Cabinet Office

ESRI Discussion Paper Series No.388

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March 2024

Economic and Social Research Institute
Cabinet Office
Tokyo, Japan

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February 28, 2024

Abstract

New Keynesian models with trend inflation exhibit an efficiency loss, known as price distortion. Is price distortion empirically relevant in the long run? To econometrically test this idea, I extend the model to a multi-country, multi-industry setting and theoretically show that a country with low inflation is relatively more productive in industries that face more sticky input prices. Consequently, in an open economy equilibrium, a country with low inflation has a comparative advantage in an industry that faces sticky input prices. World trade data support this theoretical prediction and provide evidence of price distortions in the long run.

Keywords: Sticky price; Trend inflation; price distortion; Comparative advantage.
JEL Codes: E31, F11, F14.

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1 Introduction

According to New Keynesian models, workforce models analyzing monetary policy, trend inflation theoretically lower aggregate output, even in the long run (Damjanovic and Nolan, 2010; Ascari and Sbordone, 2014). However, due difficulties in identifying the impact on real activities in standard single-good, closed-economy settings, econometric evidence of price distortion is scarce (c.f., Gorodnichenko and Weber, 2016, for short-run analysis). Does trend inflation affect an economy in the long run? To examine the empirical impact of trend inflation, I exploit two additional dimensions: (1) the magnitude of price rigidity that differs substantially across intermediate goods (Nakamura and Steinsson, 2008), and (2) the trend inflation rate that differs substantially across countries. Therefore, the effect of trend inflation may vary across industries and countries.

This study theoretically and empirically analyzes the consequences of trend inflation and price rigidity in a multi-industry open economy setting. A novel theoretical implication is that price rigidity and inflation rate affect the pattern of trade; a country with low inflation has a comparative advantage in industry that faces sticky input prices. Then, I examine the empirical validity of this theoretical implication by determining whether a low-inflation country tends to export more goods with sticky input prices. The regressions show that the world trade pattern is consistent with this theory.

Specifically, the model builds on the canonical Calvo-style sticky price model with trend inflation (Calvo, 1983; Yun, 1996; Schmitt-Grohé and Uribe, 2007, 2011; Ascari and Sbordone, 2014) and the classical two-country, two-good Ricardian model (and the many-country, many-good Armington model in the extension). This analysis focuses on the long-run steady state to understand the consequences of long-run trend of the inflation rate.[1] The key theoretical result is the consequence of allocation inefficiency under price rigidity and trend inflation, called price distortion. In this model, nontradeable differentiated intermediate inputs are produced using linear-in-labor technology, and these intermediate inputs are used to produce tradeable final goods. Each intermediate producer sets its selling price subject to the probabilistic opportunity of a price adjustment (known as "Calvo" friction).[2] In this specification, the aggregation result holds, similar to the aggregation results in single-good closed-economy settings. Final goods production is expressed as the product of the total number of workers in the industry and the effective productivity. The effective productivity depends on allocation inefficiencies. Under trend inflation, firms want to raise prices to keep up with the aggregate price level, but some firms cannot change their price because of the friction of price adjustment. The non-adjusting firms have lower prices than the adjusting firms. Price variation creates production asymmetry across ex-ante symmetric firms.

[1]Theoretically, the long-run analysis follows the tradition of trade studies, which consider a stationary (i.e., static) situation of dynamic models (e.g., Baxter, 1992; Melitz, 2003).

[2]Accordingly, price is rigid in the intermediate goods market, which is the input side of the final goods. In many open-economy macro models such as Obstfeld and Rogoff (1995), Devereux and Engel (2003), and Corsetti et al. (2011), final goods producers set their output prices. These authors analyze the short-run dynamics of the exchange rate influenced by the price-setting behavior of tradeable final goods producers (producer currency pricing vs local currency pricing). I do not adopt this specification for empirical and theoretical reasons. First, empirical price studies (see reference in Klenow and Malin, 2011) show that price rigidity is prevalent in both consumer price index data and producer price index data. Given these empirical facts, the implications of price rigidity in the domestic intermediate input market are worth analyzing. Second, theoretically, the current specification can abstract complicated cross-country price-setting behavior, which is not the target of empirical analysis.

The price distortion captures this allocation inefficiency.

If Ricardian trade is allowed, the relative price under autarky determines the trade pattern and the relative price depends on industries' effective labor productivity.[3] Consequently, the trade pattern depends on the nominal-side parameters, namely, the inflation rate and the probability of price adjustment. For example, even with high rigidity, a low (close to zero) inflation rate leads to low distortion and, hence, high industry-level productivity. Thus, a country with low inflation is more likely to have a comparative advantage in industries with sticky input prices.

The empirical section tests whether a country with low inflation exports more products with sticky input prices. This hypothesis parallels the standard prediction of comparative advantage; for example, a country whose labor is highly educated has a comparative advantage in industries that require skilled labor. Thus, the empirical strategy follows the literature on empirical tests of sources of comparative advantage (for example, Romalis, 2004). Prior studies use detailed US industry-level data to construct an industry-level variable (e.g., skill intensity of each industry) and cross-country variation in the country-level variable (e.g., education level of each country) in a regression. I calculate industry-level input price rigidity based on the US item-level price rigidity of the producer price index compiled by Nakamura and Steinsson (2008), together with the US input-output matrix. The trend inflation rate is the 10-year average inflation rate from the International Financial Statistics. I then combine these industry and country variables with country-industry-year observations of export data from the UN Comtrade Database. Identification relies on two-way fixed effects. After controlling for other determinants of comparative advantage, I compare differences in the exports of sticky and flexible input price industries between high- and low-inflation countries.

The regression results statistically support the main hypothesis; the result is robust to various examinations, and the effect is economically sizable.

This study contributes to two areas in the literature: (1) monetary studies that consider the impact of trend inflation, and (2) theoretical and empirical trade studies that consider the determinants of comparative advantage. Existing studies analyzing trend inflation consider single-good closed-economy settings (Ascari, 2004; Schmitt-Grohé and Uribe, 2007, 2011; Ascari and Ropele, 2007; Damjanovic and Nolan, 2010; Ascari and Ropele, 2009; Ascari et al., 2011; Coibion et al., 2012; Ascari and Sbordone, 2014; Kurozumi, 2016; Kurozumi and Van Zandweghe, 2016, among many). An exception is Ishise (2022), who theoretically analyze optimal trend inflation rates in an open-economy setting. Many researchers have examined price rigidity and inflation in multi-good (for example, Aoki, 2001; Carvalho, 2006; Barsky et al., 2007; Gorodnichenko and Weber, 2016) or multi-country frameworks (for example, Obstfeld and Rogoff, 1996; Benigno and Benigno, 2003; Benigno, 2004; Corsetti and Pesenti, 2005; Corsetti et al., 2011; Bergin and Corsetti, 2020). Gorodnichenko and Weber (2016) show that the impact of the monetary policy shock to the stock return differs across firms depending on the firm's price rigidity. Contrary to existing studies analyzing the role of short-run relative price stability, I highlight the long-run consequences in a context

[3]Precisely, the relative price depends also on the markup term. Markup (i.e., the ratio of output price to the marginal cost) fundamentally stems from the monopolistic competition in the input market. The effective markup depends not only on the elasticity of substitution among input varieties but also on the nominal-side parameters, owing to the price dispersion within and across industries. However, following the literature (e.g., Rotemberg and Woodford, 1997), I eliminate the markup term through a government subsidy. See equation (25) in the model section for further details.

with no shocks and where the nominal exchange rate is perfectly adjusted. This empirical discovery is fundamentally different from and complements many existing monetary studies.

Second, this study identifies a new determinant of comparative advantage. Some studies explain the determinants of productivity in Ricardian frameworks (for example Matsuyama, 2005; Costinot, 2009; Cuñat and Melitz, 2012; Ishise, 2016), and many studies empirically show various determinants of comparative advantage (for example Antràs, 2003, 2015; Romalis, 2004; Levchenko, 2007; Nunn, 2007; Manova, 2008, 2013; Costinot, 2009; Chor, 2010; Cuñat and Melitz, 2012; Nunn and Trefler, 2014). However, trade models rarely consider nominal variables.[4] My unique finding is that the nominal side is a determinant of industry-level productivity; hence, the nominal side affects the long-run (steady state) pattern of trade. In summary, as analogous to "[d]omestic institutions can have profound effects on international trade." (p.263, Nunn and Trefler, 2014), I conclude that domestic *inflation* can have profound effects on international trade.

The remainder of this paper is organized as follows. Section 2 introduces the model and presents its key empirical implications. Section 3 presents empirical evidence. Finally, Section 4 concludes the paper.

2 Model

This section presents the model and discusses its implications. The model extends the standard cashless Calvo sticky price with trend inflation (for example, Ascari and Sbordone, 2014) to include multiple goods and trade.[5]

2.1 Setup

2.1.1 Environment

There are two countries, the home and foreign. Variables with an asterisk (*) symbolize foreign variables, if necessary. Time is a discrete infinite horizon, denoted by $t = 0, ..., \infty$. The model specifies an explicit dynamic stochastic problem, whereas the analysis focuses on the long-run steady state in which the aggregate- and industry-level variables remain constant. Since my focus is on the steady state, I impose a period-by-period trade balance condition for simplicity.

The final goods indexed by i are internationally tradeable without any trade costs. Intermediate inputs are nontradeable and are distinguished by variety.[6] The parameters are symmetric across countries, except

[4]For example, in a graduate-level textbook by Feenstra (2016), the term "nominal" appears 20 times and "monetary" 10 times. Its only theoretical use is to explain price indices. Others basically mention empirical variables as "nominal" GDP or "monetary" unions. The only exception is the literature on the effects of nominal exchange rate variability (or regime) on the aggregate or bilateral value of trade. However, these studies do not consider inter-industry variations (see surveys by McKenzie, 1999; Auboin and Ruta, 2013).

[5]The model is a simplified version of Ishise (2022). The appendix allows for various generalizations, including endogenous labor choice, price indexation, asymmetry in various parameters, and other forms of price rigidity (Rotemberg and endogenous duration models).

[6]This specification for tradable final goods and non-tradable intermediate goods is for expositional convenience. An alternative specification is to relabel the intermediate good as the (new non-tradable) input and the final good as the (new tradable) intermediate product, and to introduce the final distribution service sector, which combines multiple tradable intermediate products into the (new non-tradable) final good. In this case, intermediate goods are internationally traded, while final goods are not.

for (1) the inflation rate (π and π^*), (2) exogenous labor productivity (θ_{it} and θ^*_{it}), and (3) the probability of price adjustment (ω_i and ω^*_i).

