Nominal Exchange Rate Variability, Nominal Wage Rigidity, and the Pattern of Trade

Hirokazu Ishise*

December 19, 2019

Abstract

Does the stabilization of the nominal exchange rate stimulate international trade? This paper theoretically and empirically revisits this old but unresolved question by considering the differential impacts across sectors, particularly focusing on the interactive role with industry-level nominal wage rigidity. A stylized model clarifies mechanisms; after a change in the nominal exchange rate, trade may increase or decrease. I then show that in the long-run nominal exchange rate variability reduces trade if a sector faces the wage rigidity. A testable implication is that a country whose nominal exchange rate varies less has a comparative advantage in industries that intensively use sticky-wage workers. World trade data supports this comparative-advantage-type prediction.

Keywords: Nominal exchange rate variability; International trade; Comparative advantage; Nominal wage rigidity.
JEL Codes: F11, F14, F31, E24, F41, J31.

1 Introduction

The costs and benefits of the stabilization of the nominal exchange rate have been studied for a long period. A "myth" discussed in the policy circle is that stabilizing the nominal exchange rate stimulates international trade.[1] Based on some early theoretical predictions, empirical studies examine the impact of exchange rate variability (or exchange rate regimes) on the aggregate (total, pairwise or bilateral) trade. However, the empirical researches do not coherently detect negative effects of the nominal exchange rate

*Osaka School of International Public Policy, Osaka University. Address: 1-31 Machikaneyama, Toyonaka, Osaka 560-0043, Japan; Phone: +81-6-6850-5626; Email: ishise@osipp.osaka-u.ac.jp; I appreciate comments by Eric Bond, Jingting Fan, Junichiro Ishida, Masa Kudamatsu, Yi Lu, Noriaki Matsuhima, Takeshi Murooka, Alireza Naghavi, Raymond Riezman, and Lianming Zhu. This work is supported by JSPS KAKENHI Grant Number JP 16754340. All errors are mine.

[1]The idea goes back, as far as I notice, to Nurkse (1944, p. 210) saying

> Freely fluctuating exchanges involve three serious disadvantages. In the first place, they create an element of risk which tends to discourage international trade. The risk may be covered by "hedging" operations where a forward exchange market exists; but such insurance, if obtainable at all, is obtainable only at a price and therefore generally adds to the costs of trading.

The idea is still popular. For example, "Fixed exchange rate system" in Wikipedia (accessed Nov 1, 2019) explains that "[a] fixed exchange rate is typically used to stabilize the value of a currency... This makes trade and investments between the two currency areas easier..."

variability on trade.[2] Reflecting this non-detection, several theoretical works show that depending on several conditions, exchange rate variability may increase or decrease international trade.

What is missing in the literature is studying potentially heterogeneous impacts across industries.[3] Mixed empirical results might be combined results of positive and negative impacts across industries. Moreover, the heterogeneous impacts might be a reason that fractions of people strongly oppose to common currencies as euro.

This paper theoretically and empirically revisits this old yet still puzzling question of the impacts of variabilities of the nominal exchange rate on the international trade by considering the differential impacts across sectors, especially focusing on the role of nominal wage rigidity. In the first part, I clarify potentially competing mechanisms using a stylized model as results of interactive effects of nominal exchange rate variability and the nominal wage rigidity. Including these two elements to a simple two-good small-open economy model, the model provides a simple answer to the question: if an industry faces higher level of nominal wage rigidity, the industry is more likely to lose production in the long-run. In other words, the model provides an implication about the pattern of trade. A country who faces more (less) volatile nominal exchange rate has a comparative advantage in industries which faces flexible (sticky) wages. Since the implication is similar to the usual statement about the comparative advantage, in the second part I test this implication using world trade data. Employing the standard identification strategy of comparative advantage, the data supports the model's implication.

The model builds on the standard (undergraduate textbook) two-good two-factor (two types of labor) small open economy model.[4] There are two twists. First, the nominal exchange rate is uncertain. Instead of explicitly considering the nominal exchange rate policy, I simply assume that the nominal exchange rate follows a stochastic process, which moves the nominal prices of the goods in home country measured in the price of the rest of the world. Second, the nominal price of the one type of the labor (i.e., nominal wage) needs to be predetermined. In the literature of monetary economics, nominal wage rigidity is considered to be one of the most important forms of the nominal frictions (e.g., Erceg et al., 2000). The specification of the wage rigidity follows Obstfeld and Rogoff (2000): the one-period advance determination. A big advantage of this predetermined specification is that it is straightforward to solve the model without any approximation.[5] Although Obstfeld and Rogoff (2000) consider all workers are sticky-wage workers, I add another types of workers, flexible-wage workers, and different industries use different mix of these two

[2] A closely related issue is the impact of common currency on trade (Frankel and Rose, 2002; Glick and Rose, 2002). The empirical literature generally supports positive effects (e.g., Frankel, 2010). Obviously, using a common currency implies low exchange rate variability, but the effects of common currency is not just exchange rate.

[3] In the similar logic, the effect might be heterogenous even across firms within an industry, and this point should be addressed in the future.

[4] Final goods market is perfectly competitive, and the law of one price holds. These two assumptions imply the perfect pass-through of importing goods, while zero pass-through of exporting goods. This simplification is not consistent with empirical data. Empirical studies show that pass-through rate varies across countries and goods, and somewhere between zero and one (e.g., Burstein and Gopinath, 2014). However, the main mechanism to be shown should go through even if imperfect pass-through is included.

[5] Alternative specifications of the equilibrium models of wage/price rigidities as "Calvo" (the probabilistic opportunity of wage change) or "Rotemberg" (wage adjustment costs) become simple expressions under the steady state and the first order approximations, but the interest of this paper is the effect of the variance (i.e., the second order term). Neither the steady-state analysis nor the first-order approximation work. Another possibility is to use exogenous downward wage rigidity used by Schmitt-Grohé and Uribe (2016), which might lead to an interesting future agenda.

types of workers. This extension enables me to discuss cross-industry difference in the impact of wage rigidity on the pattern of trade.

If there is no nominal-side frictions, any changes in the nominal variables do not have any impacts on the real allocations. Under two-good two-factor, the production possibilities frontier (PPF) is the standard bow-shaped, and the production bundle is at the tangent of the PPF and the relative price line.[6] When the nominal exchange rate depreciates, the nominal price of the output rises. When the wages are fully flexible, the wages also rise at the same rate as the price, and hence employment and production stay the same. There are also no effects after the nominal exchange rate appreciation. The trade quantity does not change. The value (price times quantity) changes at the same rate of the price change (by the change in the nominal exchange rate), but the values measured in the unit of the rest of the world do not change.

