur 2006, Olney 2013). Despite these concerns, Rodrik (1996), Bhakshi and Kerr (2010) and Flanagan (2003) use proxies of labor rights (e.g. adoption of ILO conventions) and fail to find empirical support for a negative relationship between international labor standards harms exports. Our paper contributes to this literature by staging the determinants of trade flows from the broader perspective of whether countries are able sign credible trade agreements with one another in the presence of an offshoring relationship. Our findings sheds light on an empirical literature that has so far been met with

[4]For studies that share the developing country focus of this paper but examine other aspects of offshoring, see for example, Díez (2014) that investigates the impact of tariffs on offshoring and intra-firm trade decisions in a North-South framework, and Burstein and Vogel (2010) in which the focus is on the impact of offshoring on the skill premium in Northern and Southern countries.

confounding answers, and suggest the presence of offshoring as a critical component of a more nuanced understanding.

3 A Parsimonious Model of Offshoring and Trade Taxes

Consider a two-country (developed (foreign, F) and developing (home, H) country) setting. The two countries are home to L^* and L number of workers respectively. There are two sectors in each country, respectively x, a tradable, and y, a non-tradable sector.

Sector y produces a homogeneous product, to be designated henceforth as the numeraire. x is a tradable sector, in which a continuum of varieties of product x are produced. Let $z_n \in [0, N]$ and $z_{n^*} \in [0, N^*]$ denote the ranges of varieties produced in the developing nation, respectively bound for local and foreign country consumption. Similarly $z_m \in [0, M]$ and $z_{m^*} \in [0, M^*]$ denote the ranges of varieties produced in the developed nation, to be consumed in the home and the foreign country respectively. For the time being, these ranges are fixed, and role of endogeneous entry will be addressed in Section 5. Let q_z and q_z^* denote home and foreign consumption of variety z. q_y and q_y^* are the consumption of good y in the two countries.

Preferences of consumer i in the home country are represented by a utility function:

$$U(q_{iz}, q_{iy}) = q_{iy} + \int_0^N u(q_{iz_n})dz_n + \int_0^M u(q_{iz_m})dz_m.$$

where $u(q_{iz}) = (\alpha - \gamma q_{iz}/2)q_{iz}$, and $z = (\{z_n\}_{n=0}^N, \{z_m\}_{m=0}^M)$. These yield aggregate demand for each variety z_n and z_m in sector x as functions of market prices p_{z_n} and p_{z_m} respectively:

$$q_{z_n}(p_{z_n}) = L(\alpha - p_{z_n})/\gamma, \;\; q_{z_m}(p_{z_m}) = L(\alpha - p_{z_m})/\gamma.$$

Similarly in the developed country,

$$U^*(q_{iz}^*, q_{iy}^*) = q_{iy}^* + \int_0^{N^*} u^*(q_{iz_{n^*}}^*)dz_{n^*} + \int_0^{M^*} u^*(q_{iz_{m^*}}^*)dz_{m^*}$$

where $u^*(q_{iz}^*) = (\alpha^* - \gamma^* q_{iz}^*/2)q_{iz}^*$, and $z = (\{z_{n^*}\}_{n^*=0}^{N^*}, \{z_{m^*}\}_{m^*=0}^{M^*})$, with aggregate demand given prices $p_{z_{n^*}}^*$ and $p^*(z_{m^*})$:

$$q_{z_{n^*}}^*(p_{z_{n^*}}^*) = L^*(\alpha^* - p_{z_{n^*}}^*)/\gamma^*, \;\; q_{z_{m^*}}^*(p_{z_{m^*}}^*) = L^*(\alpha^* - p_{z_{m^*}}^*)/\gamma^*.$$

Turning now to production technologies, let $G_y^*(L_y^*)$ and $G_y(L_y)$ respectively denote production in y in the two countries, both employing labor only subject to strictly diminishing

marginal returns. Let $L_y^*(w^*) = \{L_y^* | \partial G_y^*(L_y^*)/\partial L_y^* = w^*\}$ and $L_y(w) = \{L_y | \partial G_y(L_y)/\partial L_y = w\}$ denote the corresponding labor demand schedules at wages w^* and w.

Production of a unit of any variety of x requires a continuum of labor tasks $i \in [0,1]$ to be performed. Developing country producers of x employ only domestic workers. Each task can be accomplished by a number of developing country workers, implying a unit cost of production $c = aw$ symmetrically for each of the $N + N^*$ varieties.

Foreign producers of x allocate production tasks between the two countries. Let $\tau \in [0,1]$ denote the share of production tasks in the foreign country that can be performed in the home country. Task offshoring entails a cost. Expressed in units of labor, each task offshored requires $\beta A^* > A^*$ number of home country workers to complete, when all tasks can be completed in the foreign country with A^* number of workers. $\beta > 1$ parameterizes the cost of offshoring. Denote $a^* \equiv (1-\tau)A^*$ be the foreign labor requirement of a unit of x in the foreign country, and $a_o^* \equiv \beta\tau A^*$ as the corresponding home labor requirement. The unit cost of production for each of the $M + M^*$ varieties is

$$c^* = a^* w^* + a_o^* w^*.$$

The two countries have at their disposal import taxes t and t^* on trade in good x. We consider competitive pricing of x here, and leave the case of market power to Section 5. Accounting for unit costs (c and c^*) and trade taxes (t and t^*), let L_x and L_x^* denote labor demand in sector x in the two countries:

$$L_x(w, w^*, t, t^*) = \bar{\alpha} - [\ell(t^*)a + o(t)a_o^*]w - \ell^*(t)a_o^* w^*, \tag{1}$$

$$L_x^*(w, w^*, t) = \bar{\alpha^*} - o(t)a^* w - \ell^*(t)a^* w^* \tag{2}$$

where $\bar{\alpha}$ and $\bar{\alpha}^*$ refer to country- and sector-specific demand shifters:

$$\bar{\alpha} \equiv \frac{\alpha L(Na + Ma_o^*)}{\gamma} + \frac{\alpha^* L^*(N^* a + M^* a_o^*)}{\gamma^*} \tag{3}$$

$$\bar{\alpha^*} \equiv \frac{\alpha L M a^*}{\gamma} + \frac{\alpha^* L^* M a^*}{\gamma^*}. \tag{4}$$

These capture demand shifts governed by the size of the ranges of varieties (N, M, N^*, M^*), the height of preference parameters α and α^*, as well as the size of the labor requirements parameters (a, a^*, a_o^*).

Own-price labor demand responses in the home country come from two sources, summarized by $\ell(t^*)$ and $o(t)$, to respectively refer to labor demand arising from home production of

x for home country consumption and home country exports $\ell(t^*)$:

$$\ell(t^*) \equiv \frac{LNa}{\gamma} + \frac{L^*N^*a(1+t^*)}{\gamma^*},$$

as well as labor demand to complete offshored tasks for foreign country consumption and foreign country exports $o(t)$:

$$o(t) \equiv \frac{LMa_o^*(1+t)}{\gamma} + \frac{L^*M^*a_o^*}{\gamma^*}.$$

(1) also displays the cross-price labor demand response as $\ell^*(t)$, where:

$$\ell^*(t) \equiv \frac{LMa^*(1+t)}{\gamma} + \frac{L^*M^*a^*}{\gamma^*}.$$

Cross-price effects applies in the presence of offshoring ($a_o^* > 0$). As foreign wages rise, demand for offshored tasks falls as foreign and domestic labor are complements in this task-based setting.

Trade policies t and t^* act on the home country labor market through two channels. Consider first the dependence of home country labor demand on the foreign country import tax, $\ell(t^*) = LNa/\gamma + L^*N^*a(1+t^*)/\gamma^*$. In the usual way, a foreign country import tax dampens demand for home country exports, and thus the demand for home country as well. The strength of this link depends on the number of varieties of home exports N^*, the size of the foreign market L^*, and the labor requirement a.

Offshoring introduces a new channel of influence going from home country import tax t to home country labor demand, $o(t) = LMa_o^*(1+t)/\gamma + L^*M^*a_o^*/\gamma^*$. In particular, a home country import tax dampens home demand for imports from the foreign country, and thus the demand for home country workers employed to complete offshored tasks. Plainly, when imports embody domestic contents, an import tariff can adversely impact home country labor demand. The strength of this link depends on the number of varieties of the foreign country, the size of the home market L, and the labor requirement a_o^*.

Foreign country labor demand in (2) likewise display a cross-price effect through $o(t)$ and an own-price effect through $\ell^*(t)$. In this setting, a home country import tax depresses demand for foreign country exports jointly through $o(t)$ and $\ell^*(t)$, for its effect on labor demand is equivalent to an equiproportionate increase in w and w^*.

Taken together, full employment in the two countries requires that:

$$L(w) = L_x(w, w^*, t, t^*), \tag{5}$$

$$L^*(w^*) = L_x^*(w, w^*, t) \tag{6}$$

where $L^*(w^*) \equiv \mathcal{L}^* - L_y^*(w^*)$ and $L(w) \equiv \mathcal{L} - L_y(w)$ respectively denote effective labor supply to x in the two countries. (5) and (6) above highlight an offshoring-induced asymmetry in the incidence of the import tariffs on the two labor markets. Specifically, an increase in any one of the two tariffs have direct and adverse consequences on home country labor demand, but foreign country labor demand is only affected by the home country import tax.

We are now in a position to examine the general equilibrium impacts of the two import tax rates t and t^* on wages in the two countries:[5]

Proposition 1 *An increase in the foreign country import tax t^* benefits foreign workers through an increase in w^*, and depresses the home country wage w. An increase in the developing country import tax t has a negative impact on both w^* and w.*

Proposition 1 illustrates a hitherto underappreciated consequence of the creation of offshoring linkages, in the form of a reversal in the effectiveness of deploying developing country import tariff to advance the well being of developing country workers. Put simply, since developed country exports contains developing country labor content, rising trade barriers against these exports, in addition to having the standard negative foreign developed country wage consequences, will now also negatively impact the developing country wage as well.

It is also noteworthy that the canonical role of the developing country import tax in reaping terms of trade gains has not changed just because of the introduction of offshoring. Indeed, since both w^* and w decrease upon the introduction of the import tax t, the price of imports, namely $c^* = a^*w^* + a_o^*w$ necessarily decrease subsequent to a rise in home import tariff.

Now a developed country import tax t^* likewise restricts demand for developing country export of labor services directly by impeding developing country export. The result is a reduction in the wage of the developing country. This wage reduction implies a reduction in the cost of offshored tasks, which in turn stimulates demand for developed country workers in x. Thus in sharp contrast to the developing country import tax, an increase in t^* ends up raising w^*.