2.1.2 Households

A representative household in each country inelastically supplies a unit of labor ($l_t = 1$) to earn a real wage (w_t), consumes final goods (c_{it}), transacts bonds (b_t), pays a lump-sum tax to the government (τ_{Lt}), and receives real profits from firms (f_t). Households maximize expected lifetime utility

$$\max_{\{\{c_{it}\}_i, b_{t+1}\}} E_0 \sum_{t=0}^{\infty} \beta^t \log \underbrace{\left(\prod_i c_{it}^{\alpha_i} \right)}_{\equiv c_t}, \tag{1}$$

subject to the period budget constraint,

$$\sum_i \frac{P_{it}}{P_t} c_{it} + b_t + \tau_{Lt} = \frac{1+i_{t-1}}{1+\pi_t} b_{t-1} + w_t + f_t, \tag{2}$$

and the transversality condition. P_t is the nominal aggregate price index, P_{it} is the nominal price of goods i, i_t is the nominal interest rate of bonds, $\pi_t \equiv P_t/P_{t-1} - 1$ is the inflation rate, $\beta \in (0,1)$ is the subjective discount factor, and $\alpha_i \in [0,1]$ is the share parameter of the different final goods satisfying $\sum_i \alpha_i = 1$. Based on the functional form of c_t,

$$P_t = \prod_i (P_{it}/\alpha_i)^{\alpha_i}. \tag{3}$$

Let

$$\Lambda_{tt+j} \equiv \beta^j c_t / c_{t+j} \tag{4}$$

denote the ratio of marginal utility at $t+j$ and t.

2.1.3 Final goods producers

Final goods producers sell the final goods (y_{it}) in a perfectly competitive international market using a continuum of differentiated intermediate inputs ($y_{it}(\upsilon)$). The profit maximization problem is

$$\max_{\{y_{it}, \{y_{it}(\upsilon)\}_{\upsilon \in (0,1)}\}} \frac{P_{it}}{P_t} y_{it} - \int_0^1 \frac{P_{it}(\upsilon)}{P_t} y_{it}(\upsilon) \mathrm{d}\upsilon, \tag{5}$$

where the production function is

$$y_{it} = \left(\int_0^1 y_{it}(\upsilon)^{\frac{\eta-1}{\eta}} \mathrm{d}\upsilon \right)^{\frac{\eta}{\eta-1}}. \tag{6}$$

$P_{it}(\upsilon)$ is the nominal price of the input and υ is the differentiated input index. The elasticity of subsitution, $\eta > 1$, determines the markup rate and is assumed to be uniform across countries and industries for simplicity.[7]

From the profit-maximization problem, the demand for each input variety is

$$y_{it}(\upsilon) = \left(\frac{P_{it}}{P_{it}(\upsilon)}\right)^{\eta} y_{it}, \tag{7}$$

and the price of the industry's product is

$$P_{it} = \left(\int_0^1 P_{it}(\upsilon)^{1-\eta} \mathrm{d}\upsilon\right)^{\frac{1}{1-\eta}}. \tag{8}$$

2.1.4 Intermediate input producers

An intermediate-input producer has access to linear-in-labor production technology with productivity θ_{it}. The wage payment is subsidized at a rate of $\tau_{it} > 0$. This subsidy is widely used to eliminate distortions caused by monopolistic competition (for example Rotemberg and Woodford, 1997; Benigno and Woodford, 2005; Schmitt-Grohé and Uribe, 2007). An input producer sets its own price to maximize profits but can adjust the price with a probability of $1 - \omega_i$. As households earn profits, future profits are evaluated using Λ_{tt+j}. Each intermediate producer's problem is

$$\max_{\{p_{it}(\upsilon), \{y_{it+j}(\upsilon), l_{it+j}(\upsilon)\}_{j=0}^{\infty}\}} E_t \sum_{j=0}^{\infty} \Lambda_{tt+j} {\omega_i}^j \left[\frac{P_{it}(\upsilon)}{P_{t+j}} y_{it+j}(\upsilon) - (1 - \tau_{it+j}) w_{t+j} l_{it+j}(\upsilon)\right], \tag{9}$$

subject to production technology

$$y_{it+j}(\upsilon) = \theta_{it+j} l_{it+j}(\upsilon), \tag{10}$$

and demand (7), where its own price ($P_{it}(\upsilon)$) is fixed over $j = 1, 2, ...,$

$$y_{it+j}(\upsilon) = \left(\frac{P_{it+j}}{P_{it}(\upsilon)}\right)^{\eta} y_{it+j}. \tag{11}$$

When a firm has the chance to adjust its price, the optimal price is symmetric across firms in the industry that make the adjustments. The optimal price ($\tilde{P}_{it}$) satisfies

$$\frac{\tilde{P}_{it}}{P_{it}} = \frac{\eta}{\eta - 1} \frac{E_t \sum_{j=0}^{\infty} \Lambda_{tt+j} \omega_i^j \left(\frac{P_{it+j}}{P_{it}}\right)^{\eta} (1 - \tau_{it+j})\, w_{t+j} \frac{y_{it+j}}{\theta_{it+j}}}{E_t \sum_{j=0}^{\infty} \Lambda_{tt+j} \omega_i^j \frac{P_{it+j}}{P_{t+j}} \left(\frac{P_{it+j}}{P_{it}}\right)^{\eta-1} y_{it+j}}. \tag{12}$$

[7] This simplifying assumption does not align with the empirical fact that the markup differs across sectors (Edmond et al., 2015); the Appendix shows derivations allowing cross-country, cross-industry differences in this parameter. As shown in the Appendix, the qualitative implications do not change.

Compared to the standard single-good Calvo models, the equation above involves relative price terms (P_{it+j}/P_{t+j}) because the aggregate price index differs from the price of the final good i. Otherwise, the interpretation of the equation follows the standard Calvo-model (e.g., Ascari and Sbordone, 2014).

2.1.5 Law of industry price motion and industry aggregate

In each period, $1-\omega_i$ fraction of firms chooses a new price, $\tilde{P}_{it}$, while the other firms maintain the same price. In the industry-level aggregation, from (8), the industry-level price is the weighted average of the previous and adjusted prices,

$$P_{it} = \left(\omega_i P_{it-1}^{1-\eta} + (1-\omega_i)\tilde{P}_{it}^{1-\eta}\right)^{\frac{1}{1-\eta}}. \tag{13}$$

I obtain the industry-level output by combining (7) and (10)

$$y_{it}\left(\frac{P_{it}}{P_{it}(\upsilon)}\right)^{\eta} = \theta_{it} l_{it}(\upsilon), \tag{14}$$

and then

$$y_{it} = \frac{\theta_{it}}{s_{it}} l_{it}, \tag{15}$$

where $s_{it} = \int_0^1 \left(\frac{P_{it}}{P_{it}(\upsilon)}\right)^{\eta} \mathrm{d}\upsilon$ and $l_{it} = \int_0^1 l_{it}(\upsilon)\mathrm{d}\upsilon$. The variable s_{it} captures real resource costs (price distortion), as described in the following subsection.

2.1.6 Equilibrium

The remaining equilibrium conditions include government budget balance,

$$\sum_i \int_0^1 \tau_{it} w_t l_{it}(\upsilon)\mathrm{d}\upsilon + \tau_{Lt} = 0, \tag{16}$$

bond and labor market-clearing conditions,

$$b_t = 0, \tag{17}$$

$$\sum_i l_{it} = l_t, \tag{18}$$

trade balances in each period,

$$\sum_i P_{it}(y_{it} - c_{it}) = 0, \tag{19}$$

and the final goods market-clearing condition for each i,

$$c_{it} + c_{it}^* = y_{it} + y_{it}^*, \tag{20}$$

where c_{it}^* and y_{it}^* represent foreign consumption and production of goods i, respectively. As a simple abstraction, the home government directly chooses the country's aggregate inflation rate π_t. Equilibrium is defined in a standard manner.

In this model, the law of one price holds for each final goods market; hence purchasing power parity (PPP) holds. The nominal exchange rate is the ratio of foreign and home price indices.

2.2 Key implication

2.2.1 Price distortion in the steady state

The following analysis focuses on the steady state in which (1) productivity is constant ($\theta_{it} = \theta_i$), (2) industry- and aggregate-level allocations are constant, and (3) the aggregate price grows at rate π (and π^* in the foreign country). The steady-state variables are expressed by eliminating the time subscripts.

Industry prices grow at rates of π (and π^*), and the nominal exchange rate is fully adjusted.[8] At a steady state, there are simple expressions for the aggregate variables.[9] From (15), the industry-level output is

$$y_i = \frac{\theta_i}{s_i} l_i, \tag{21}$$

where the price distortion s_i is

$$s_i = \frac{1-\omega_i}{1-\omega_i(1+\pi)^{\eta}} \left(\frac{1-\omega_i(1+\pi)^{\eta-1}}{1-\omega_i} \right)^{\frac{\eta}{\eta-1}}. \tag{22}$$

From (12) and (13), the industry-level real price ($p_i \equiv P_i/P$) is

$$p_i = (1-\tau_i)\, v_i \frac{s_i}{\theta_i} w, \tag{23}$$

where the markup term v_i is

$$v_i = \frac{\eta}{\eta-1} \frac{1-\beta\omega_i(1+\pi)^{\eta-1}}{1-\beta\omega_i(1+\pi)^{\eta}} \frac{1-\omega_i(1+\pi)^{\eta}}{1-\omega_i(1+\pi)^{\eta-1}}. \tag{24}$$

Previous studies agree that v_i is much smaller than s_i. For this reason, and for simplicity, the rest of the analyses focus on the standard case in which subsidies eliminate markup distortion,[10]

$$(1-\tau_i)v_i = 1. \tag{25}$$

[8]Since the real exchange rate is always unity, the nominal exchange rate is the price ratio: $e_t = P_t/P_t^*$. Then, in the steady state, the nominal exchange rate grows at a constant rate: $e_t = e_0\left((1+\pi)/(1+\pi^*)\right)^t$.

[9]Note that when deriving s_i and v_i in the steady state, one needs to calculate the sum in the definition of $s_{it}(= \int_0^1 (P_{it}/P_{it}(v))^{\eta} dv)$ and the infinite sum in (12). I restrict the parameter space to ensure finite sums (cf., p.693 and footnote 35 on p. 699 Ascari and Sbordone, 2014): $\beta \in (0,1)$, $\eta > 1$, $\omega_i \in [0,1)$, and $\omega_i(1+\pi)^{\eta} < 1$.

[10]In the Appendix, I show the result without introducing the subsidy. The main result analytically holds if β is close to one. The main result quantitatively holds under standard parameter values because v_i is much smaller than s_i. See also discussions in King and Wolman (1999), Schmitt-Grohé and Uribe (2006), and Ascari and Sbordone (2014).

After dropping v_i, s_i becomes of interest. The variable s_i has the following properties: (1) $s_i = 1$ if no price rigidity exists($\omega_i = 0$) or if there is zero inflation ($\pi = 0$), (2) s_i increases as the absolute value of the inflation rate increases ($\partial s_i / \partial \pi \gtreqless 0$ if $\pi \gtreqless 0$), and (3) the response is larger for inflation than deflation (See Schmitt-Grohé and Uribe, 2011; Ascari and Sbordone, 2014; Ishise, 2022).

The variable s_i captures the price distortion. Under price rigidity and inflation, a firm's price setting is not optimal on a period-by-period basis. Each firm may want to raise its price, but some firms cannot adjust their prices due to adjustment friction. Thus, non-adjusting firms have lower prices than the adjusting firms. This price variation creates production asymmetry across ex-ante symmetric firms. Therefore, some firms produce too much, while others produce too little. However, since all these firms are ex-ante symmetric, efficient allocation produces the same amount. At the aggregate level, allocation inefficiency under trend inflation appears to be a resource cost. Note that even with price rigidity, under zero inflation, non-adjusting firms do not face automatic price deterioration and hence do not need to employ excess labor. Consequently, the economy incurs no price distortion in the zero-inflation steady state.