Under wage rigidity, the output price rises after a depreciation, but the wage of the sticky-wage workers does not change. Firms then demand for sticky-wage workers, employ more workers, and then produce more. This positive response of output is larger for firms whose employment share of the sticky-wage worker is higher. After an appreciation of the nominal exchange rate, the exactly opposite happens. Firms now face low output price with high labor costs, and then the production decreases. This negative effect is again larger for firms which use sticky-wage workers more. Thus in the short-run, due to the wage rigidity and the nominal exchange rate movements, an industry relying more on sticky-wage workers experiences a larger fluctuation than an industry relying more on flexible-wage workers.[7]

What are then the long-run (average) effects? In the long-run, on average, both depreciation and appreciation can happen. However, the wage setter who maximizes households expected utility does not like a fluctuations in leisure. Households on average dislike the fluctuations in leisure caused by wage rigidity. To compensate the potential fluctuations, the wage for rigid wage workers is higher than the fully flexible benchmark. Due to this high costs, the use of rigid wage worker is lower. The reduction of low usage of rigid worker is partly made up by using flexible wage workers, but the allocation of workers is inefficient. Consequently, the industry which heavily relies on sticky-wage workers hurts more by the fluctuations in the nominal exchange rate.

In summary, the model implies that a rigid sector relatively more affected from the disturbance of the economy. This implication echoes a work by Cuñat and Melitz (2012). Cuñat and Melitz (2012) shows that the volatility of an industry hurts more if the country's labor market is rigid. Both models consider the combination of the disturbance and frictions in labor market, but the logic is contrasting. In Cuñat and Melitz (2012), the disturbance is industry-specific and the rigidity is country-specific, while in my case, the disturbance is country-specific and the rigidity is industry-specific.

The model's empirical prediction is that a country whose nominal exchange rate is more (less) volatile tends to export more on goods which are produced by less (more) sticky-wage workers. This prediction exactly corresponds to usual statement about the comparative advantage, e.g., a country whose workers are highly educated tend to export more on goods which requires more skilled labor. Hence, the empirical

[6] This situation is similar to the undergraduate textbook model of the premise of the Heckscher-Ohlin model.

[7] An important assumption is that firms do not have an access to the forward contract of the nominal exchange rate. Availability of forward contract is the key issue in Ethier (1973). Here I abstract the forward contract. Even if it is available, if the firm incurs the extra costs associated with the contract, the qualitative implication should go through.

strategy follows the empirical literature of comparative advantage (e.g., Romalis, 2004; Nunn and Trefler, 2014; Cuñat and Melitz, 2012). Specifically, I regress the country-industry-year level exports to the world on country-year and industry-year fixed effects, and the interaction term of a country's measure of the nominal exchange rate variability and an industry's measure of the wage rigidity. The prediction is a negative coefficient to the interaction term. In the implementation, I also control for various other interaction terms, e.g., a country's measure of education-level and labor market flexibility and an industry's measure of the skill-intensity and output volatility.

The industry-level wage rigidity is constructed from the Outgoing Rotation Group Survey of the US Current Population Survey (CPS) data. From this data, I calculate the fraction of workers who earns the same hourly wage after one year. An advantage of using US CPS is that the data has many observations so I can obtain reasonable industry-level variations. The measured industry-level wage rigidity has some variations across industries, and is negatively correlated with other prominent industry characteristics as capital intensity, skill intensity, and external finance dependency. Roughly speaking, wage rigidity is higher for light industry than heavy industry. Yet, the correlations are not large. Hence, the wage rigidity measure captures some additional characteristics of industry.

Combining this wage rigidity measure with world trade data from UN Comtrade and the nominal exchange rate variability measure from International Financial Statistics, I ran standard regressions of comparative advantage. The regression results support the hypothesis.

After summarizing the related literature in the following section, the rest of the paper proceeds as follows. Section 3 analyzes the model, and draws an empirical prediction. Section 4 shows the empirical results. Finally section provides a short summary of the paper and a few suggestive future directions.

2 Literature

This paper contributes to two strands of the literature: the effects of nominal exchange rate on trade and determinants of comparative advantage.

Many researchers examine the effects of variability of the nominal exchange rate on international trade.[8] McKenzie (1999) and Auboin and Ruta (2013) provide nice surveys on the literature. In summary, empirical results are at most very weekly supportive for the assertion of trade stimulating effects of exchange rate stabilization.[9] Most of these empirical studies focus on the aggregate or bilateral trade, except for Bini-Smaghi (1991), Bélanger et al. (1992), and McKenzie (1998). Even these works, they do not explicitly consider potential determinants affecting the different impacts across sectors.

Theoretically, although early works hinges on firm's risk averseness and currency hedgeing (Ethier, 1973), some later works focus on the interactive impacts with nominal rigidity. In particular, Bacchetta and van Wincoop (2000) analyze the impacts of the variability of the nominal exchange rate using the rigid price setting in buyer's currency. An interesting result is that the effect depends on the substitutability between leisure and consumption. However, they have only one type of the exporting good, and hence

[8] The initial analysis and the policy assertion are about the nominal exchange rate (Ethier, 1973; Clark, 1973), but the literature also consider the impacts of variability of the real exchange rate. I focus on the nominal exchange rate.

[9] Closely related question is the effects of common currency on trade, and using common currency tends to have positive impacts on trade (e.g., Glick and Rose, 2002; Frankel and Rose, 2002; Frankel, 2010).

analyze the aggregate level of trade. Relatedly, the open-economy macro literature studies the effects of the nominal rigidity on the real allocation of variables in international context (e.g., Obstfeld and Rogoff, 1996; Devereux and Engel, 2003; Benigno and Benigno, 2003; Obstfeld and Rogoff, 2003; Benigno, 2004; Corsetti and Pesenti, 2005; Schmitt-Grohé and Uribe, 2016). These studies focus on the short-run aggregate exports (as the home good), and hence not suitable to study the heterogeneous impacts across exporting sectors.[10] Contrary to these existing studies, I examine the inter-industry difference of the impacts of the nominal exchange rate on the long-run pattern of trade.

Second, this paper provides a new determinant of comparative advantage. As theoretically shown by Costinot (2009a), what is important to determine the pattern of trade is the interaction of the country's and industry's characteristics. For example, a country whose labor is well-educated has a comparative advantage in skill-intensive industries (Romalis, 2004), a country with well-enforced law has a comparative advantage in an industry whose input requires specific contract structures (Antràs, 2003; Matsuyama, 2005; Nunn, 2007; Levchenko, 2007; Nunn and Trefler, 2014), a financially developed country has a comparative advantage in an industry that requires large external finance (Manova, 2008, 2013), a country with well-enforced laws or that has a high population of skilled labor has a comparative advantage in an industry with complex jobs (Costinot, 2009b), and a flexible labor market country has a comparative advantage in an industry with high sales volatility (Cuñat and Melitz, 2012).[11] This strand of literature exclusively focus on the real side of the economy except for Ishise (2019), who shows that a low inflation country has a comparative advantage in an industry that has sticky input prices. None of these papers consider the nominal exchange rate nor the wage rigidity.