[5]The proof of this proposition is relegated to the appendix.

4 Rationale for Protection and Retaliation

We now demonstrate the trade policy consequences of the offshoring-induced asymmetry in the effectiveness of using trade policies to advance the well-being of domestic workers, illustrated in Proposition 1.

4.1 The Pro-Trade Bias of Offshoring

From the perspective of the developed country equilibrium indirect utility, with lump sum transfers of tariff revenues back to consumers, is given by:

$$V^* = w^*L^* - L^*\int_0^{N^*} cq^*_{iz_{n^*}} - u^*(q^*_{iz_{n^*}})dz_{n^*} - L^*\int_0^{M^*} c^*q^*_{iz_{m^*}} - u^*(q^*_{iz_{m^*}})dz_{m^*}.$$

where gross national product is simply given by w^*L^*.[6] Evaluated at $t^* = 0$,

$$\frac{dV^*}{dt^*}_{t^*=0} = \left(L^* - a^*N^*q^*_{z_{m^*}}\right)\frac{\partial w^*}{\partial t^*} - a^*_oM^*q^*_{z_{m^*}}\frac{\partial w}{\partial t^*} - aN^*q^*_{z_{n^*}}\frac{\partial w}{\partial t^*}. \tag{7}$$

where $L^* - a^*M^*q_{z^*_{m^*}}$ denotes employment of foreign country workers in y, as well as in the exportable varieties in x. From Proposition 1, unless otherwise penalized, the above shows that the foreign country can expect to benefit from imposing an import tariff for two reasons: to raise the local wages w^*, and to lower the price of her imports w.

General equilibrium indirect utility in the developing country is given by

$$V = wL - L\int_0^N cq_{iz_n} - u(q_{iz_n})dz_n - L\int_0^M c^*q_{iz_m} - u(q_{iz_m})dz_m.$$

Evaluated at $t = 0$,

$$\frac{dV}{dt}_{t=0} = \left(L - aNq_{z_n} - a^*_oMq_{z_m}\right)\frac{\partial w}{\partial t} - a^*Mq_{z_m}\frac{\partial w^*}{\partial t} \tag{8}$$

where $L - aNq_{z_n} - a^*_oMq_{z_m}$ denotes developing country labor employed in the y sector, plus x sector workers producing the N^* exported variety, and the M variety of the products made to be sold in the developing country. From Proposition 1, an import tariff from the developing country lowers w^* by restricting demand for imports with developed country labor content, as it also lowers the wage w in the developing country. These two effects thus work in opposite directions in terms of developing country welfare. Let $s_M = a^*_Mc^*Mq_{z_m}/wL$ as the income

[6] The above follows from budget balance requiring that total consumption of the numeraire commodity is equal to the gross national product (w^*L^*) net of expenditure on the $N^* + M^*$ varieties of sector x products, $L^*\int_0^{N^*} c(1+t)q^*_{z^*_{n^*}}dz^*_{n^*} + L^*\int_0^{M^*} c^*q^*_{z^*_{m^*}}dz^*_{m^*}$, plus tariff revenue $L^*\int_0^{N^*} ctq^*_{z^*_{n^*}}dz^*_{n^*}$.

share of the developing country on imports from the developed country. Using (8), we find that on balance:

Proposition 2 *An small increase in t^* always increases the developed country welfare. An small increase τ is improves the developing country welfare only if s_M is sufficiently large. Otherwise, developing country welfare always decreases with t.*

It follows that an offshoring relationship can give rise to strong disincentives for the developing country to implement unilateral trade restrictions through t. If an import subsidy is not an option due to budgetary considerations, the developing country is better off engaging in free trade even in the absence of a trade agreement. By contrast, the developed country strictly benefits from imposing import tariffs, which stands to raise the foreign wage w^* and lower the price of imports through w.

4.2 Dispute Settlement Reciprocity in the Presence of Offshoring

Consider a trade agreement struck between the two countries wherein a pair of import tariffs (t_0, t_0^*) are to be maintained. Market access reciprocity is a fundamental guiding principle of the World Trade Organization, and in particular, the manner in which trade disputes are settled in the event of any trade agreement violations, are guided by market access stability. Starting from Bagwell and Staiger (2002), and extended to the context of offshoring with Antras and Staiger (2012), dispute settlement reciprocity in a trade agreement stipulates that any unilateral violation of the agreed upon tariffs will be met with counterveiling tariffs such that the value of market access remain unchanged.