2.2.2 Trade equilibrium

Suppose that there are two types of final goods, $i = A, B$, where each type of good from a different country is perfectly substitutable. Under autarky, the relative price of final goods is

$$\frac{p_A}{p_B} = \frac{s_A}{s_B}\frac{\theta_B}{\theta_A}. \tag{26}$$

As in the standard Ricardian model, production-side parameters determine the relative price, whereas household-side parameters play no role. However, contrary to the standard Ricardian model, the relative price depends not only on exogenous productivity (θ_i) but also on price distortion (s_i). This relative price under autarky is a critical variable in determining trade patterns when the economy engages in international trade.

International trade is allowed only for final goods, and final goods markets are perfectly competitive. Industry-level technology is a linear-in-labor function. Therefore, the model implies a Ricardian trade structure. The comparative advantage is determined by the autarky relative prices of the two countries. The costless trade equilibrium is similar to that in the textbook Ricardian model (see, for example, Ch. One in Feenstra, 2016)

Suppose that the home country possesses a comparative advantage in producing good A, whereas the foreign country possesses a comparative advantage in good B. This is true if the relative price in the home country under autarky is lower than that in the foreign country,

$$\frac{s_A}{s_B}\frac{\theta_B}{\theta_A} < \frac{s_A^*}{s_B^*}\frac{\theta_B^*}{\theta_A^*}. \tag{27}$$

A typical equilibrium is such that the home country produces A and the foreign country produces B. In this trade equilibrium, the trade pattern depends on the relative magnitudes of exogenous productivity and price distortion terms. Price distortion, in turn, depends on inflation rates (π, π^*) and price rigidity terms (ω_i, ω_i^*). Specifically,

Empirical prediction for the trade pattern: Holding other things constant, a country with low (high) inflation has a comparative advantage in an industry with sticky (flexible) input prices.

Unlike the Calvo (probabilistic price change) model, the Rotemberg (adjustment cost) model allows for simple intuition. When changing the price is costly and high inflation induces a large price change, an industry using sticky-priced inputs (facing the high adjustment cost in the Rotemberg model) is hurt more under inflation, and hence the industry has less international competitiveness.

Section 3 explores the empirical validity of this idea and concludes the current section by discussing model extensions.

2.3 Extensions

The baseline model is illustrative but is not necessarily comparable to the data. In particular, the model assumes that each sector uses its specific inputs and implies perfect specialization of a two-country, two-good world. Simple extensions can address these problems.[11]

2.3.1 Non-industry-specific intermediate goods

In the baseline model, each sector used its own intermediate inputs. In reality, different sectors use the same intermediate inputs, as captured by the input-output table. The extended version of the model allows sectors to use common inputs to map data onto the model. In other words, the producers of different final goods use common inputs with different weights. In particular, the new tradeable final good (y_m, $m = 1, ...$) comprises various y_{mi} via Cobb-Douglas technology with different weights $\ln y_m = \sum \sigma_{mi} \ln y_{mi}$. There are multiple inputs ($i = 1, ...$), with the total supply of each input, y_i, matching the total demand of each input $\sum_m y_{mi} = y_i$. Each input y_i is obtained from the problems specified in 2.1.3 and 2.1.4.

In this case, the effective productivity of y_m is the geometric average of the effective productivity of y_is with weight σ_{mi}. Even if the two industries share the same inputs, the weights matter. The main implication is a straightforward extension of the baseline model's implication: an industry that heavily uses sticky price inputs has lower productivity than an industry that heavily uses flexible price inputs.

2.3.2 Value of the trade

The two-country, two-industry Ricardian model predicts perfect specialization, which is unrealistic. However, the main implication of comparative advantage applies to the multi-country, multi-product case by incorporating the Armington-type structure (Armington, 1969; Anderson, 1979), following Levchenko (2007). In this case, all countries export all types of products, with the amount depending on effective productivity (= exogenous productivity / price distortion). The model predicts that the value of exports increases if the country has higher effective productivity.

[11] The Appendix shows the detailed results.

Specifically, let X_i^c be the value of exports of industry i from country c. As shown in the Appendix, by comparing the goods from c and another country c', and between good i and another good i', the difference-in-differences can be expressed as

$$\begin{aligned}(\log X_i^c - \log X_{i'}^c) - (\log X_i^{c'} - \log X_{i'}^{c'}) =& (\mu - 1)\left((\log \theta_i^c - \log \theta_{i'}^c) - (\log \theta_i^{c'} - \log \theta_{i'}^{c'})\right) \\ & -(\mu - 1)\left((\log s_i^c - \log s_{i'}^c) - (\log s_i^{c'} - \log s_{i'}^{c'})\right), \end{aligned} \quad (28)$$

where μ is the Armington elasticity, that is, the elasticity of substitution between different goods and countries.

Hence, compared with a country with high inflation, a country with low inflation exports more sticky-priced input goods than flexibly priced input goods. I tested this implication in the following empirical section.

3 Empirical evidence of inflation-driven comparative advantage

This section empirically examines the testable implication of a country with a high inflation rate having a comparative advantage in industries with flexible input prices. This implication parallels other standard implications of comparative advantage; for example, a country with highly educated labor has a comparative advantage in industries that use skilled labor intensively. Hence, the empirical strategy follows a standard methodology for examining comparative advantages (for example, Romalis, 2004; Nunn and Trefler, 2014).

3.1 Identification and specification

The empirical exercise regresses country-industry-year-level exports (to the world) on the interaction term of the country's inflation rate and the industry's measure of input price flexibility, after controlling for other factors, country-year dummies, and industry-year dummies. A high-inflation country may export less overall product than a low-inflation country because high inflation is frequently accompanied by economic or political turmoil. Country-year fixed effects control for overall differences in country-year export values. The reasons for this difference are not only high or low inflation but also high or low overall productivity, high or low education, abundant or scarce labor endowment, etc. Similarly, in any country, an industry with products facing high input price rigidity tends to have low productivity, and therefore, lower exports. In addition, some industries trade more than others simply because some products incur higher transportation costs. Moreover, trade costs are time-varying owing to changes in world oil prices. The industry-year fixed effects remove all differences in export values across industries. Furthermore, both dummies include a time dimension to remove the effects of country- and industry-specific business cycles.

Identification relies on the idea of two-way fixed effects. After controlling for other determinants of comparative advantage, I compare the differences in the exports of sticky and flexible input price industries between high- and low-inflation countries.

The dependent variable is country-industry-year exports to the world. The analysis is limited to manufacturing products due to data availability for the explanatory variables, and because this type of analysis is a standard practice in the literature (Nunn and Trefler, 2014). I do not use bilateral data for several reasons.[12] First, in the current specification, I do not need to specify the functional forms and determinants of trade costs or other explanatory variables in the gravity regressions, which are required for bilateral gravity-type specifications. Second, with many industry disaggregations in the current data, bilateral data lead to numerous observations. Since I use the Poisson pseudo-maximum likelihood (PPML) as explained below, the nonlinear nature of the estimation makes computationally infeasible. Third, using a log-linear specification instead of PPML for the bilateral data is problematic considering the criticism of Santos Silva and Tenreyro (2006), as industry-level bilateral data tend to have many zero trade flows.

Currently, this line of literature (see a survey by Nunn and Trefler, 2014) further limits the sample in which nonzero exporting is observed; after dropping zero flows, the natural log of the trade flow is regressed onto explanatory variables using linear regression models. In the context of gravity regression, Santos Silva and Tenreyro (2006) criticize the log-linear specification without zero observations and recommended using PPML estimator for the level of the dependent variable and the exponential form of the linear combination of explanatory variables. This specification is consistent under mild assumptions (Windmeijer, 2008; Wooldridge, 2010). The main specification of the regression is

$$y_{it}^{c} = \exp\left(\beta\left(\bar{\pi}^{c} q_{i}\right) + \alpha_{t}^{c} + \alpha_{it} + \mathbf{X}_{i}^{c}\boldsymbol{\gamma}\right) u_{it}^{c}$$

where y_{it}^{c} is country c's exports for industry i in year t, β is the coefficient of interest, $\bar{\pi}^{c}$ is the c's absolute value of the average inflation rate over the past years, q_i is i's input price flexibility measure, α_{t}^{c} is the country-year fixed effect, α_{it} is the industry-year fixed effect, $\mathbf{X}_{i}^{c}$ is a vector of other control variables (that is, other interaction-terms of country and industry characteristics), $\boldsymbol{\gamma}$ is a vector of coefficients on the other control variables, and u_{it}^{c} is the error term.

3.2 Data

Here, I present a summary of the data construction. The Appendix explains these additional details.

3.2.1 Trade data

The dependent variable is the country-industry-year value of global exports from 2011 to 2015. The data are taken from the UN Comtrade database, which reports industry values in a six-digit Harmonized System. To match the industry classification of the explanatory variables, I aggregate the industries into 266 industries according to the 2002 US Input-Output (I-O) table. Although the original I-O table contains 279 industries, I match 266 industries with the trade data. I restricted my years for two reasons. First, years before 2011 are the period of the Great Trade Collapse (Bems et al., 2013). Even with various control variables (including country-year and industry-year dummies), the trade data during that period

[12] Some authors use different types of data. Nunn (2007) uses cross-sectional data for country-industry exports (to the world) of a particular year. Levchenko (2007) also uses cross-sectional data for industry-level US imports from various countries. Chor (2010) and Manova (2013) use industry-level bilateral trade data, which leads to gravity-type regressions.

have unusual patterns compared with other periods. Second, the explanatory variables are the interaction terms of industry and country characteristics, where country variables are based on lagged values. Some control variables are unavailable for the years prior to 2004.

3.2.2 Input price flexibility

Input price flexibility is measured by the frequency of price changes. Prior studies generally agree that the frequency of price changes is an empirical counterpart to the probability of a price change (Nakamura and Steinsson, 2008; Klenow and Malin, 2011). Many studies calculate the frequency of price changes at the retail level (see the survey by Klenow and Malin, 2011); however, few studies calculate the frequency at the intermediate level with detailed disaggregation. The best available study presents Nakamura and Steinsson's (2008) calculations using US Producer Price Index (PPI) data. Therefore, I calculate the measure of input price flexibility based on US data.

Input price rigidity likely varies across countries; however, aside from data availability, using US data has important advantages supported by the literature. First, the US produces most products, including as many industries as possible in the dataset. Second, given market economies with minimal institutional distortions, price rigidity in the US likely reflects transactions' technological limitations. Thus, the rigidity measured in the US likely captures technological constraints rather than economic conditions, which may be endogenous. Econometrically, using US data to represent all countries is a "reduced form" of instrumental variable estimation in which US industry-level price rigidity serves the instrument for the country-specific price rigidity measures.

I construct an industry-level input price flexibility measure as follows: Nakamura and Steinsson (2008) calculate the frequency of price change for 345 PPI items over the period 1998–2005. I assign each PPI item to the US-IO industry. If two or more items are assigned to the same industry category, the arithmetic average is calculated. I then calculate input price flexibility by taking the weighted average of the different input industries. The weight comes from the use-value ("ProVal") of the IO table. Keeping the input industries at the frequency of price changes, I calculate the weighted average of the input price frequency. Weight is the ratio of the use values among the included industries.