3 Wage rigidity and the exchange rate variability: a model

The model describes a two-good small open economy facing nominal wage rigidity and uncertainty about the nominal exchange rate. The purpose of presenting the model is to formally organize the intuitive idea. I impose many simplifying assumptions to highlight the main mechanisms.

Two key ingredients in the model are (i) the uncertainty about the nominal exchange rate and (ii) the nominal wage rigidity. Without either one of these two ingredients, the model is essentially the undergraduate textbook model of two-good economy, which is the premise of the two-country two-good Heckscher-Ohlin model. After showing the setup, I first explain the case without the nominal rigidity. Then I show the case with the nominal rigidity. The detail derivations are shown in the Appendix.

3.1 Setup

The model is a discrete infinite horizon ($t = 0, 1, ...$) model, but it is essentially reduced into the single period problem. I drop time subscript from the notations when the meaning is clear. A small open economy can produce two types of goods $i = 1, 2$ using two types ($j = f, s$) of labor l_{ji}. Labor is specific to (j, i) pair, and is not mobile across countries. The subscript f stands for flexible, meaning that l_{fi} is

[10] Bergin and Corsetti (2016) examine the impact of monetary policy on the allocation across firms whose productivities are heterogenous.

[11] Careful summaries are found in Chor (2010), Nunn and Trefler (2014) and Antràs (2015).

the flexible-wage labor whose nominal wage W_{fi} is determined at the same timing of the other variables. The subscript s stands for sticky, meaning that l_{si} is the sticky-wage labor whose nominal wage W_{si} is set in the end of the previous period.

The labor-leisure choice of the households determines the supply of labor. For each type of labor, each household supplies differentiated "variety" $\upsilon \in (0,1)$ of workers. Due to this differentiation, each household behaves as a monopolist of the "variety" of workers, and the household sets (υ, j, i) wages.

Households purchase two types of goods to consume. Households have an access to a complete set of state contingent claims to ensure consumption level, but the claims do not provide insurance for disutility from labor. Adding to the claim, goods are tradeable. The nominal prices of the goods in the world, P_1^* and P_2^*, are exogenously given. The only source of the uncertainty is the nominal exchange rate, $\mathcal{E}$, which follows an iid log-normal distribution,

$$\ln \mathcal{E} \sim N(\mu, \sigma^2). \tag{1}$$

Since the nominal prices and the nominal exchange rate are exogenously determined, the nominal prices in the country are exogenous to firms and households in the home country,

$$P_i = \mathcal{E} P_i^*. \tag{2}$$

3.1.1 Firms

Firms use Cobb-Douglas production technology to produce good y_i. Each of two types of labor is differentiated $\upsilon \in (0,1)$, and a firm employs all types of workers. Labor market is monopolistically competitive. Firms are price taker in both output and input markets.[12]

Households set wages in the input (i.e., labor) market.[13]

A firm which produces good i maximizes its profits, which is revenue minus total labor costs

$$P_i y_i - \int_0^1 W_{si}(\upsilon) l_{si}(\upsilon) \mathrm{d}\upsilon - \int_0^1 W_{fi}(\upsilon) l_{fi}(\upsilon) \mathrm{d}\upsilon. \tag{3}$$

The production function is

$$y_i = a_i l_{fi}^{\omega_i} l_{si}^{1-\omega_i}, \tag{4}$$

where a_i is the level of productivity, $\omega_i \in (0,1)$, and for $j = f, s$,

$$l_{ji} = \left(\int_0^1 l_{ji}(\upsilon)^{\frac{\phi-1}{\phi}} \mathrm{d}\upsilon \right)^{\frac{\phi}{\phi-1}}. \tag{5}$$

[12] This assumption implies a specific form of pass-through rate. As an importer, in home, P_i fully reflects changes in $\mathcal{E}$, 100% pass-through. As an exporter, in the rest of the world, P_i^* stays the same regardless $\mathcal{E}$, 0% pass-through. Reality is in the middle....CHECK.

[13] The monopoly power given to the households is a standard specification in the nominal wage rigidity literature regardless of the specific formulation of rigidity (See e.g., Erceg et al., 2000; Obstfeld and Rogoff, 2000).

The share parameter ω_i captures the relative importance of wage rigidity in the sector. A lower ω_i sector relies on sticky wage workers more.

The firm's problem essentially has two blocks, a profit maximization under Cobb-Douglas technology and cost minimization of differentiated labor for each j. It is straightforward to show that, for $j = f, s$,

$$l_{ji}(\upsilon) = \left(\frac{W_j(\upsilon)}{W_j}\right)^{-\phi} l_{ji}, \tag{6}$$

where

$$W_{ji} \equiv \left(\int_0^1 W_{ji}(\upsilon)^{1-\phi} \mathrm{d}\upsilon\right)^{\frac{1}{1-\phi}}. \tag{7}$$

In the Cobb-Douglas block, the first order conditions are the standard share forms,

$$W_{fi} = \omega_i P_i a_i l_{fi}^{\omega_i - 1} l_{si}^{1-\omega_i}, \tag{8}$$

and

$$W_{si} = (1 - \omega_i) P_i a_i l_{fi}^{\omega_i} l_{si}^{-\omega_i}. \tag{9}$$

3.1.2 Households

A continuum of symmetric $\upsilon \in (0, 1)$ types of households consume two types of goods $c_i(\upsilon)$ and supply four types of labor $l_{ji}(\upsilon)$. I here introduce an explicit notation of state of the economy h_t and the history of the economy up to t by h^t to explicitly express the nature of the insurance. A household maximizes expected utility

$$\mathrm{E}\sum_{t=0}^{\infty} \beta^t \left[\ln c(\upsilon, h^t) - \sum_i \sum_j \frac{\Gamma}{\eta} l_{ji}(\upsilon, h^t)^{\eta}\right], \tag{10}$$

where the parameter controlling the labor supply elasticity $\eta > 1$ and the level of labor supply $\Gamma > 0$,[14] $c(\upsilon, h^t) = \prod_i c_i(\upsilon, h^t)^{\alpha_i}$, $\alpha_i \in (0, 1)$ and $\sum_i \alpha_i = 1$, subject to the budget constraint

$$c(\upsilon, h^t) + \int_{h_{t+1}} q(h_{t+1}, h^t) b(\upsilon, h_{t+1}, h^t) \mathrm{d}h_{t+1} = \sum_i \sum_j \frac{W_{ji}(\upsilon, h^t)}{P(h^t)} l_{ji}(\upsilon, h^t) + b(\upsilon, h^t), \tag{11}$$

$$c(\upsilon, h^t) = \sum_i \frac{P_i(h^t) c_i(\upsilon, h^t)}{P(h^t)}, \tag{12}$$

[14] To highlight the effects driven by the labor demand side mechanism, I impose common η and Γ across $i = 1, 2$ and $j = s, f$.

the corresponding Non-Ponzi condition, and the labor demand condition (6). Each type of the households purchases $b(v, h_{t+1}, h^t)$ amount of the set of state contingent claims, and the claim pays a unit of "final" consumption c conditional on a particular realization of state as $b(v, h^t)$. The claim covers all possible state of the economy h_{t+1}, and $q(h_{t+1}, h^t)$ is the price of the claim. As a result, households can achieve constant level of consumption denoted by c^*. In the rest, I suppress the notations of time, state and history.