Thus, let 0 denote a trade agreement phase (base period), and 1 denote a violation by the developed country with counterveiling tariffs from the developing country. Also let the value of developing and developed country exports in the two periods, evaluated at base period prices be E_s and E_s^* respectively, $s = 0, 1$, where

$$\begin{aligned} E_s &= w_0 \left[aN^* q^*_{z_{n^*}}(c_s(1+t_s^*)) + a_o^* \left(M q_{z_m}(c_s^*(1+t_s)) + M^* q^*_{z_{m^*}}(c_s^*) \right) \right] \\ E_s^* &= c_0^* M q_{z_m}(c_s^*(1+t_s)). \end{aligned}$$

Dispute settlement reciprocity requires that the values of exports remain unchanged in both countries, evaluated at based period prices, or

$$E_1 - E_0 = E_1^* - E_0^*.$$

With balanced trade in both the base ($E_0 = E_0^*$) and the trade violation ($E_1 w_1/w_0 = E_1 c_1^*/c_0^*$) periods, dispute settlement reciprocity effectively requires that:[7]

$$\begin{aligned} & E_1 = E_1^* \\ \Leftrightarrow \quad & w_0 \left[aN^* q^*_{z_{n^*}}(c_1(1+t_1^*)) + a_o^* \left(M q_{z_m}(c_1^*(1+t_1)) + M^* q^*_{z_{m^*}}(c_1^*) \right) \right] = c_0^* M q_{z_m}(c_1^*(1+t_1) \\ \Leftrightarrow \quad & \frac{w_0 - w_1}{w_1} = \frac{c_0^* - c_1^*}{c_1^*}. \end{aligned} \tag{9}$$

Consistent with the Bagwell-Staiger rationale, dispute reciprocity requires that the price of developing country exports $c = aw$ and the price of the developed country export c^* to always change (i) in the same direction, and (ii) at the same rate. Effectively, dispute settlement reciprocity requires that the two countries have at their disposal trade policies that are able to fully nullify any terms of trade gains obtained by another country. In the presence of offshoring, where $c^* = a^* w^* + a_o^* w$, full nullification of terms of trade gains is equivalent to[8]

$$\frac{w_0 - w_1}{w_1} = \frac{c_0^* - c_1^*}{c_1^*} \quad \Leftrightarrow \quad \frac{w_0 - w_1}{w_1} = \frac{w_0^* - w_1^*}{w_1^*}. \tag{10}$$

Thus, dispute settlement reciprocity requires that the countries have trade policies at their disposal to meet any trade policy violation with a counterveiling duties that match any foreign wage gains with domestic wage gains.

Consider therefore a trade agreement violation by the developed country, for example, through an increase in the import tax t^*. From Proposition 1, such an import tax decreases w and increases w^*. Any counterveiling increase in the developing country import tax t will need to ensure that w^* declines, but this comes at the cost of a further reduction in home country wage w. An import subsidy in this case can offset the adverse effect of a developed country import tax t^*, but doing so will only magnify the developed country wage improvement:

Proposition 3 *There does not exist a developing country import tax / subsidy t that can nullify the terms of trade impact of a developed country import tax.*

It follows that an offshoring relationship renders dispute settlement reciprocity ineffective as means to discourage trade agreement violation by the developed country.

[7]The third equality follows by first substracting and then dividing the left hand side by $E_1 w_1/w_0$. By balanced trade in period 1, likewise first subtracting and then divide the right hand side by $E_1 c_1^*/c_0^*$.

[8]To see this, note that $c_0^* - c_1^*)/c_1^* = (1 - \theta_o^*)(w_0^* - w_1^*)/w_1^* + \theta_o^*(w_0 - w_1)/w_1$, implying (9).

4.3 The Labor Standards, Offshoring and Trade Agreement Nexus

So far, we have seen that offshoring harbors a pro-trade bias that impacts developing country trade policy incentives. Particularly when final goods import constitutes a small share of the developing country's total expenditure (Proposition 2), an import tariff worsens developing country welfare, in an otherwise standard two-country setting. This pro-trade bias affects exclusively the developing country. In Proposition 3, we show that the guiding principle of the multilateral trade agreements is not sufficient to deter developed countries from leveraging this asymmetry in trade policy stances. Indeed, the offshoring link can render it impossible for the developing country to use import taxes to nullify the adverse terms of trade impact of trade agreement violations.

What are therefore some available pathways to facilitate and sustain multilateral trade agreements? In a setting where an international holdup problem in the input markets applies due to the lock-in effects of costly search, Antras and Staiger (2012) shows that trade agreements will need to entertain deep integration, in which governments coordinate actions in trade and input market policies. Furthermore, any efficient trade agreement must simultaneously mitigate against incentives for using trade policies to reap terms of trade gains, and reduce the deadweight losses associated with export promotion programs of traded intermediate goods.

While our model does not feature such lock-in effects, our findings agree with Antras and Staiger (2012) in that cooperation may break down if trade agreements continue to focus exclusively on market access in the presence of offshoring. From the developing country point of view, participation in the global supply chain favors international trade policy coordination, because policies that are detrimental to one party is detrimental to others as well along the same supply chain. The key distinction we make here, is that this tendency to favor open trade in the presence of offshoring applies only selectively, and in our case, only to the developing country.

In what follows, we propose an alternative perspective in conceptualizing policy measures that can help sustain an open trade environment between developed and developing countries in the presence of offshoring. Specifically, we seek to illustrate the important role that labor standards play in trade agreements between economies engaged in offshoring relationships. Consider a setting wherein workers in the developing country employed in sector x, inclusive of workers doing offshored tasks, are now protected by a well-enforced minimum wage, $\bar{w}$. In

doing so, developed country producers are not able to undercut $\bar{w}$ when trade tax τ^* increases. The wage in the rest of the economy continues to be competitively determined. It follows that offshoring jobs protected by a minimum wage are rationed, since from (1) - (2)

$$L(w) = L_x(\bar{w}, w^*, t, t^*) = \bar{\alpha} - (\ell(t^*)a + o(t)a_o^*)\bar{w} - \ell^*(t)a_o^* w^*, \tag{11}$$

$$L^*(w^*) = L_x^*(\bar{w}, w^*, t) = \bar{\alpha^*} - o(t)a^*\bar{w} - \ell^*(t)a^* w^* \tag{12}$$