Table 1 summarizes the process for calculating the flexibility measure of "Knit fabric mills" (code 313240), which is 10.0. This value is calculated as follows: This industry uses 87 inputs.[13] Among 87 industries, 59 (mainly labor services) have no observations for frequency of price change, while 28 (mainly intermediate inputs) have observations for frequency of price change. The frequency of input price changes is the weighted average of the frequencies of these observable 28 industries, and the weights are ratios of the use value of the input to the total use value of the 28 included industries. The largest fraction in the total production values with frequency observations is "Fiber, yarn, and thread mills" (313100), (Freq. =6.5, Weight=50.9%). This frequency is 6.5, which I in turn construct by taking the average of the two PPI items assigned to this industry 313100, "Yarn" (PPI item code 326), 8.3 and "Thread" (PPI item code 327), 4.7. The second-largest weight is "Artificial and synthetic fibers and filaments manufacturing" (325220), (Freq. =8.4, Weight=19.6%), and the third "Textile and fabric finishing mills"

[13]The I-O table includes 92 industries, but 5 industries have zero production values, so I drop them from calculations.

(313310), Freq. =12.6, Weight=16.1%). The final value is the weighted average of these frequencies (i.e., $10.0 = 6.5 \times 0.509 + 8.4 \times 0.196 + 12.6 \times 0.161 + ...$).

Table 1: Industry-level input price flexibility construction example

PPI item (code)	Freq.	Input industry (code)	Freq.	Weight	Industry (code)	Freq.
Yarns (326)	8.3	Fiber, yarn, and thread mills (313100)	6.5	0.509	Knit fabric mills (313240)	10.0
Threads (327)	4.7					
Unprocessed filament yarns (315)	8.4	Artificial and synthetic fibers and filaments mfg. (325220)	8.4	0.196		
Broadwovens (337)	22.4	Textile and fabric finishing mills (313310)	12.6	0.161		
Fabricated products, n.e.c. (383)	2.8					
⋮	⋮	⋮	⋮	⋮		

Source: PPI item frequency of price changes from Nakamura and Steinsson (2008). The input industry frequency of price changes is the arithmetic average of the included PPI items based on industry matching. The industry-level input price frequency is the weighted average of the input industries. Weights are the ratio of the use-value ("ProVal") to the total use-value of the observable industries. The use value is taken from the 2002 US input-output table.

Table 2 shows the PPI item-level frequency of the price changes from Table 23 of the supplement to Nakamura and Steinsson (2008). This table reports the monthly probability of a price change. There are two points worth noting. First, the cross-item frequency variation is large, from completely flexible to very sticky items. Second, the raw materials are flexible, and the processed items are sticky.

Table 3 and Figure 1 show the mapping results, that is, the mean input price frequency of price changes for the US I-O industries. Table 3 lists the top, middle, and bottom three industries in terms of flexibility measures. Reflecting the variation in item-level flexibility, the measure has large cross-industry variation, ranging from 4.0 to 95.5. The most flexible industry is "petroleum refineries" (code 324110), which mainly uses a very flexible price item as the major input, crude petroleum (Freq. =98.9, which ranks ninth and does not appear in Table 2). In contrast, the electronics and precision manufacturing industries are the least flexible (Freq. around 5), using many processed items as inputs.

Figure 1 shows the flexibility measure for the 279 categories by color; a darker color indicates greater flexibility. The industries are aligned by industry code, and the three-digit aggregation categories are as follows: Some industries are generally flexible, such as "Food manufacturing" and "Petro and coal product manufacturing." Some other categories are generally sticky, such as "Machinery" manufacturing and "Computer and electronic product" manufacturing.

3.2.3 Inflation rate

The inflation rate is the Consumer Price Index (CPI) inflation rate in International Financial Statistics (IFS) of the International Monetary Fund.[14] Some robustness specifications employ the GDP deflator

[14] There are two exceptions. Data for Taiwan are from Taiwan's statistical office. Data for Argentina are from Cavallo and Bertolotto (2016). See the Appendix for details.

Table 2: Frequency of price change (PPI items) from Nakamura and Steinsson (2008)

	Item	Freq.
1	Chickens (141)	100.0
1	Raw cotton (151)	100.0
1	Kerosene and jet fuels (572)	100.0
	⋮	
171	Alcoholic beverages (261)	6.6
171	Television receivers (1252)	6.6
171	Aircraft engines and engine parts (1423)	6.6
	⋮	
343	Leather/leather-like goods, n.e.c. (261)	0.5
344	All other footwear (439)	0.4
345	Services for the printing trade (939)	0.3

Source: Table 23 of the Supplement to Nakamura and Steinsson (2008).

Table 3: Flexibility (avg. freq.) of input prices

	Industry	Freq.
1	Petroleum refineries (324110)	95.5
2	All other petroleum & coal products mfg (324199)	86.1
3	Soybean & other oilseed processing (31122A)	84.7
	⋮	
139	Doll, toy & game mfg (339930)	15.8
140	Plate work & fabricated structural product mfg (332310)	15.8
141	Jewelry & silverware mfg (339910)	15.7
	⋮	
277	Broadcast & wireless communications eqpt (334220)	5.4
278	Electricity & signal testing instruments mfg (334515)	4.7
279	Printed circuit (electronic) assembly mfg (334418)	4.0

Source: Input price-level average frequency of price changes based on the PPI item frequency of price changes and the US input-output table. The PPI item frequency of price changes from Nakamura and Steinsson (2008). The frequency of price changes in the input industry is the arithmetic average of the included PPI items based on industry matching. The industry-level input price frequency is the weighted average of the input industries. Weights are the ratio of the use-value ("ProVal") to the total use-value of the observable industries. The use value is taken from the 2002 US input-output table.

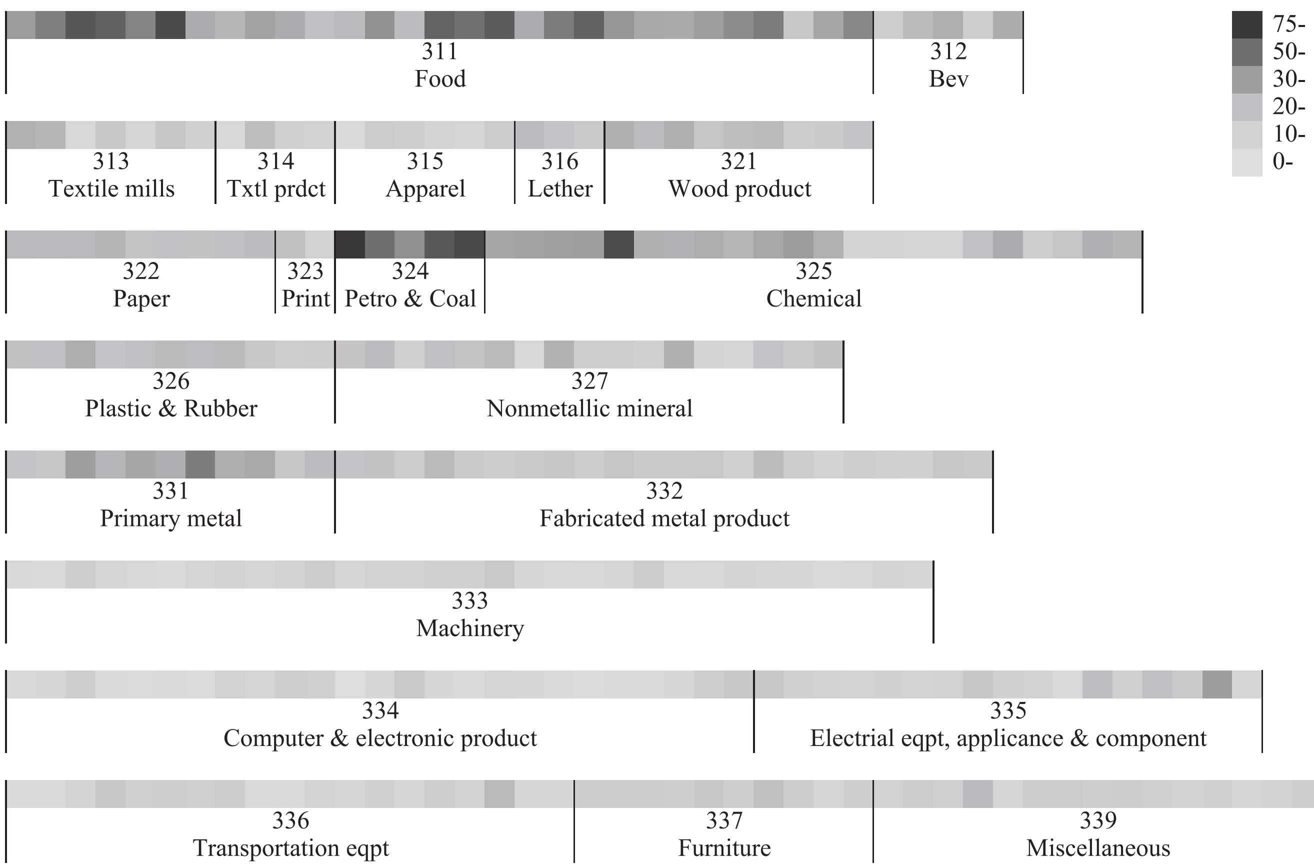

Figure 1: Industry-level input price flexibility.

Each square corresponds to one industry. Industries are aligned based on the US-Input-Output table industry code. A darker color indicates high flexibility and a lighter color indicates low flexibility (price stickiness).
Source: My calculation based on Nakamura and Steinsson (2008) and 2002 US Input-Output table.

Figure 2: CPI inflation rate (2003–2012 average).

Source: International Financial Statistics, Cavallo and Bertolotto (2016) for Argentina, and Taiwan's statistical office for Taiwan.

(inflation rate) from the IFS.

I use the 10-year average for the inflation rate measure because the long-run inflation rate is a theoretically relevant measure. Furthermore, to minimize possible endogeneity issues, the regression uses the lag of the 10-year average. For example, in the panel estimation using 2011–2015 trade data, I use the average inflation rate from 2001 to 2010.[15] In the cross-sectional estimation, I use the average inflation rate over 2005–2014 for the 2015 trade data, the average inflation rate over 2004–2013 for the 2014 trade data, and so on.[16]

Figure 2 shows the average inflation rate for the 2003–2012 period. These years are matched to the cross-sectional estimation for the 2013 trade data, which is in the middle of the sample period. It is widely recognized that the inflation rate differs across countries. The main variation is in the difference between developed and developing countries. Generally, inflation rates are higher in developing countries than in developed countries. However, some variation can be observed between developed and developing countries. For example, among the developed countries, the inflation rate of South Korea (3.1%) is higher than that of neighboring Japan (−0.1%). Among the developing countries, Ghana's inflation rate (14.0%) is higher than that of the nearby country of Cameroon (2.4%).

[15] If each year of the trade is matched with each set of 10-year lagged values (2015 trade data are explained by the average country characteristics in 2005–14, 2014 trade data by characteristics in 2004–13, and so on), the explanatory variable contains year-to-year change in the average 10-year inflation rate within a country. The variation is closely related to the short-run (year-to-year) change in inflation, which is not what I want to capture.

[16] If a country has missing inflation rate observations, I drop the missing year from the calculation of the average inflation rate, but keep it in the regression.