At the current period the household can change the consumption, labor supply, and the wages of the flexible-wage labor, but not the wages of the sticky-wage labor. The wages of the sticky-wage labor are set at the end of the previous period based on the expectation about the current period.[15] I consider a symmetric situation in which v does not matter.

From consumption aggregation,

$$P = \prod_i \left(\frac{P_i}{\alpha_i}\right)^{\alpha_i}, \tag{13}$$

and

$$\alpha_i Pc = P_i c_i. \tag{14}$$

By solving the maximization problem, the wage of the flexible-wage labor is

$$W_{fi} = \frac{\phi}{\phi - 1} \frac{\Gamma l_{fi}^{\eta}}{\frac{l_{fi}}{Pc}}. \tag{15}$$

The first term of the right-hand-side is the mark-up, and the second term is the marginal cost of labor. The marginal cost comes from the disutility of working normalized by the marginal utility of consumption.

For sticky-wage labor, the wages are set based on the expected values of the disutility of working and consumption,

$$W_{si} = \frac{\phi}{\phi - 1} \frac{\Gamma \mathrm{E}\left[l_{si}^{\eta}\right]}{\mathrm{E}\left[\frac{l_{si}}{Pc}\right]}. \tag{16}$$

As anticipated, the second term of the right-hand-side now involves the expectation operators.[16]

3.2 Benchmark: No wage rigidity

Suppose first that there is no wage rigidity for both types of wages. The economy is then almost the same as the classical two-goods small open framework in which the production possibilities frontier has a bow-shaped curve.

Contrary to standard Heckscher-Ohin setting, labor is sector and type specific. However, from the labor-leisure choice, households never supply infinite time to work. Households instead equalize the

[15]This timing assumption exactly follows Obstfeld and Rogoff (2000) except that I add flexible-wage labor.
[16]This equation corresponds to (11) of Obstfeld and Rogoff (2000).

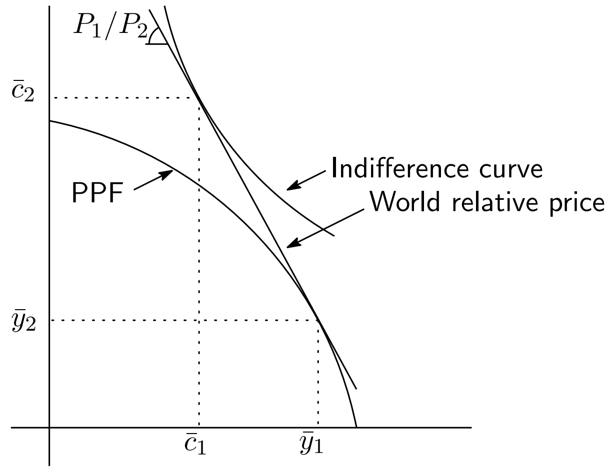

Figure 1: No wage rigidity in the two-good model

marginal disutility from working (after adjusting wages) for different types and sector of labor to the marginal utility from consumption. Besides, consumption (c^*) level is given, and hence total supply of labor for each type and sector is determined. As a result, the production possibilities frontier (PPF) is a bow-shaped as shown by Figure 1.

In the figure, production is at the tangent of the relative price line and the PPF. The consumption bundle achieved by the households is at the tangent of the indifference curve and the relative price. The difference between consumption and output corresponds to the amount of exports or imports. Figure 1 shows the case in which the home country exports good 1 and imports good 2.

Given the world relative price, the relative price in the country P_1/P_2 is exogenously determined. Without wage rigidity, the economy adjusts depending on the realization of $\mathcal{E}$. Since the nominal-side does not affect the real allocations, any changes in the nominal exchange rate do not affect the quantity of exports (which by assumption equals to quantity of imports times relative price). Moreover, by measuring values by the unit of the rest of the world (e.g., US dollar), any changes in the nominal exchange rate do not affect the values of exports and imports.

In the equilibrium, l_{si}, l_{fi} and y_i do not depend on $\mathcal{E}$, while W_{si} and W_{fi} are proportional to $\mathcal{E}$. Let $\bar{W}_{si}$ and $\bar{W}_{fi}$ stand for the values of wages at the fully flexible wage equilibrium. These values are constant value multiplied by $\mathcal{E}$. One percent reduction in the nominal exchange rate is associated with the one percent reduction in the nominal wages as

$$\bar{W}_{si} = P_i^* a_i \omega_i^{\frac{\omega_i}{\eta}} (1-\omega_i)^{\frac{\eta-\omega_i}{\eta}} \mathcal{E}. \tag{17}$$

Let $\bar{l}_{si}$, $\bar{l}_{fi}$, and $\bar{y}_i$ denote the values at the fully flexible wage equilibrium. Let $\bar{c}^*$ denote the consumption level under fully flexible wage setting, which is determined by solving the budget constraint. These values with bar are constant. In particular, output is

$$\bar{y}_i = a_i^{\frac{\eta}{\eta-1}} \left(\frac{P_i^*}{P^*} \frac{\phi - 1}{\phi \Gamma} \right)^{\frac{1}{\eta-1}} \omega_i^{\frac{\omega_i}{\eta-1}} (1-\omega_i)^{\frac{1-\omega_i}{\eta-1}} \left(\frac{1}{\bar{c}^*} \right)^{\frac{1}{\eta-1}} . \tag{18}$$

I interpret the values with bar as the "fundamental" (i.e., driven by exogenous productivity terms) determinants of trade. What I analyze in the next subsection is the deviations from these fundamental determinants caused by the nominal wage rigidity and exchange rate variability.

3.3 The effect of wage rigidity on the specialization

Now I examine the case in which one type of the wage is determined in advance.