Clearly, a well-enforced minimum wage renders developing country workers in x immune from the perverse wage impact of a developed country tariff t^*. In addition, an increase t^* has no impact on w^*, since a minimum wage in the developing country severs the link between t^* and the cost of hiring developing country workers. It follows that while t^* decreases demand for developing country workers, it will now fail to give rise to a reduction in wage cost $\bar{w}$, nor can it stimulate further demand for developed country worker. Using (11) - (12), a developing country minimum wage eliminates the developed country welfare gains associated with the erection of import barriers:

$$\frac{dV^*}{dt^*}_{t^*=0} = \left(L^* - a^* M^* q^*_{z^*_{m^*}}\right)\frac{\partial w^*}{\partial t^*} - a_o^* q^*_{z^*_{m^*}}\frac{\partial \bar{w}}{\partial t^*} - a q^*_{z^*_{n^*}}\frac{\partial \bar{w}}{\partial t^*} = 0.$$

Turning now to the developing country, from (11) - (12), a well-enforced minimum wage in sector x means that any labor market adjustments due to trade policy changes will need to take place in the numeraire sector. Indeed, an increase in the developing country tariff in the presence of offshoring will continue to have adverse wage consequences, as reduced demand for imports negatively impacts the demand for offshored tasks, implying a lower equilibrium wage in sector y. Since the developing country import tariff negatively affect demand for developed country exports, the developed country labor market adjusts via a reduction in w^*.

Altogether, this means that a minimum wage not only changes the comparative statics of trade policy, the incentives for the developing country to raise her own import barriers change as well:

$$\frac{dV}{dt}_{t=0} = L_y(w)\frac{\partial w}{\partial t} + (\bar{w} - w)\frac{\partial L_x}{\partial t} - (a^* M q_{z_m})\frac{\partial w^*}{\partial t} > 0$$

if a sufficiently small fraction of the developing country's labor force is employed in sector y, and if the minimum wage is set sufficiently close to the competitive wage. In summary,

Proposition 4 *With a binding minimum wage sufficiently close to the competitive wage, a small increase in the developing country import tax t is always welfare improving for the developing country if the fraction of developing country workers in y is sufficiently small. A small increase in τ^* is always welfare worsening for the developed country.*

A binding minimum wage can thus encourage the developing country to take advantage of the terms of trade benefits of an import tariff. Now, suppose a trade agreement is struck requiring the two countries to restrict their import tariffs at t and t^* respectively. Dispute settlement reciprocity requires that:

$$\frac{w_0 - w_1}{w_1} = \frac{c_0^* - c_1^*}{c_1^*}$$
$$\Leftrightarrow \quad 0 = \frac{c_0^* - c_1^*}{c_1^*}$$

where the equality follows since $w_0 = w_1 = \bar{w}$. We have thus the following result:

Proposition 5 *In the presence of a minimum wage $\bar{w}$, for any developed country trade agreement violation $\hat{t^*} > 0$, there exists a corresponding $\hat{t}$ such that the wages in the two countries' x sector, $\bar{w}$ and w^*, and the value of total trade remain the same.*

The above shows that well-enforced labor standards in the form of a minimum wage has two effects. It unlocks the ability on the part of the developing country to use her own trade tax to nullify the adverse consequences of the developed country policies. Second, a well enforced minimum wage also restore the ability of the dispute settlement reciprocity to deter the developed country from violating the trade agreement.

5 Discussion and Extensions

We showcased above a parsimonious model in which the mechanics of the pro-trade bias of offshoring can be shown clearly. We now make additional observations both regarding the properties of the model we use, as well as extensions to incorporate important nuances that should be understood as well.

Endogenous Offshoring Intensities

So far, we have assumed that offshoring intensity τ is given. This may well be a deviation from

reality. Thus, suppose instead that the share of offshorable tasks is determined endogenous based on relative cost considerations. Specifically, in a by now standard way, let $\beta\phi(\tau)A^*$ denote the home labor requirement for task $\tau \in [0,1]$, where $\phi(\tau)$ is strictly increasing in τ, and $\phi(\tau) > 1$, while A^* continues to denote the foreign labor requirement for all tasks. The threshold task τ^* is determined by the following cost minimizing condition:

$$\beta\phi(\tau^*)w = w^*$$

where τ^* increases as the wage ratio w^*/w rises. Accounting for this endogenous τ^*, we can proceed as we have and denote $a^* = (1-\tau^*)A^*$, while $a_o^* = \beta\int_0^{\tau^*}\phi(\tau)d\tau A^*$.

Accounting for changes in τ^* thus allows for an extensive margin variation along the task spectrum. This makes demand for both home and foreign country workers more responsive to own-price changes, since an increase in home country wage decreases the range or tasks performed by home country worker, in addition lowering total output and thus demand for home country workers as a result of the wage cost increase. The same is true for an increase in foreign worker wages.

But accounting for extensive margin variations along the task spectrum makes demand for both home and foreign country workers *less* responsive to cross price changes, since an increase in foreign country wage will increase the range of tasks performed by home country workers, while it lowers total output and thus demand for home country worker due to the wage cost increase. A similar argument can be made for the foreign labor demand elasticity with respect to changes in the home country wage.