The data period includes Zimbabwe's hyperinflation period, in which the average inflation rate exceeded 3,000% per year. This number is far higher than the second and third highest (25.5% in Angola and 23.5% in Venezuela). Zimbabwe is an obvious outlier, so I exclude it from the entire estimation sample.

In the regression, I calculate the natural logarithm of the absolute value of the gross inflation rate, log(1+|CPI inflation rate (%)|/100), as the variable. For example, the value for South Korea is log(1.031), and that for Japan is log(1.001). The absolute value comes from the theoretical reasoning that both inflation and deflation are costly in price-rigid industries.[17]

3.2.4 Other country- and industry-level variables

A country's income level affects its productivity and trade patterns. For this purpose, I use a country's GDP per capita and per worker, both from Penn World Table 9.0 (Feenstra et al., 2015). Both values are PPP-adjusted.

As a set of control variables, I include 13 "other comparative advantage terms" in the regressions (for example, Chor, 2010). These are (1) a country's capital-endowment times the industry's capital-intensity, (2) skill-endowment times skill-intensity, (3)–(4) the level of financial development times measures of external financial dependence and asset tangibility (Manova, 2013), (5)–(9) a measure of institution level times five measures of contract intensity (Nunn, 2007; Levchenko, 2007; Costinot, 2009; Antràs and Chor, 2013; Antràs, 2015), (10) skill-endowment times the complexity of jobs (Costinot, 2009), and (11) a measure of labor market rigidity times sales volatility (Cuñat and Melitz, 2012). I also add (12) the country's natural resource endowment times natural resource intensity and (13) the interaction of the country's variability of the nominal exchange rate and the frequency measure.

For this, I take country- and industry-level variables, following the above-mentioned studies. See the Appendix for further details. I also control for the interaction terms of the inflation rate and industry-level variables as well as the interaction terms of country-level variables and the industry's flexibility measure.

The reasons for including (12) and (13) are as follows: One concern is that both the trend inflation rate and price rigidity are proxies for the other variables. One plausible explanation is that price rigidity captures the industry's natural resource intensity, and the inflation rate captures the country's level of natural resource endowment. The former is empirically plausible, because industries that use natural resources (whose prices are volatile) tend to have low input price rigidity. The latter is also empirically plausible, because the inflation rate tends to be high in countries rich in natural resources. Thus, I include an interaction term of country-level natural resource endowment (taken from the World Development Indicators) and an industry-level measure of energy intensity (measured by the ratio of values of energy input to the value of total shipment using US data).

Another concern is the exchange rate. The model in the previous section abstracts the price rigidity of traded goods. The model also excludes the price rigidity of imported intermediate inputs because it does not include imported intermediate goods. This complementary price rigidity may be relevant empirically.

[17]Under Calvo specification, inflation and deflation have asymmetric impacts, while taking absolute values imposes symmetric impacts; however, a country with deflation is very exceptional and hence, there is no significant impacts on the results.

I control for the effects of changes in the nominal exchange rate to minimize this concern. I include the interaction terms for a country's level of nominal exchange rate variability and several industry-level characteristics, including the price rigidity measure. The idea is that the effects of transactions with other countries are influenced by changes in the nominal exchange rate and that an industry facing rigid domestic input prices is more prone to this international effect. The nominal exchange rate variability is measured by the coefficient of variation over the previous 120 months, and the nominal exchange rate is the country's currency against the US dollar. All variables are lagged 10-year averages, as in the inflation rate measure.

Table 4 reports the summary statistics for the main variables. The summary statistics for other variables are reported in Table A1. Regarding trade data, approximately 20% of trade flow is zero, which calls for PPML estimation.

In the Appendix, I report the cross-country correlations of the country variables and the cross-industry correlations of the industry-level variables. In summary, both the inflation rate and the frequency measure are correlated with other variables of a certain magnitude but are not fully explained by these other variables.

Table 4: Summary statistics of the main variables (for 2013 data)

	Mean	SD	Min	Max	Obs.
Exports value (Billion USD)	0.32	2.40	0	130.6	43,092
Exports value (Billion USD) $\mid > 0$	0.39	2.67	3.0e-11	130.6	34,587
log (Exports value (Billion USD) $\mid > 0$)	−5.99	4.35	−21.4	4.87	34, 587
$\bar{\pi}^c \times \text{Freq}_i$	1.23	1.48	0.0050	21.7	40,166
Country-level variable (avg. 2003–12)					
CPI inflation (%)	6.26	4.78	−0.13	25.5	180
$\bar{\pi}^c$ (log(1+‖Gross inf rate‖), CPI)	0.060	0.044	0.0013	0.23	180
Industry-level variable					
Price flexibility (Freq_i)	21.1	16.0	3.98	95.5	279

Source: See Section 3.2.

3.2.5 Illustrative example

Table 5 shows a snapshot of the data. The first column shows the names of the two countries—the Republic of North Macedonia (FYR Macedonia during the data period) and the Republic of Azerbaijan—and their average real GDP per capita and inflation rates from 2003 to 2012. The remaining columns show the top three exporting industries in 2013, their export values, and their input price flexibility measures.

These two countries have similar GDP per capita (9907 for North Macedonia and 9769 for Azerbaijan), both of which are transition economies; among their top three exporting industries, both countries include heavy industries (iron and steel mills, chemical, petroleum refineries, and petroleum and grease) as well as light industries (apparel and sugar). However, these two countries differ in their inflation rates and in

Table 5: Illustrative example

Country RGDPpc Inf. rate	Top 3 exporting industries	Value ($\times 10^9$) USD	Freq. (%)
N. Macedonia	Iron & steel mills & ferroalloy mfg (331110)	0.78	21.5
9907	All other basic inorganic chemical mfg (325188)	0.64	26.7
2.4%	Women's and girls' cut and sew apparel mfg (315230)	0.35	11.2
Azerbaijan	Petroleum refineries (324110)	0.65	95.5
9769	Petroleum lubricating oil and grease mfg (324191)	0.59	76.9
8.0%	Sugar mfg (31131X)	0.24	33.3

Source: RGDPpc is the PPP-adjusted real GDP per capita, with average 2003–2012 values taken from Penn World Table 9.0. Inf. rate is the average inflation rate from 2003 to 2012 from International Financial Statistics. The export value is obtained from the UN Comtrade database. The frequency (Freq) of input prices is the measure of flexibility by industry input prices and is calculated based on Nakamura and Steinsson (2008) and the 2002 US Input-Output table.

the frequency of price changes in their export industries.

The inflation rate is higher in Azerbaijan (8.0%) than in North Macedonia (2.4%). Azerbaijan exports goods with a high frequency of price change. Price change frequencies for exported goods from North Macedonia are higher than the median (see Table 3), but relatively lower than those from Azerbaijan.

This example is illustrative; however, countries' comparative advantages depend on various other factors. For example, Azerbaijan's large exports of petroleum products are likely driven by its natural resource (crude oil) endowment. Similarly, some export industries require both physical and human capital. Generally, the characteristics of a country or industry are important determinants of its export value. Other sources of comparative advantage may have also affected these examples. To control for these potential determinants, I move to the regression framework.

3.3 Results

3.3.1 Main result

Table 6 shows the main regression coefficients. I begin with the specifications using cross-sectional observations for 2013.[18] This year is in the middle of the sample period. The dependent variable is country-industry exports in 2013. The inflation rate is the average inflation rate for the period 2003–2012.

Column (1) shows the OLS results, using the log of export values as the dependent variable. Observations with zero-flow are excluded from this specification. The specification includes the key explanatory variable, the interaction term of the inflation rate and the measure of price flexibility, and country- and industry-fixed effects. The coefficient is positive and statistically significant at the 1% level (and is even below 0.1% level). A positive coefficient indicates that a country with a high average inflation rate tends to export more goods with flexible input prices. Thus, the data support the model's prediction.

Column (2) simply switches to the PPML estimation. The number of observations in this specification

[18]The Appendix reports the cross-sectional estimates using other years. The results are essentially the same.

is 40,166 (151 countries × 266 industries). The interpretation of the coefficient is the same, and the estimated coefficient is close to that in the previous case.

Column (3) shows the PPML estimation, including 13 other determinants of comparative advantage (e.g., financial development × external financial dependence). Although the coefficient is essentially the same, the standard error becomes larger than in the previous case yet is still statistically significant at the conventional level. Column (4) further controls for the interaction terms of the inflation rate and other industry-level variables (e.g., the log of the absolute value of the inflation rate × external finance dependence), and the interaction terms of country-level variables and the frequency of price changes. The main coefficients remain essentially the same. Column (5) controls for the industry fixed effect interacting with real GDP per capita, originally used by Levchenko (2007) and recommended by Nunn and Trefler (2014). The idea is to eliminate the industry-specific effects of the overall level of economic development. Here, real GDP per capita is also the lagged 10-year average, as is the case for other country-level variables. The estimated main coefficients are within the same ranges.

Column (6) returns the OLS specification, including all explanatory variables used in (5). Here, the coefficient is a standardized coefficient that facilitates the interpretation of the result. A one standard deviation change in the interaction term of inflation and price rigidity is associated with a 0.06 standard deviation change in industry-level log exports from a country to the world. By fixing price flexibility to the mean (21.1), a one-percentage-point change in the inflation rate leads to 0.14 ($\approx 21.1 \times 0.01/1.48$) standard deviation change in the interaction term; hence this leads to a 0.0084 ($\approx 0.14 \times 0.06$) standard deviation change in log exports from the interaction term contribution. Since a change in the inflation rate has its own impact but is captured by the country fixed effect in this specification, I am going to provide a more concrete interpretation in the next subsection.

The following two columns report the panel data results: The specifications use country-year and industry-year fixed effects. The standard errors are country- and industry-clustered. As shown in the Appendix, the choice of clustering is the most conservative among the various possibilities. Column (7) shows the panel version of Column (3), which includes 13 other main interaction terms (e.g., physical capital endowment × physical capital intensity). The estimated coefficient and its standard error are close to those of its cross-sectional counterparts. Column (8) shows the panel version of (5); again, the results are similar.

3.3.2 Economic impact

The regression coefficients in Table 6 support the main implication, but an important question is to what extent does the inflation rate affect exports. Table 7 presents the estimation results for understanding the economic impact.

Columns (1)–(4) eliminate country and industry fixed effects. Of course, excluding fixed effects is far from desirable when identifying the main effect, but the specification is (almost) identical to a standard difference-in-differences specification, so the economic interpretation is straightforward.