First, from (2), (8), (9), and (15), l_{si} is written as a function of W_{si} and $\mathcal{E}$. Substituting this function into (16),

$$W_{si} = P_i^* a_i \omega_i^{\frac{\omega_i}{\eta}} (1-\omega_i)^{\frac{\eta-\omega_i}{\eta}} \underbrace{\left(\frac{\mathrm{E}\left[\mathcal{E}^{\frac{\eta(\eta-\omega_i)}{\omega_i(\eta-1)}} \right]}{\mathrm{E}\left[\mathcal{E}^{\frac{\eta(1-\omega_i)}{\omega_i(\eta-1)}} \right]} \right)^{\frac{\omega_i}{\eta}}}_{\equiv \tilde{\mathcal{E}}_i} . \tag{19}$$

Contrary to the flexible wage settings, the households need to set the wage before the realization of the nominal exchange rate. Since the terms other than $\tilde{\mathcal{E}}_i$ are the same as fully flexible wage version ($\bar{w}_{si}$) and consists of the parameters, the only difference comes from the "expected" value, $\tilde{\mathcal{E}}$, not the realization of $\mathcal{E}$. When households set the wage, households make the best effort to predict the future. They know the distribution of $\mathcal{E}$, but not the actual realization. Consequently, the nominal wages of sticky-wage labor depend on the "expected" values. The "expected" nominal exchange rate is actually not a simple average of the nominal exchange rate, instead it is a complex function of it. Mathematically, this complexity comes from (16) which is a nonlinear function of labor, price and consumption. Consumption is fully insured in this model.[17] However, disutility from working is not insured. Moreover, a change in the nominal exchange rate affects relative supply of sticky and flexible wage labor, and hence the level of disutility from different types of working.

Another remark is that if there is no uncertainty on $\mathcal{E}$ (by just dropping E operator), then $\tilde{\mathcal{E}}_i$ is reduced to $\mathcal{E}$. Without exchange rate uncertainty, even with nominal wage rigidity, the model goes back to the benchmark.

[17] Obstfeld and Rogoff (2000) do not include consumption insurance. Here, I include the insurance to handle complexity of multiple goods and labor.

3.3.1 Effects of depreciation and appreciation

Now I consider the deviation of output from the "fundamental" (no wage rigidity) situation. After determining W_{si}, other variables are easily calculated. In particular, output is

$$y_i = a_i^{\frac{\eta}{\eta-1}} \left(\frac{P_i^*}{P^*} \frac{\phi-1}{\phi\Gamma} \right)^{\frac{1}{\eta-1}} \omega_i^{\frac{\omega_i}{\eta-1}} (1-\omega_i)^{\frac{1-\omega_i}{\eta-1}} \left(\frac{1}{c^*} \right)^{\frac{1}{\eta-1}} \left(\frac{\mathcal{E}}{\tilde{\mathcal{E}}_i} \right)^{\frac{\eta(1-\omega_i)}{\omega_i(\eta-1)}}. \tag{20}$$

From (18) and (20), the gap is

$$\frac{y_i}{\bar{y}_i} = \left(\frac{\bar{c}^*}{c^*} \right)^{\frac{1}{\eta-1}} \left(\frac{\mathcal{E}}{\tilde{\mathcal{E}}_i} \right)^{\frac{\eta(1-\omega_i)}{\omega_i(\eta-1)}}. \tag{21}$$

The gap depends on the consumption ratio $\bar{c}^*/c^*$, which is common across industries. As shown in the Appendix, $\bar{c}^* \leq c^*$ and equality holds if there is no uncertainty on the exchange rate. It means that if I ignore the last term, then the output is higher under wage rigidity than the output under fully flexible setting. If $\omega_i = 1$, then the sector does not depend on sticky-wage workers. In this case, the output of this sector is higher than one in the flexible-wage case. Third, depending on the realization of $\mathcal{E}$, real-side variables now change. The reason is that the nominal wage of one of the the factor is predetermined, the gap between the expected and realized values of the nominal exchange rate affect labor demand, labor supply, and output.

In particular, the output is an increasing function of $\mathcal{E}$. That is, after an increase in $\mathcal{E}$ (depreciation), the output increases. In this model, one of the input prices is fixed regardless of the realization of the output price ($= \mathcal{E}P_i^*$, the nominal exchange rate times price in the world). A devaluation leads to high output price while one of the input prices stays the same. Hence, the output increases.

This depreciation effect is larger for industry which uses sticky-wage worker more. This is also obvious by taking the cross derivative of (21) with respect to $\mathcal{E}$ and ω_i. In reverse, after an appreciation (a decrease in $\mathcal{E}$), output decreases, and the reduction is larger for the industry with more sticky wage workers. Thus in the short-run a change in the nominal exchange rate leads to an increase or decrease of output of sectors intensively using sticky-wage workers.

The next question is average impact, that is, the impact in the long-run.

3.3.2 Average impacts

Under the log-normal distribution of the nominal exchange rate (1), $\tilde{\mathcal{E}}$ can be explicitly calculated. Using the properties of log-normal distribution (see e.g., Johnson et al., 1994),

$$\tilde{\mathcal{E}} = \exp\left(\mu + \frac{\sigma_{\mathcal{E}}^2}{2} \frac{\eta}{\omega_i} \frac{\eta + 1 - 2\omega_i}{\eta - 1} \right). \tag{22}$$

Using this

$$
\begin{aligned}
\mathrm{E}\left[\frac{y_i}{\bar{y}_i}\right] &= \left(\frac{\bar{c}^*}{c^*}\right)^{\frac{1}{\eta-1}} \mathrm{E}\left[\left(\frac{\mathcal{E}}{\tilde{\mathcal{E}}_i}\right)^{\frac{\eta(1-\omega_i)}{\omega_i(\eta-1)}}\right] \\
&= \left(\frac{\bar{c}^*}{c^*}\right)^{\frac{1}{\eta-1}} \exp\left(-\frac{\sigma^2}{2}\left(\frac{\eta}{\omega_i(\eta-1)}\right)^2 (1-\omega_i)(\eta-\omega_i)\right). \qquad (23)
\end{aligned}
$$

Suppose now fix effects common across industries ($\bar{c}^*/c^*$). The derivative with respect to σ is negative, the derivative with respect to ω_i is positive, and the cross derivative with respect to σ and ω_i is negative.

That is, the variability of the exchange rate on average hurts the output of the industry. Given nominal exchange rate variability, less ω_i (industry relying sticky-wage workers more) hurts more.

In short, the model says that a rigid sector relatively more affected from the disturbance of the nominal exchange rate.

4 Empirical evidence of exchange variability on the pattern of trade

The testable hypothesis of the model is that after controlling for other determinants of trade, a country who faces volatile nominal exchange rate (against US dollar) has a comparative advantage in industries which faces flexible wages. The implication is similar to the usual statement about the comparative advantage, e.g., a country which has more skilled labor has a comparative advantage in industries that intensively use skilled labor. Hence, the empirical methodology basically follows the literature examining the comparative advantages (see, e.g., Nunn and Trefler, 2014).