We show in the appendix that introducing endogenous offshoring intensities substantially add more length to the proofs, but does not change our primary observation regarding the inability on the part of the home country to use home country tariffs to improve the well-being of home country workers.

Market Power

Since each variety in sector x is distinct, we can readily incorporate market power in the product market, wherein each variety is produced by a single producer who wields the ability to set prices given wage costs w, w^*, and the share of offshorable tasks τ. Using demand functions $q_{z_n}(p_{z_n})$

and $q_{z_m}(p_{z_m})$, the profit maximizing prices are

$$p(z_n) = (\alpha + aw)/2, \;\; p(z_m) = (\alpha + c^*(1+t))/2.$$

for the N and M number of varieties sold in the home country. Meanwhile, using demand functions $q^*_{z^*_n}(p^*_{z^*_n})$ and $q^*_{z^*_m}(p^*_{z^*_m})$, the profit maximizing prices are

$$p^*(z_{n^*}) = (\alpha^* + aw(1+t^*))/2, \;\; p^*(z_{m^*}) = (\alpha^* + c^*)/2.$$

These are once again all functions just of the competitive market prices only. The corresponding output levels are

$$q_{z_n}(p_{z_n}) = L(\alpha - aw)/(2\gamma), \;\; q_{z_m}(p_{z_m}) = L(\alpha - c^*(1+t))/(2\gamma).$$

$$q^*_{z_{n^*}}(p^*_{z_{n^*}}) = L^*(\alpha^* - aw(1+t^*))/(2\gamma^*), \;\; q^*_{z_{m^*}}(p^*_{z_{m^*}}) = L^*(\alpha^* - c^*)/(2\gamma^*).$$

Naturally, market power raises prices and restricts demand. The corresponding labor market equilibrium conditions are:

$$L(w) = L_x(w, w^*, t, t^*) = \frac{1}{2}\left[\bar{\alpha} - (\ell(t^*)a + o(t)a^*_o)w - \ell^*(t)a^*_o w^*\right], \tag{13}$$

$$L^*_x(w, w^*, t) = \frac{1}{2}\left[\bar{\alpha^*} - o(t)a^* w - \ell^*(t)a^* w^*\right] \tag{14}$$

It is straightforward to verify that adding market power does not change any of our comparative statics predictions regarding how wages respond to trade policies.

Endogenous Varieties

With product market power, we can furthermore take into account endogenous changes in the number of varieties (N, M, N^*, M^*) in response to trade policies. To consider the simplest case, let the fixed entry cost of the variety n be given by kn, where $k > 0$. Intuitively, more varieties of x will only come at increasing fixed cost. Likewise, let the fixed cost of variety m be given by k^*m in the foreign country, where $k^* > 0$.

Free entry implies, for example in the home country, that

$$(p(z_n) - aw)L(\alpha - aw)/2\gamma = L(\alpha - aw)^2/2\gamma = kN \;\; \Leftrightarrow \;\; N = L(\alpha - aw)^2/(2\gamma k).$$

Home country labor demand for use in producing goods for home country consumption is thus:

$$aNq_{z_n}(p_{z_n}) = \left(\frac{L}{2\gamma}\right)^2 \frac{(\alpha - aw)^3}{k}.$$

Clearly, since both output (q_{z_n}), and the total number of varieties (N) fall when production cost increases, it follows that labor demand, which is the product of the two, is now more responsive changes in the labor cost compared to when the number of varieties is exogenous. Home country labor demand for use producing exports, and home country labor demand to complete foreign offshored tasks are:

$$\begin{aligned} aN^*q_{z_n^*}(p_{z_n^*}) &= \left(\frac{L^*}{2\gamma^*}\right)^2 \frac{(\alpha^* - aw(1+t^*))^3}{k}, \\ a_o^*Mq_{z_m}^*(p_{z_m}^*) + a_o^*M^*q_{z_m^*}^*(p_{z_m^*}^*) &= \left(\frac{L}{2\gamma}\right)^2 \frac{(\alpha - c^*(1+t))^3}{k^*} + \left(\frac{L^*}{2\gamma^*}\right)^2 \frac{(\alpha^* - c^*)^3}{k^*}. \end{aligned}$$

Summing up and appealing once again to labor market clearance in both countries, it can be verified that the comparative statics predictions of our parsimonious model remain robust.

Cross-Price Demand Effects

Finally, we have so far kept to the Antras-Staiger assumption of additively separable utility in order to single out a product variety's labor and trade costs as the primary determinants of labor demand in the two countries. A more general setting can also incorporate consumption demand effects that arise in the presence of substitution possibilities across varieties.