Columns (1) is for OLS and (2) is for PPML results, respectively. The specification includes country- and industry-level characteristics (e.g., GDP per capita and physical capital endowment for country variables and capital intensity for industry variables), along with three main variables: inflation rate,

Table 6: The impact of the trend inflation on country- and industry-specific export value

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	PPML	PPML	PPML	PPML	STD	PPML	PPML
$\bar{\Pi}^c \times \text{Freq}_i$	0.20***	0.25***	0.41***	0.43***	0.38***	0.06***	0.28***	0.28**
	(0.024)	(0.037)	(0.057)	(0.12)	(0.12)	(0.018)	(0.078)	(0.105)
Other comparative adv.			✓	✓	✓	✓	✓	✓
Country-terms$^c \times \text{Freq}_i$				✓	✓	✓		✓
$\bar{\pi}^c \times$industry-terms				✓	✓	✓		✓
Country FE	✓	✓	✓	✓	✓	✓		
Industry FE	✓	✓	✓	✓	✓	✓		
GDPpc$^c \times i$-FE					✓	✓		
Country-year FE							✓	✓
Industry-year FE							✓	✓
GDPpc$^c \times (i,t)$-FE								✓
Year	2013	2013	2013	2013	2013	2013	2011–15	2011–15
# Country	151	151	119	119	119	119	123	123
# Industry	266	266	257	256	256	256	256	256
# Obs.	32,861	40,166	30,464	30,464	30,464	26,609	148,992	148,992

Numbers in parentheses are robust standard errors for (1)–(6) and two-way (country and industry) clustered standard errors for (7)–(8); asterisks indicate significance levels: *** 1%, ** 5%, and * 10%. Equation (6) estimates the OLS and reports the standardized beta coefficient. The dependent variable is the log of the export value of industry i from country c for (1), the standardized value of the log of exports for (6), and the export values for (2)–(5) and (7)–(8): The main explanatory variable is the interaction term of the inflation rate in country c ($\bar{\pi}^c$), the frequency of price changes (Freq_i) for (1)–(5) and (7)–(8), and the standardized value of the interaction term for (6). The inflation rate for (1)–(6) is the average absolute value of the annual inflation rate for the 2003–2012 period. The inflation rate for (7) and (8) is the average absolute value of the annual inflation rate for 2001–2010. See Section 3.2.4 for the additional control variables.

Table 7: Regressions without fixed effects, and the comparison to the theory

	(1) OLS	(2) PPLM	(3) PPLM	(4) PPLM	(5) OLS	(6) PPML	(7) 2SLS	(8) 2SLS
$\bar{\Pi}^c \times \text{Freq}_i$	0.25***	0.39***	0.58***	0.52***				
	(0.044)	(0.065)	(0.074)	(0.12)				
$\bar{\Pi}^c$	−18.0***	−38.4***	−42.7***	−28.0				
	(1.18)	(3.16)	(3.31)	(24.4)				
Freq_i	−0.0090***	−0.017***	−0.014***	0.059				
	(0.0029)	(0.0037)	(0.0034)	(0.057)				
$\log s_i^c$					−0.30***	−2.07***	−2.28**	−5.01**
					(0.095)	(0.62)	(0.95)	(2.28)
Other comparative adv.			✓	✓			✓	✓
Country-terms$^c \times \text{Freq}_i$				✓				✓
$\bar{\Pi}^c \times$industry-terms				✓				✓
Country FE					✓	✓	✓	✓
Industry FE					✓	✓	✓	✓
Country variables	✓	✓	✓	✓				
Industry variables	✓	✓	✓	✓				
Year	2013	2013	2013	2013	2013	2013	2013	2013
# Country	118	118	118	118	151	151	117	117
# Industry	256	256	256	256	266	266	256	256
# Obs.	26,506	30,208	30,208	30,208	31,525	38,294	25,462	25,462
Kleibergen-Paap Wald F							49.5	1.89
Kleibergen-Paap rk LM							66.7	28.4
(p-value of rk LM)							0.00	0.00

The numbers in parentheses are robust standard errors where the asterisks indicate significance levels: *** 1%, ** 5%, and * 10%. The dependent variable is the log of the export value of industry i from country c for (1), (5), (7) and (8); and the export value for (2)–(4) and (6). See notes for Table 6 for the explanatory variables.

flexibility measure, and interaction. Column (3) adds 13 other comparative advantage terms, and column (4) includes the interaction terms of country-level characteristics and the industry's price flexibility measure, as well as the interaction terms of the country's inflation rate and industry-level characteristics. Despite this identification issue, the main coefficients are in the same range as, or slightly higher than, the coefficients in Table 6.

I now focus on Column (2) to provide an interpretation. Inflation itself has a negative impact; a one-percentage-point increase in the inflation rate (e.g., from 3% to 4%) is associated with an approximately −38% reduction in trade if the price is very rigid (zero frequency). The reduction is mitigated to $-30\%(\approx -38 + 0.39 \times 21)$ for mean-frequency industries and is almost offset to $-0.5\%(\approx -38 + 0.39 \times 95.5)$ for most flexible industries. Thus, I conclude that both inflation and price rigidity play important roles for determining pattern of trade. However, owing to identification issues, these effects should be interpreted with caution.

Another question is to what extent do the empirical results explain the theoretical predictions. I can compare the empirical and theoretical effects by directly estimating the Armington version of Equation (28). For this estimation, I first calculate the price distortion term (22). However, several issues must be addressed. First, as discussed in footnote 9, there is a bound on the parameters of the Calvo model. Imposing this restriction systematically excludes observations of high inflation rates and sticky industries, potentially leading to a selection bias. Second, the calculation of (22) requires the value of the elasticity of substitution η. As discussed in footnote 7, the value may differ across industries and countries. Here, I set $\eta = 10$ (c.f., Ascari and Sbordone, 2014). Thus, the s_i^c contains the measurement errors. The use of an instrumental variable (IV) resolves this second problem. An obvious candidate for IV is the interaction term between price rigidity and the lagged inflation rate. I use the lagged inflation rate for a reason explained in the next subsection. Note that the IV specification cannot resolve the first problem. In addition, the IV specification is based on the log-linear specification where observations with zero-trade are dropped. This elimination of zero-trade is also a potential source of selection bias.

Columns (5) to (8) of Table 7 report the results. Columns (5) and (6) do not use IV, whereas Columns (7) and (8) do. Specification (5) suffers from several problems, including zero trade. Specification (8) shows a low correlation between the IV and the explanatory variable. However, the coefficients (6) and (7) are reasonably close to each other. I use the coefficient -2 for interpretation. The coefficient corresponds to $-\mu + 1$ where μ is Armington elasticity. The coefficient -2 implies that μ is 3, which is smaller than the median value of 3.8 from the meta-analysis by Bajzik et al. (2020), but within their suggested range of values 2.5–5.1. Thus, although there are several methodological limitations, I conclude that the Calvo model is aligned with international trade data.

3.4 Additional robustness examinations

Other empirical issues also merit further discussion. Detailed results are reported in the Appendix.

3.4.1 Potential endogeneity of the inflation rate

One concern is the endogeneity problem. As explained in the Data section, an industry's frequency of price changes likely reflects its technological characteristics. Moreover, these data are obtained from the US. This means that flexibility measures and other industry-level characteristics do not depend on a country's trade policy or structure.

A concern centers on the country's inflation rate. The inflation rate may vary owing to the country's bundles of exported goods. To address the endogeneity problem, Table 8 compares the OLS and IV estimations for cross-sectional data from 2013. The IV for the inflation rate (the average inflation rate between 2003 and 2012) is the 2002 inflation rate. Note that the inflation rate interacts with various industry-level characteristics, all of which are treated as endogenous regressors; the excluded instruments are the interaction terms of the inflation rate in 2002 with these industry-level characteristics.

The inflation rate is highly autocorrelated. Thus, the inflation rate in 2002 is strongly correlated with the average inflation rate from 2003 to 2012. This high autocorrelation validates the instrument's relevance condition. The exclusion restriction imposed is that the inflation rate in 2002 affects the country's industry-level export mix in 2013 only through the average inflation rate from 2003 to 2012. More precisely, inter-industry differences in the flexibility measure that interacted with the inflation rate in 2002 do not have a direct impact on the inter-industry differences in the value of exports in 2013 after controlling for various other determinants of trade. If the 11-year lagged inflation rate affects certain industry-specific trade policies, this exclusion restriction may fail. This type of policy has not been discussed when central banks set their target inflation rates. However, there is a potential concern that the average inflation rate policy is correlated with other economic policies, which may have different impacts across industries. Thus, IV estimations have potential limitations.

Table 8 presents the results. Columns (1), (3), and (5) show the OLS estimations, and (2), (4), and (6) show the corresponding 2SLS estimations. The values reported in OLS columns differ slightly from the corresponding specifications in Table 6. This difference is due to the differences in the samples. The sample is restricted to cases for which instrumental variables are available. The 2SLS estimations yield results similar to OLS results. The large F-values of the first stage regressions validate the instrument's relevance. The rank condition test (rk LM) also supports this instrument. In the first two specifications, the endogeneity test of the inflation term cannot reject the null hypothesis. The null hypothesis is that the regressor satisfies the orthogonality condition. Moreover, in these specifications, the OLS and 2SLS coefficients are close. In Column (6), this null hypothesis is rejected. However, the OLS coefficient and the corresponding 2SLS coefficients are still close. Overall, the instrumental variable estimations suggest that endogeneity might be a problem, but the estimates without instruments are not significantly different from those with instruments.

3.4.2 Income level

Is there any heterogeneity in the effects among countries? Even with various control variables, high- and low-income countries face different economic conditions, especially in terms of inflation rates. Table 9 divides the sample into two approximately equal groups. Based on the lagged 10-year average GDP per capita, countries are divided into low-income (lower than \$12,000) and high-income countries (higher than \$12,000).

Columns (1) to (3) show the results for low-income countries, whereas Columns (4) to (6) show the results for high-income countries. Most coefficients are within the same range as the baseline results, although the coefficients for low-income countries are sometimes small and estimated less precisely. In summary, the data support inflation-driven trade patterns among low- and high-income countries, whereas the mechanism is more strongly observed among high-income countries.

3.4.3 Definitions and construction of the variables

The results are robust when modifying various variable construction procedures. The results based on the following changes to the definition of variables are not essentially different from the baseline results and are reported in the Appendix.

- Real GDP per capita or real GDP per worker

  For specifications including real GDP per capita, I also examine specifications that include real

Table 8: Instrumental variable estimations

	(1) OLS	(2) 2SLS	(3) OLS	(4) 2SLS	(5) OLS	(6) 2SLS
$\bar{\pi}^c \times \text{Freq}_i$	0.22***	0.18***	0.24***	0.16**	0.19***	0.27**
	(0.025)	(0.034)	(0.034)	(0.058)	(0.059)	(0.11)
Other comparative adv.			✓	✓	✓	✓
Country-terms$^c \times \text{Freq}_i$					✓	✓
$\bar{\pi}^c \times$industry-terms					✓	✓
Country FE	✓	✓	✓	✓	✓	✓
Industry FE	✓	✓	✓	✓	✓	✓
GDPpc$^c \times i$-FE					✓	✓
Year	2013	2013	2013	2013	2013	2013
# Country	145	145	118	118	118	118
# Industry	266	266	256	256	256	256
# Obs.	31,808	31,808	26,358	26,358	26,358	26,358
Kleibergen-Paap Wald F stat		747		281		16.2
Kleibergen-Paap rk LM stat		359		586		487
(p-value)		0.00		0.00		0.00
F for endogeneity of inflation rate		2.13		2.09		62.1
(p-value)		0.14		0.15		0.00

The numbers in parentheses are robust standard errors and the asterisks indicate significance levels: *** 1%, ** 5%, and * 10%. The dependent variable is the log of the export value of industry i in country c. The main explanatory variable is the interaction term of the average over 2003–2012 for the absolute value of the annual inflation rate in country c ($\bar{\pi}^c$) and the frequency of price change (Freq_i). All industry and country characteristics other than the inflation rate are treated as exogenous variables. The lagged average inflation rate (using one to ten year lagged values) is treated as an endogenous variable and instrumented by the 11-year lagged inflation rate. See notes for Table 6 for the explanatory variables.