4.1 Specification and identification idea

The baseline specification of the regressions is to fit the country-industry-year level exports on the interaction-term of a variability measure of the country's nominal exchange rate and the industry-level measure of wage rigidity. All the regressions include country-year and industry-year fixed effects. Adding to these two fixed effects, I control for other determinants of comparative advantage examined in the literature.

The specification is

$$
\ln x_{it}^c = (\mathbf{z}^c \circ \mathbf{q}_i)'\boldsymbol{\beta} + \gamma_t^c + \delta_{it} + ... + u_{it}^c
$$

where x_{it}^c is country c's exports for industry i in year t, $\mathbf{z}^c$ is a vector of country specific variables including the nominal exchange rate variability), $\circ$ is the element-by-element multiplication operator, $\mathbf{q}_i$ is a vector of industry characteristics including the wage rigidity measure, $\boldsymbol{\beta}$ is the vector of coefficients including main interest, γ_t^c is the country-year fixed effect, δ_{it} is the industry-year fixed effect, and u_{it}^c is the error term.

The country-year fixed effects controls for any potential effects specific to the country at the year, e.g., the effect of business cycle and politically stabilization. The industry-year fixed effects controls for any potential effects specific to the industry-year, e.g., trade costs and industry-specific boom and bust. This identification strategy is analogous to the difference-in-differences estimations. Instead of comparing before and after status for the treated and control groups, the estimation detects the difference between high and low wage stickiness industries for high and low countries in terms of the variability of the nominal exchange rate.

The dependent variable is country-industry-year exports to the world. Due to the data availability as well as following the standard practice in the literature (Nunn and Trefler, 2014), analysis focuses on manufacturing products. In the literature, researchers use several types of data. Nunn (2007) employs cross-sectional data for country-industry exports (to the world). Levchenko (2007) uses cross-sectional data for industry-level US imports from countries in the world. Chor (2010) and Manova (2013) use industry-level bilateral trade data, which leads to gravity-type regressions. Bilateral data gives much more observations, but many of the exporter-importer-industry-level trade is zero. Although Santos Silva and Tenreyro (2006) propose a methodology to handle zero trade flows, the nonlinear nature of their estimation makes difficult to handle dataset with millions of observations. To avoid this implementation issue, I stick to the current data structure.

4.2 Data

I explain the summary of variable constructions, while the interested readers refer to the Appendix for the detail. Summary statistics are also reported in the Appendix.

4.2.1 Trade data

The left-hand-side variable, country-industry-year value of exports to the world, 2011–2015, is taken from the UN Comtrade database. The original data reports the industry exports values in the 6-digit harmonized system classification. Since the explanatory variables are coded in the industries of the US Input-Output table, I convert the trade data using the concordance table provided by the US Bureau of Economic Analysis.

I restrict the years for two reasons. First, a control variable is available only after 2004, and I use average of eight years lagged values. Second, the trade data right after the global financial crisis shows the great trade collapse, which may bring an additional noise to the regressions.

4.2.2 Exchange rate variability

Exchange rate variability is measured by 96 months coefficient of variations (standard deviation divided by the mean) of the nominal exchange rate against US dollar. The monthly nominal exchange rate is taken from the International Financial Statistics (IFS) of International Monetary Fund.

A straightforward measure might be the variance (volatility) of the nominal exchange rate or the standard deviation, but these measures are unit dependent. Instead I use the coefficient of variations, and by which unit does not affect the level of the variability measure. The literature does not agree on what types of measures should be used for the regressions. The discussion is mainly about how to calculate risk measures. However, my model is not about the (potential) risk of the currency but more

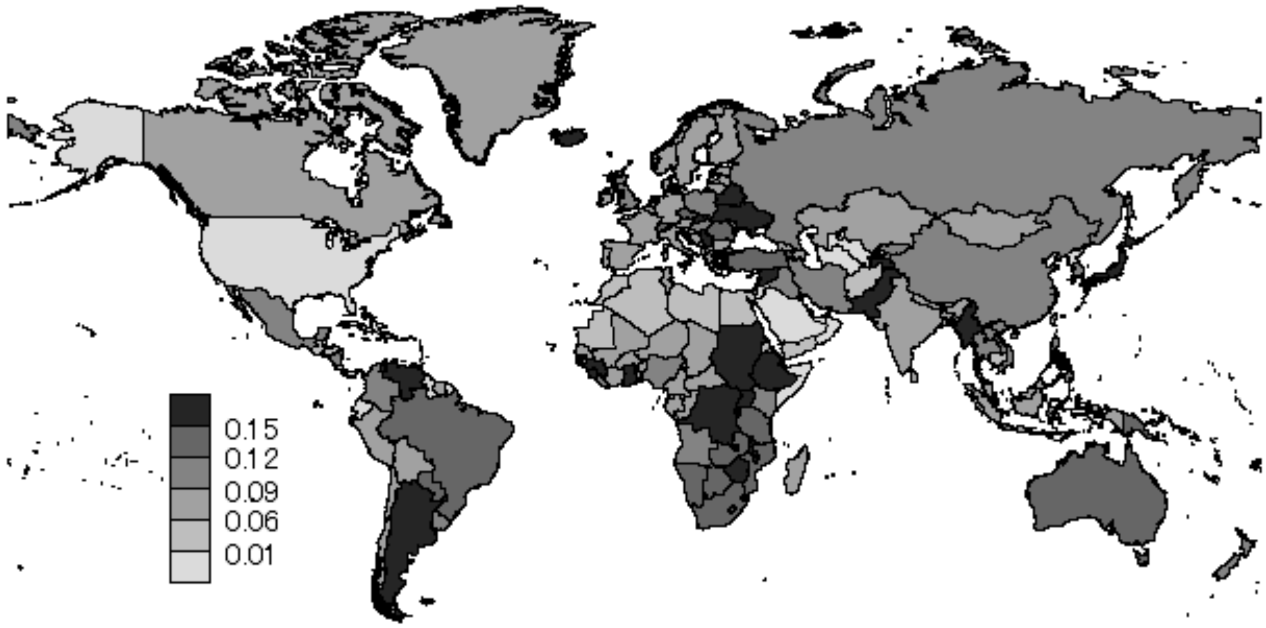

Figure 2: Nominal exchange rate variability (2005–2012 average).

Source: International Financial Statistics.

direct impacts of the changes in the face value, and hence I use a type of the variance as it is. I also run the regressions using the coefficient of variation of the growth rate of the nominal exchange rate against US dollar.