In the context of offshoring, these cross-substitution possibilities give rise to novel considerations. To illustrate, let consumer i's utility function in the home country be given by:

$$U(q_{iz}, q_{iy}) = q_{iy} + \int_0^N u(q_{iz_n})dz_n + \int_0^M u(q_{iz_m})dz_m - \eta\left(q_i\right)^2.$$

where q_i denote aggregate consumption:

$$q_i = \int_0^N q_{iz_n}dz_n + \int_0^M q_{iz_m}dz_m.$$

Similarly in the developed country,

$$U^*(q_{iz}^*, q_{iy}^*) = q_{iy}^* + \int_0^{N^*} u^*(q_{iz_{n^*}}^*)dz_{n^*} + \int_0^{M^*} u^*(q_{iz_{m^*}}^*)dz_{m^*} - \eta^*\left(q_i^*\right)^2.$$

where

$$q_i^* = \int_0^{N^*} q_{iz_n^*}^* dz_n^* + \int_0^{M^*} q_{iz_m^*}dz_m^*.$$

Utility maximization yields aggregate demand for each z_n and z_m in sector x as functions of market prices of both p_{z_n} and p_{z_m}:

$$q_{z_n}(p_{z_n}) = L(\tilde{\alpha} - p_{z_n})/\gamma, \;\; q_{z_m}(p_{z_m}) = L(\tilde{\alpha} - p_{z_m})/\gamma,$$

where

$$\tilde{\alpha} \equiv \frac{\gamma\alpha + \eta(Np_{z_n} + Mp_{z_m}))}{\gamma + \eta(N+M)}.$$

Through the revised demand shifter $\tilde{\alpha}$, the demand functions above features cross-substitution whenever $\eta > 0$. This occurs as the demand for any individual variety z_n increases when the average price of all x sector varieties increases, or when $(Np_{z_n} + Mp_{z_m})/(N+M)$ increases. Likewise in the foreign country,

$$q^*_{z^*_n}(p^*_{z^*_n}) = L^*(\tilde{\alpha}^* - p^*_{z^*_n})/\gamma^*, \;\; q^*_{z^*_m}(p^*_{z^*_m}) = L^*(\tilde{\alpha} - p^*_{z^*_m})/\gamma^*,$$

where

$$\tilde{\alpha}^* \equiv \frac{\gamma^*\alpha^* + \eta^*(N^*p^*_{z^*_n} + M^*p^*_{z^*_m}))}{\gamma^* + \eta^*(N^* + M^*)}.$$

Consider therefore an increase in the home country wage, which raises production cost and thus the price of each variety manufactured both at home $p_{z_n} = aw$ and in the foreign country $p_{z_m} = (a^*w^* + a^*_o w)(1+t)$. The latter applies only in the presence of offshoring. When consumption demand allows for cross substitution, the increase in the price of the foreign variety will also increase demand for the home variety through the revised demand shifter $\tilde{\alpha} = \frac{\gamma\alpha+\eta(Np_{z_n}+Mp_{z_m}))}{\gamma+\eta(N+M)}$. Thus, the demand for home country workers, if the substitution effect is sufficiently large, can increase, giving rise to *upward sloping labor demand*. Clearly, our results are sensitive to cross-substitution effects when η is sufficiently large.

These substitution effects can also be applied to understand the workings of tariffs in the presence of offshoring. A developing country import tariff can raise the price on foreign imports since $p_{z_m} = c^*(1+t)$. The resulting increase in demand for home varieties through $\tilde{\alpha}$, and hence for the employment of home country workers, may rise enough to increase wages. In summary, therefore, our results should be understood as applicable when cross-variety substitution effects are mild.

6 Conclusion

Offshoring has become an indispensable feature of the global trading system. Governments in both offshoring countries and offshoring destinations face new challenges in setting rules to facilitate and sustain efficient and mutually beneficial trade agreements. These new challenges provide fertile grounds for revisiting long held assumptions about the role of labor standards

in global trade. In particular, the effectiveness of labor standards to advance the interest of workers has been previously challenged on the grounds that such standards chase employers away, thus robbing developing country labor markets of their main source of advantage.

In this paper, we shed new light on the role of labor standards, and show that when workers' wages are not protected by a minimum wage, the developing country is rendered unable to nullify the terms of trade impact of an import tariff by the developed nation, for any developing country tariff will further deteriorate the developing country's terms of trade through a reduction in their wages. We show that a well-enforced minimum wage resolve this difficulty on the part of the developing nation to impose import tariffs by severing the link between the export demand facing the developed nation, and wages in the developing country. Thus, labor standards in this context can facilitate the signing of trade agreements enabling countries to use retaliatory measures ensuring that violators can appropriately punished.

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Table 1: Summary of Statistics (N=17,150; 2005-2011)