Table 9: Low vs. high income countries

	(1)	(2)	(3)	(4)	(5)	(6)
	GDPpc< 12000			GDPpc≥ 12000		
	PPML	PPML	PPML	PPML	PPML	PPML
$\bar{\pi}^c \times \text{Freq}_i$	0.46***	0.050	0.29**	0.28***	0.47***	0.34**
	(0.064)	(0.18)	(0.15)	(0.041)	(0.16)	(0.15)
Other comparative adv.		✓	✓		✓	✓
Country-terms$^c \times \text{Freq}_i$		✓	✓		✓	✓
$\bar{\pi}^c \times$industry-terms		✓	✓		✓	✓
Country FE	✓	✓	✓	✓	✓	✓
Industry FE	✓	✓	✓	✓	✓	✓
GDPpc$^c \times i$-FE			✓			✓
Year	2013	2013	2013	2013	2013	2013
# Country	73	54	54	78	65	65
# Industry	266	256	256	265	255	255
# Obs.	19,418	13,824	13,824	30,464	30,464	26,609

The numbers in parentheses are robust standard errors and the asterisks indicate significance levels: *** 1%, ** 5%, and * 10%. The dependent variable is the export value. The main explanatory variable is the interaction term of the average over 2003–2012 for the absolute value of the annual inflation rate in country c ($\bar{\pi}^c$) and the frequency of price change (Freq_i). See Section 3.2.4 for the additional control variables.

GDP per worker instead of real GDP per capita.

- CPI or GDP deflator

  Using the GDP deflator as a measure of the inflation rate, instead of the CPI inflation rate does not change the main results. The tiny difference is already anticipated from the high correlation of the two measures, as reported in Table A2.

- Frequency including product turnover

  Nakamura and Steinsson (2008) report another frequency of price changes, that is, the price change due to product changes as a part of the price change. Naturally, the average frequency of the price change in this second concept is higher than for the original, but the cross-sectional variation does not differ much. As a result, the estimation results barely change.

- Median frequency

  In the baseline, I use weighted averages for the aggregation across categories. Another aggregation would use the weighted median. This change plays no essential role.

- Purchase value

  The aggregation of multiple inputs is weighted by the use-value in the I-O table, which represents the use of inputs by industries in the producers' price. Another choice is purchase-value ("PurVal"), which represents the use of inputs by industries in the purchasers' price. The latter basically includes transportation costs and margins. The choice does not matter.

- Years for calculating average

In the baseline calculation, I use a lag of the 10-year average values. I also examine 8-year and 12-year averages. The results are essentially the same.

4 Concluding remarks

Motivated by the prevalence of positive trend inflation rates across countries and cross-industry differences in input price rigidity, this study adds a stylized model of nominal rigidity with trend inflation to the Ricardian and Armington international trade models. In the long-run steady state, the resulting integrated model implies that price rigidity and inflation rate affect the pattern of trade. The model predicts that a country with high inflation has a comparative advantage in an industry with flexible input prices.

The regression analysis shows that the international trade data are consistent with this key prediction. Overall, a difference in the trend inflation rate has a sizable impact on the export structure, providing evidence of price distortion in the long run.

This result indicates the existence of additional interactions between monetary and trade policies. Short-run monetary policy is known to affect the nominal exchange rate in the short run and, hence, is considered a part of trade policy. In addition to this short-run impact, monetary policy has a long-term effect on a country's production and export structures.

However, several empirical problems remain unresolved. The first is the plausibility of price rigidity under relatively high inflation rates. In Calvo models, the frequency of price adjustment is an exogenous parameter. However, if a country's inflation rate is extremely high, the price changes more frequently. As Klenow and Malin (2011) summarize, price rigidity is prevalent across countries and times, including countries with somewhat high inflation (e.g., more than 5% per year). Alvarez et al. (2019) study price adjustments in Argentina during high-inflation years and find that price changes are infrequent until the inflation rate becomes extremely high (i.e., more than 50% per year). They also provide a summary of price adjustment frequencies during episodes of high inflation. Their data show that even under a 10% inflation rate, the likelihood of monthly price changes can be less than 25%, indicating that ω is greater than 0.75. Nontheless, it is important to empirically examine cross-country differences in price rigidity for different inflation rates.

The second issue concerns cross-country differences in inter-sector variations in price rigidity. This study is constrained by only US data on detailed industry-level price rigidity. Vermeulen et al. (2012) find some cross-country differences in inter-sector variations in the frequency of price adjustment in European countries. However, their data cover price rigidity of outputs and use large industry classifications. More empirical assessments of the nominal side effects on trade patterns are an important future research topic.

The third issue is the need for additional mechanisms. This study highlights the mechanism by which price rigidity in intermediate inputs interacts with domestic inflation rates. This is one of several potential mechanisms. The price adjustment friction are also prevalent in the output price or wages. Similarly, a change in the nominal exchange rate can drive a nominal-side change. Literature study the aggregate short-run impacts of these nominal-side variables, but not long-run. Regression results shown in the Appendix suggest that some interaction terms (industry characteristics interacting with inflation rate) have sizable coefficients. This study does not focus on these coefficients, yet some of them may be logically important. The exclusive focus on one particular channel is a limitation of this study. However, as virtually no studies have considered the impact of the nominal-side variable on the long-run disaggregated trade variable, it would be better to start from one of the many; here, I choose a particular one. Future theoretical and empirical studies should explore other interactions between nominal variables and trade.

A Data Appendix

A.1 Trade data

Trade data are taken from the United Nations Comtrade database. The downloaded data include, for each country, total exports and re-exports to the world coded in the "as reported" 6-digit Harmonized System (HS) classifications. Exports in the regressions are the differences between (original) exports and re-exports. Comtrade data are continuously updated. I supplement the newly uploaded data at various points in time using the list of new data `https://comtrade.un.org/db/mr/daYearsNewResults`. The data used in this study are updated as of June 30, 2018.

The original export values are encoded into 6-digit HS categories. The HS code is mapped to the US-IO 2002 category by using a concordance table provided by the US Bureau of Economic Analysis (BEA, `https://www.bea.gov/industry/xls/HSConcord.xls`). The BEA concordance table is a mapping between each US-IO 2002 category and the 10-digit HS category. In most cases, each 10-digit HS industry within a 6-digit industry is included in the same IO industry. For some 10-digit industries, the BEA allocates two or more US-IO industries and provides weights. These weights are used to divide the export values allocated to each IO industry. If two (or more) 10-digit industries within a 6-digit industry are allocated to two different IO industries, the export value is divided by the number of industries to be allocated. When a 1-digit HS industry is already divided into multiple industries with BEA weights and further requires allocation to multiple IO industries at the 6-digit level, the BEA weights are multiplied by equal share weights based on the number of industries to be allocated.

Some 6-digit HS industries are not included in the BEA table. In this case, I supplement the mapping. Priority is given to the corresponding 1997 table (`https://www.bea.gov/industry/zip/NDN0317.zip`). When the 1997 table does not show the mapping, the match is done by hand using the description in the HS6, BEA's IO-NAICS concordance table (The Excel file `AppendixA_rev4-24-08.xls` of `https://www.bea.gov/industry/zip/2002detail.zip`) and item descriptions of NAICS items (`https://www.census.gov/eos/www/naics/`). These additional matches are tabulated in the excel file "additional-matchfile.xlsx" in the file set.

A.2 Main variables

A.2.1 Input price flexibility

The original source of input price flexibility is Nakamura and Steinsson (2008). Their data include the monthly frequency of price changes for 345 PPI items, including agricultural products (e.g., leaf tobacco) and natural resources (e.g., iron ore). The first step in the conversion procedure is to allocate each PPI item to the US-IO industry. The concordance table I use is included in the file set ("concordance" sheet of freq.xlsx). At this stage, all industries in the IO table are included. The mapping is based on the description of the IO-industry, its mapping to NAICS products, and the detailed categories of PPI items ("wp.item.txt" and "wd.item.txt"). The frequency of the input industry is the frequency of the items included. If two or more items are assigned to the same industry category, a simple arithmetic average is used because no type of weight is available. The frequency of input prices is the weighted average of the frequency of different input industries, and the weights are the shares of the available input industries' use values (ProVal) in the USE of the 2002 US-IO table. Note that the frequency of price changes for intermediate services is not available; hence, it is not included here.

To check the robustness of the flexibility measure construction process, I examine the regression results using three alternative flexibility measures. (1) Nakamura and Steinsson (2008) report the frequency of price changes in PPI items, including price changes due to product turnover. Another measure uses broader frequency as a measure of PPI item-level frequency. (2) The baseline aggregates multiple PPI items and inputs by taking (weighted) averages. The second measure uses (weighted) medians. (3) The aggregation of multiple inputs is weighted by the use value in the I-O table, which represents the use of inputs by industries in the producers' price. Another choice is purchase-value ("PurVal"), which represents the use of inputs by industries in the purchasers' price. The latter includes the transportation costs and margins.

A.2.2 Inflation rate

The main source of inflation is the annual CPI inflation rate from IMF's International Financial Statistics (IFS). The inflation rate of the GDP deflator is used for robustness, and the deflator is obtained from the IFS. The two exceptions are Argentina and Taiwan. Argentina's official inflation rates (adopted by the IMF Fund) after 2007 are discredited. I employ the measure proposed by Cavallo and Bertolotto (2016). The IMF statistics do not include data for Taiwan, so I use data from the National Statistics of Taiwan (`http://statdb.dgbas.gov.tw/pxweb/dialog/statfile1L.asp`).

A.3 Other country-level variables

Country-level variables (rule of law, financial development, capital stock, and skill level of workers) are updated to the average values in the sample period based on the descriptions in the original papers and in Antràs (2015).

A.3.1 Real GDP per capita and real GDP per worker

Real GDP per capita is the purchasing power parity (PPP) adjusted values of real GDP ("rgdpe") divided by population ("pop"). Real GDP per worker is the PPP adjusted values of real GDP divided by the number of persons engaged ("emp"). Both are from the Penn World Table (PWT) 9.0 (Feenstra et al., 2015).

A.3.2 Nominal exchange rate variability

The original data come from the IFS's (end-of-period) monthly nominal exchange rate (domestic currency per U.S. dollar). First, I calculate the means and standard deviations over 120 months (requiring at least 60 months of observation). The coefficient of variation is then calculated as the ratio of the standard deviation to the mean. This coefficient of variation is a measure of variability in the nominal exchange rate.

A.3.3 Capital endowment

Following Nunn (2007) and Antràs (2015), the original source of the countries' capital endowment is PWT 9.0. Value is capital stock at the current PPPs (in mil. 2011US$) ("ck") divided by the number of people engaged (in millions) ("emp"). For each country, I calculate the capital-labor ratio for each year, and then take the lagged 10-year averages.

A.3.4 Skill endowment

The skill endowment is the average number of years of education from Barro and Lee's (`BL2013_MF1599_v2.1.csv` `http://www.barrolee.com`). Their data showed values for each of the five periods (1990, 1995, 2000, etc.). Thus, I use the average of the 2005 and 2010 values for the 2011 to the 2015 trade data.