I use an eight-year average for the variability measure to focus on the long-run pattern. Further, to minimize the possible endogeneity issues, the regressions use the one-year lag of the eight-year averages. In the cross-sectional estimation, I use the average exchange rate variability over 2007–2014 for 2015 trade data, I use the average over 2006–2013 for 2014 trade data, and so on. In the panel estimation using 2013–2015 trade data, all the year variables are average over 2005–2012 regardless the year of the dependent variable.[18]

Figure 2 shows the variability measure countries. By construction, the measure is zero for countries using US dollars and those who peg to US dollar. The cross-country pattern of variability does not reflect the level of economic development. Some developed countries (e.g., Japan, Australia, New Zealand) face more volatile nominal exchange rate against US dollar than other developed countries (e.g., Euro countries) do. Some oil producing countries (e.g., Venezuela, and remember that the data is before the hyperinflation era), while other countries (e.g., Saudi Arabia which employs peg to US dollar). Some developing countries (e.g, Pakistan) face more volatile rate than other developing countries (e.g., Egypt).

[18] If each year of the trade is matched with the each own eight-year lags, the explanatory variable contains year-to-year change in the average eight-year value within country. The variation is closely related to the short-run (year-to-year) change, which is not what I want to capture.

4.2.3 Wage rigidity measure

The ideal measure about the wage rigidity is country-industry level of the wage rigidity for different types of workers (skilled, unskilled, etc.). However, obtaining such a country-industry level data is virtually impossible. European countries conduct a cross-country cross-industry comparison of wage rigidities by Wage Dynamics Network (see e.g., Druant et al., 2012), but the industry aggregation is single-digit level (e.g., manufacturing, construction, and financial service).

By considering this data limitation, I use the US data to construct the industry-level measure of wage rigidity. Actually, using US data to calculate industry-level characteristics is standard practice in the literature of comparative advantage (see, e.g, Nunn and Trefler, 2014). There are two reasons. First, the detail industry-level data is available only for a limited number of countries and usually the best data is from the US. Second, for industry characteristics about any types of frictions, the US is likely least countries facing the frictions and hence the frictions detected in the US reflect industry characteristics, not the country characteristics (See, e.g., discussion about the financial friction by Manova, 2013). Second, Using US data can be considered as a reduced-form IV estimation.

Specifically, I use the Current Population Survey (CPS) to calculate the industry-level wage rigidity (Flood et al., 2018). Two possible alternative data sources are the Survey of Income and Program Participation (SIPP) and the Panel Study of Income Dynamics (PSID). Barattieri et al. (2014) use SIPP data to calculate wage rigidities for several subdivisions of US population. The SIPP has an advantage which is higher frequency observations. The PSID has an advantage which tracks longer time period. However, the number of observations are fairly limited for these two surveys. In Barattieri et al. (2014), total number of observations for manufacturing is 6,785. The number of observations in PSID is also limited.

To obtain the variations across industries, I use the data from Outgoing Rotation Group (ORG) Survey of CPS. In the CPS, each household is surveyed for a consecutive four months, and not for the next eight months, and then surveyed for four months. In the last months of each four-month consecutive surveys, workers have additional questions regarding wage and earnings, which is the data for ORG. By this construction, panel version of ORG gives wages and earnings of an individual for a month and the month after one year. Through IPUMS-CPS, the panel linkage of CPS is available after 1989.[19] I pool individuals included in the ORG from 1989 to 2007. Even after several sample selections, I have 44,557 observations in the data.

The industry classification of the CPS is a simplified version of the Census industry classification, which in turn is based on 1987 SIC system. However, all other variables are based on 2002 US Input-Output (IO) industry classification, which in turn based on 1997 NAICS system. Matching the SIC to NAICS uses the concordance table of 1997 Economic Census.

Specifically, the calculation of the wage rigidity measure goes through the following steps. First, I drop several samples due to logical inconsistency of age and sex (e.g., an individual after one year becomes younger). In addition, for each individual of ORG, I drop those who have changed occupation, industry, or residential area (defined by the metro-area).[20] I further restrict samples to those who report hourly wage

[19] Rivera Drew et al. (2014) explain the detail about the panel linkage of CPS.

[20] Those who live in "Non-metro" area, the residential status is captured by State-"Non-metro" pair.

for two possible reporting timings. Second, I create a dummy variable of unchanged wage by comparing the hourly nominal wage in a month and the hourly nominal wage after one year. Based on the sample weight provided by CPS, I then calculate the average probability of wage change for each industry in CPS categories. Third, I map the CPS industry-level wage rigidity to the 53 US IO industry by using the number of workers in each industry as the weight of the mapping.

Table 1 shows the industry-level wage rigidity. Some notable features are as follows. Textile (3130–3160), printing (3230) and petro and coal (3240) industries face relatively rigid wages, whereas chemical (3251–3259) and metal (331A–332B) industries face relatively flexible wages. Machineries (3331–3339), electronic products (3341–3359), transportation equipment (3361–336B) industries are in the middle.

The pattern does not necessarily correspond to the classical light–heavy industry division. However, as will be explained in the next subsection (Table 3), this measure is correlated with other industry characteristics. In this sense, the measure is not purely random noises, but something empirically relevant. At the same time, the correlations are not high. Thus, the measure captures an aspect of industry characteristics.

4.2.4 Other country- and industry-level variables

Even after controlling for country and industry fixed effects, many other variables matter for the patterns of trade. To control for other determinants, I include several interaction-terms. The comparative advantage driven by the capital stock is controlled by including a country's level of capital stock and the industry's measure of capital-intensity. Similarly, I include country's human capital and industry's skill-intensity (Romalis, 2004), financial development and external finance dependence (Manova, 2013), institution-level and various industry characteristics (Nunn, 2007; Levchenko, 2007; Costinot, 2009b), and measure of labor market rigidity and volatility of sales of industries (Cuñat and Melitz, 2012).

For this, I prepare a country's capital-endowment (capital-labor ratio from the PWT, skill-endowment (years of schooling from Barro and Lee (2013)), a measure of financial development (from the World Bank's Global Financial Development Indicators), a measure of the rule of law from the World Bank's World Governance Indicators (WDI), and a measure of employment flexibility from the World Bank's Doing Business Reports. Natural resource endowment is measured by total values of natural resource taken from WDI. The average inflation rate is also important for capturing nominal side effects, and data is taken from IFS.

The industry-level variables follow or are directly taken from the literature. 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 capital-employment ratio of the industry, and human capital intensity (H-intensity) is the log of share of the non-production workers among all workers. Similarly, using the same data I calculate industry's energy intensity (E-intensity) as the log share of the energy input value to the value of shipment.