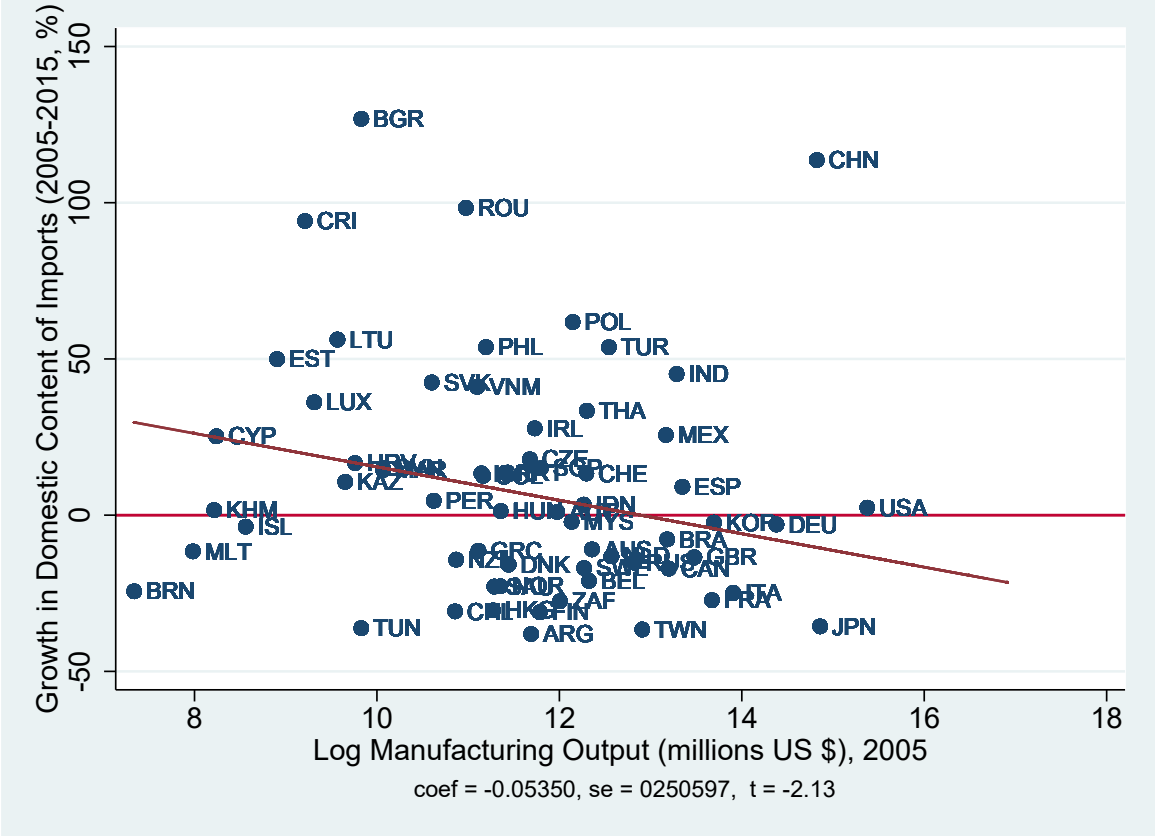
	Pooled		Domestic Content Dummy =1		Domestic Content Dummy = 0	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Trade Dispute	0.0026	0.0506	0.0075	0.0862	0.0023	0.0477
Domestic Content Dummy	0.0546	0.2272	1.0000	0.0000	0.0000	0.0000
Domestic Content Share (\%)	0.2656	0.6732	2.2591	1.6989	0.1505	0.2651

Table 2: Determinants of Importer Launched Trade Disputes (2005-2011)

	(1)	(2)	(3)
VARIABLES			
Domestic Content Share	0.392***		
	(0.0768)		
Domestic Content Dummy		1.184***	
		(0.414)	
Domestic Content of Imports (Value)			0.001***
			(0.0003)
Production (Value)			1.05e-06***
			(1.59e-07)
Constant	-7.288***	-7.213***	-7.450***
	(0.711)	(0.710)	(0.715)
Year Fixed Effects	Yes	Yes	Yes
Observations	17,150	17,150	17,150

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure 1: Growth in Domestic Content of Imports (2005-2015)



Appendix

Proof of Proposition 1:

Labor market equilibrium in the two countries require

$$L(w) = \bar{\alpha} - [\ell(t^*)a + o(t)a_o^*]w - \ell^*(t)a_o^*w^*, \tag{15}$$

$$L^*(w^*) = \bar{\alpha^*} - o(t)a^*w - \ell^*(t)a^*w^*. \tag{16}$$

where

$$\ell(t^*) \equiv \frac{LNa}{\gamma} + \frac{L^*N^*a(1+t^*)}{\gamma^*},$$

as well as labor demand to complete offshored tasks for foreign country consumption and foreign country exports $o(t)$:

$$o(t) \equiv \frac{LMa_o^*(1+t)}{\gamma} + \frac{L^*M^*a_o^*}{\gamma^*}.$$

(1) also displays the cross-price labor demand response as $\ell^*(t)$, where:

$$\ell^*(t) \equiv \frac{LMa^*(1+t)}{\gamma} + \frac{L^*M^*a^*}{\gamma^*}.$$

Also denote η as the slope $\partial L(w)/\partial w$ and η^* as the slope $\partial L^*(w^*)/\partial w^*$. We have:

$$[\eta + \ell(t^*)a + o(t)a_o^*]dw + [\ell^*(t)a_o^*]dw^* = -\frac{L^*N^*a}{\gamma^*}dt^* - \frac{LMa_o^*}{\gamma}dt \tag{17}$$

$$o(t)a^*dw + [\eta^* + \ell^*(t)a^*]dw^* = \frac{LMa^*}{\gamma}dt. \tag{18}$$

It follows that

$$\frac{\partial w}{\partial t} = -\frac{\eta^* LNa_o^*}{\gamma\Omega} < 0, \quad \frac{\partial w^*}{\partial t} = -\frac{(\eta + \ell(t^*)a)LMa^*}{\gamma\Omega} < 0$$

and

$$\frac{\partial w}{\partial t^*} = -\frac{(\eta^* + \ell^*(t)a^*)L^*N^*a}{\gamma\Omega} < 0, \quad \frac{\partial w^*}{\partial t^*} = \frac{o(t)a^*L^*M^*a}{\gamma\Omega} > 0,$$

where

$$\Omega = [\eta + \ell(t^*)a][\eta^* + \ell^*(t)a^*] + o(t)a_o^*\eta^* > 0.$$