A.3.5 Financial development

Financial development follows Manova (2013), Chor (2010) and Antràs (2015). The original data source is the World Bank's Global Financial Development Indicators (`http://databank.worldbank.org/data/download/GFDD_Excel.zip`). I use the value of "Private credit by deposit money banks and other financial institutions to GDP (%)" (code GFDD.DI.12) to measure a country's financial development. I calculate this value for each country for each year and then took the lagged 10-year average.

A.3.6 Rule of law

The measure of institutions is the "Rule of Law" index reported in the World Bank's World Governance Indicator dataset (`https://data.worldbank.org/data-catalog/worldwide-governance-indicators`). The measure is available for 1996, 1998, 2000, and 2002–2014. I use the lagged 10-year averages, excluding missing years.

A.3.7 Employment flexibility

This is measured using the labor market rigidity index included in the World Bank's Doing Business Reports (`http://www.doingbusiness.org/reports/`). The data start in 2005, which reports the measures for the previous year (2004). Until 2009, the reports show the rigidity index, whereas later issues only showed the subcategories of the index. For data after 2009, the rigidity is calculated based on the formula used for 2009. For 2014 and 2015, the values for multiple cities in the country are reported. For these countries, the values for the largest cities in the country are used. For each country, I use the lagged 10-year averages, excluding missing years.

A.3.8 Natural resource endowment

The natural resource rents reported in WDI "NY.ADJ.DRES.GN.ZS" multiplied by the real GDP of the country in the year from the Penn World Table. The WDI constructs this measure by calculating the price and costs, and the total rents are computed and then calculated as a share of the country's GDP.

A.4 Industry-level variables

Most industry-level variables are from Antràs's (2015) dataset, which in turn depends on Chor (2010) and Antràs and Chor (2013).

A.4.1 Input price flexibility

The measure is constructed using PPI item-level price change data from Nakamura and Steinsson (2008) and the US input-output table. The details are presented in Section 3.2.2.

A.4.2 Capital, skill and energy intensities

I calculate an industry's physical and human capital intensities using 1995–2005 data from the NBER-CES manufacturing database (Becker et al., 2016). Physical capital intensity (K-intensity) is the log of the industry's capital-employment ratio; skill (human capital) intensity (H-intensity) is the log of the share of nonproduction workers among all workers. Energy intensity is the ratio of energy input value to total shipment value. For each variable, I take the values for each year and then averaged the 1995–2005 data.

A.4.3 Other industry variables

Definitions and descriptions of the following variables are provided in the data appendix of Antràs (2015) and the original papers: external financial dependence and asset tangibility (Manova, 2013), relationship specificity (Nunn, 2007), input concentration (Levchenko, 2007), job complexity (Costinot, 2009), and sales volatility (Cuñat and Melitz, 2012). I employ three additional industry-level variables from Antràs (2015): the intermediation measure from Bernard et al. (2010), the demand elasticity measure constructed by Antràs and Chor (2013) based on the estimates of elasticity by Broda and Weinstein (2006), and the downstreamness measure constructed by Antràs and Chor (2013).

A.5 Summary statistics and correlation matrices

Table A1 reports summary statistics for these variables. The upper and middle panels show country- and industry-level variables. For the country-level variables, the table reports only the averages of 2003–2012, which are used for the cross-sectional specifications of the 2013 trade data. The bottom panel of Table A1 presents summary statistics for the variables used in the regressions.

Table A2 reports the cross-country correlations of the country-level variables. This table reports the 10-year averages of the 2003–2012 data. These coefficients are calculated using data for 221 countries; however, in the regression, many of these countries are excluded because of missing trade data. Several variables are found to be correlated. The CPI inflation rate (i.e., the log of the absolute value of the gross inflation rate) is highly correlated with the GDP deflator inflation rate(Table A2), which I use in the robustness checks in the Appendix. The inflation rate is also correlated with many other country-level characteristics, such as the degree of financial development, rule of law, and real GDP per capita. In the empirical implementation, I controlled for the effects of these correlations by including the interaction terms of the price flexibility measure and country-level characteristics.

Table A3 reports the cross-industry correlations of the industry-level variables. The coefficients are calculated for a maximum of 279 industries. Again, many of these variables are correlated, notably the price flexibility measure, which is correlated with many industry-level variables. Hence, it is important to control for the effects of these other characteristics.

B Model Appendix (Separate Appendix)

C Additional robustness results (Separate Appendix)

The separate Appendix is available at
`https://drive.google.com/file/d/1-bUU6qzkSkGP4rUtZ4zKFfs8RytmD57L/view`.

Table A1: Summary statistics of the variables

	Mean	SD	Min	Max	Obs.
Country-level variables (avg. 2003–12)					
CPI inflation (%)	6.26	4.78	−0.13	25.5	180
$\bar{\pi}^c$ (log(1+Gross inf rate), CPI)	0.060	0.044	0.0013	0.23	180
log(1+Gross inf rate), deflator	0.066	0.058	0.0015	0.48	155
log K/L ratio ($\bar{K}^c$)	11.1	1.31	7.86	13.2	172
log Schooling ($\bar{H}^c$)	2.01	0.44	0.47	2.57	145
log Financial development ($\bar{F}^c$)	3.47	0.95	0.71	5.28	182
Rule of Law ($\bar{R}^c$)	0.013	0.99	−2.39	1.95	213
log Labor flexibility ($\bar{LF}^c$)	0.67	0.15	0.30	0.96	185
log Natural resource ($\bar{N}^c$)	11.8	3.34	−0.030	17.9	167
Variability of Nom. exch. rate (σ(NXR)^c)	0.12	0.24	0	3.25	201
RGDP per capita (GDPpc^c)	9.11	1.25	6.19	11.7	181
Industry-level variables					
Price flexibility (Freq$_i$)	21.1	16.0	3.98	95.5	279
Physical capital (K)-intenity$_i$	4.58	0.83	2.05	7.37	279
Skill (H)-intensity$_i$	−1.30	0.39	−2.32	−0.37	279
Energy (E)-intensity$_i$	−4.32	0.84	−6.56	−1.47	279
External financial dependency$_i$	0.21	0.49	−1.15	3.08	258
Asset tangibility$_i$	0.29	0.097	0.14	0.66	258
Relationship specificity$_i$	0.46	0.22	0.033	0.97	258
Concentration of input$_i$	0.13	0.087	0.032	0.53	258
Job complexity$_i$	−0.51	0.21	−1.00	−0.068	257
Volatility of sales$_i$	0.18	0.051	0.084	0.42	258
Intermediation$_i$	0.40	0.13	0.16	0.74	258
Subst. elasticity$_i$	9.13	12.8	1.30	108.5	258
Downstreamness$_i$	0.56	0.22	0.22	1.00	258
Data used for regressions (country-level variables for avg. 2003–12)					
Exports value (Billion USD)	0.32	2.40	0	130.6	43,092
Exports value (Billion USD) | > 0	0.39	2.67	3.0e-11	130.6	34,587
log (Exports value (Billion USD) | > 0)	−5.99	4.35	−21.4	4.87	34,587
$\bar{\pi}^c \times$Freq$_i$	1.23	1.48	0.0050	21.7	40,166
$\bar{K}^c \times$K-intensity$_i$	51.3	11.1	22.6	97.3	39,102
$\bar{H}^c \times$H-intensity$_i$	-2.65	0.99	-5.95	-0.18	33,516
$\bar{F}^c \times$Ext. finance$_i$	0.75	1.84	-6.07	16.3	39,578
$\bar{F}^c \times$Asset tangibility$_i$	1.05	0.45	0.19	3.49	39,578
$\bar{R}^c \times$Relationship specificity$_i$	0.034	0.49	-1.78	1.89	40,863
$\bar{R}^c \times$Concentration$_i$	0.0097	0.15	-0.97	1.02	40,863
$\bar{R}^c \times$Job complexity$_i$	-0.038	0.54	-1.95	1.84	40,704
$\bar{H}^c \times$Job complexity$_i$	-1.06	0.48	-2.57	-0.032	32,256
$\bar{R}^c \times$Intermediation$_i$	0.030	0.41	-1.36	1.44	40,863
$\bar{R}^c \times$Subst. elasticity$_i$	0.68	15.3	-199.4	211.7	40,863
$\bar{LF}^c \times$Volatility of sales$_i$	0.12	0.043	0.025	0.40	39,578
$\bar{N}^c \times$NR-intensity$_i$	-51.7	17.5	-117.7	0.20	38,038
σ(NXRT)$^c \times$Freq$_i$	2.54	7.23	0	310.3	42,560

Source: See Section 3.2.

Table A2: Correlations of country-level variables

	$\bar{\pi}$	D	$\bar{K}^c$	$\bar{H}^c$	$\bar{F}^c$	$\bar{R}^c$	$\bar{LF}^c$	$\bar{N}^c$	V	G	w
$\bar{\pi}^c$ (log(1+‖Gross inf rate‖), CPI)	1.00										
log(1+Gross inf rate), Deflator	0.87	1.00									
log K/L ratio ($\bar{K}^c$)	−0.37	−0.34	1.00								
log Schooling ($\bar{H}^c$)	−0.24	−0.22	0.78	1.00							
log Financial development ($\bar{F}^c$)	−0.58	−0.55	0.72	0.63	1.00						
Rule of Law ($\bar{R}^c$)	−0.60	−0.59	0.77	0.59	0.78	1.00					
log Labor flexibility ($\bar{LF}^c$)			0.30	0.34	0.29	0.34	1.00				
log Natural resource ($\bar{N}^c$)	0.23	0.35				−0.26		1.00			
Var. of NXR ($\sigma(\mathrm{NXR}^c)$)	0.32	0.24			−0.22				1.00		
RGDP per capita (GDPpc^c)	−0.42	−0.38	0.96	0.79	0.75	0.79	0.35			1.00	
RGDP per worker	−0.37	−0.35	0.97	0.78	0.71	0.76	0.34			0.98	1.00

Coefficients shown are significant at the 5% levels

Note: This is a cross-country correlation using the 10-year averages of the 2003–2012 values for each country. The coefficients are calculated for 221 countries.

Source: See Section 3.2.4.

Table A3: Correlations of industry-level variables

	P	K	H	E	F	A	R	C	J	V	I	S	D
Price flexibility	1.00												
K-intensity	0.45	1.00											
H-intensity			1.00										
E-intensity	0.43	0.51	−0.33	1.00									
Ext. financial dep.	−0.25		0.46		1.00								
Asset tangibility	0.46	0.34	−0.35	0.57	−0.39	1.00							
Relationship specificity	0.62	0.44	−0.29	0.56	−0.17	0.46	1.00						
Concentration of input	0.61	0.25	−0.23	0.25	−0.27	0.34	0.52	1.00					
Job complexity	0.22	−0.25	−0.61		−0.52	0.32	0.24	0.29	1.00				
Volatility of sales			0.23	−0.17	0.41	−0.32			−0.19	1.00			
Intermediation		−0.29	−0.34		−0.40				0.49		1.00		
Substitution elast.												1.00	
Downstreamness	−0.26	−0.35		−0.62		−0.37	−0.44	−0.23			0.25	0.16	1.00

The coefficients are significant at the 5% level. The coefficients are calculated using a maximum of 279 industries. Source: See Section 3.2.4.

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