For other industry-level variables, I take the values from the dataset organized by Antràs (2015), which in turn depends on Chor (2010) and Antràs and Chor (2013). I follow Manova (2013) for external financial dependence and asset tangibility, Nunn (2007) for the relationship specificity, Levchenko (2007) for concentration of input, Costinot (2009b) for job complexity, and Cuñat and Melitz (2012) for sales

Table 1: 53 US Input-Output table Industry-level wage rigidity

Code	Name	Rigidity
3110	Food manufacturing	9.35%
3121	Beverage manufacturing	10.74%
3122	Tobacco manufacturing	9.31%
3130	Textile mills	10.29%
3140	Textile product mills	15.39%
3150	Apparel manufacturing	15.58%
3160	Leather and allied product manufacturing	20.23%
3210	Wood product manufacturing	13.68%
3221	Pulp, paper, and paperboard mills	9.79%
3222	Converted paper product manufacturing	10.85%
3230	Printing and related support activities	14.63%
3240	Petroleum and coal products manufacturing	13.68%
3251	Basic chemical manufacturing	8.99%
3252	Resin, rubber, and artificial fibers manufacturing	10.15%
3253	Agricultural chemical manufacturing	7.75%
3254	Pharmaceutical and medicine manufacturing	9.98%
3255	Paint, coating, and adhesive manufacturing	9.57%
3256	Soap, cleaning compound, and toiletry manufacturing	7.56%
3259	Other chemical product and preparation manufacturing	9.54%
3260	Plastics and rubber products manufacturing	12.78%
3270	Nonmetallic mineral product manufacturing	11.10%
3315	Foundries	8.48%
331A	Iron and steel mills and manufacturing from purchased steel	9.06%
331B	Nonferrous metal production and processing	8.61%
3321	Forging and stamping	12.26%
3322	Cutlery and handtool manufacturing	7.99%
3323	Architectural and structural metals manufacturing	10.86%
3324	Boiler, tank, and shipping container manufacturing	12.44%
332A	Ordnance and accessories manufacturing	3.12%
332B	Other fabricated metal product manufacturing	11.93%
3331	Agriculture, construction, and mining machinery manufacturing	11.57%
3332	Industrial machinery manufacturing	8.13%
3333	Commercial and service industry machinery manufacturing	7.89%
3334	HVAC and commercial refrigeration equipment manufacturing	9.11%
3335	Metalworking machinery manufacturing	11.99%
3336	Engine, turbine, and power transmission equipment manufacturing	10.27%
3339	Other general purpose machinery manufacturing	10.09%
3341	Computer and peripheral equipment manufacturing	10.38%
3344	Semiconductor and other electronic component manufacturing	11.42%
3345	Electronic instrument manufacturing	11.15%
3346	Manufacturing and reproducing magnetic and optical media	11.71%
334A	Audio, video, and communications equipment manufacturing	11.60%
3351	Electric lighting equipment manufacturing	11.44%
3352	Household appliance manufacturing	7.41%
3353	Electrical equipment manufacturing	11.53%
3359	Other electrical equipment and component manufacturing	11.62%
3361	Motor vehicle manufacturing	9.77%
3364	Aerospace product and parts manufacturing	9.26%
336A	Motor vehicle body, trailer, and parts manufacturing	10.70%
336B	Other transportation equipment manufacturing	10.31%
3370	Furniture and related product manufacturing	12.25%
3391	Medical equipment and supplies manufacturing	9.57%
3399	Other miscellaneous manufacturing	12.65%

Source: Author's calculation based on the Outgoing Rotation Group Survey of the Current Population Survey. Wage rigidity is the average probability of staying the same nominal wage after one year.

Table 2: Correlations of country-level variables

	E	C	K	S	F	R	L	N
Exch. vari. inflation								
CPI inflation	0.89							
K/L ratio								
Schooling			0.62					
Financial Development			0.65	0.60				
Rule of Law	−0.20		0.78	0.66	0.78			
Labor flexibility			0.25	0.26	0.28	0.34		
Natural resource								
RGDP per capita			0.86	0.51	0.54	0.71	0.29	

Coefficients shown are significant at the 5% levels

Note: This is cross-country correlation using the 8-year averages of the 2005–2012 values for each country. These coefficients are calculated using 236 countries.

Source: See Section 4.2.4.

volatility. I also 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). The first two measures are relevant for the institution-driven comparative advantage story. The downstreamness measure is not directly related to comparative advantage, but is constructed based on the US I-O table to capture the stage of production in I-O table.

Another important dimension is to control price rigidity rather than wage rigidity. Ishise (2019) constructs a measure of price flexibility based on the data by Nakamura and Steinsson (2008).[21] I include interaction terms with this price flexibility measure as control variables.

Finally, country's income-level affects the pattern of trade. I use a country's GDP per capita and GDP per worker, both from the Penn World Table 9.0 (Feenstra et al., 2015). Both are PPP adjusted values.

[21] See Ishise (2019) for details.

Table 3: Correlations of industry-level variables

	W	P	K	H	N	E	A	R	C	J	V	I	B
Wage rigidity													
Price flexibility													
K-intensity	−0.40	0.48											
H-intensity	−0.28												
NR-intensity		0.51	0.38	−0.30									
External financial dep.	−0.30			0.59									
Asset tangibility		0.64	0.40	−0.29	0.64	−0.32							
Relationship specificity		0.72	0.44		0.67		0.54						
Concentration of input		0.73	0.32			−0.43	0.46	0.62					
Job complexity	0.46		−0.34	−0.71		−0.64			0.41				
Volatility of sales						0.43				−0.33			
Intermediation	0.32		−0.49	−0.39		−0.42				0.52			
Broda-Weinstein elast.												−0.31	
Downstreamness		−0.35	−0.31		−0.73		−0.45	−0.58	−0.23			0.25	0.30

Coefficients shown are significant at the 5% levels.
Note: The coefficients are calculated using 53 industries.
Source: See Section 4.2.4.

4.3 Results

Table 4 and 5 report the main regression coefficients. The Appendix contains the full regression tables and additional robustness specifications.

The coefficients reported in the table are standardized beta coefficients, i.e., all the explanatory variables are subtracted by their means and then divided by their standard deviations.

Column (1) in Table 4 reports a simple specification using a cross-sectional data. The dependent variable is country-industry exports in 2013. The nominal exchange rate variability is the average from 2005–2012.[22] The specification includes country- and industry-fixed effects. Contrary to the hypothesis, the coefficient is positive, but it is not statistically significant. Column (2) controls for interaction terms relevant in this context—inflation rate, input price rigidity, labor market flexibility, and sales volatility. In this case the coefficient becomes negative and statistically significant. Column (3) includes interaction terms associated with additional sources of comparative advantage, and other interaction terms related to nominal exchange rate and wage rigidity. The result is the same as the previous column. Column (4) further adds additional interaction terms. The coefficient slightly rises. Column (5) and (6) control for the industry-fixed effects interacted with the log real GDP per capita or worker. Still, the coefficients are similar. Finally, Column (7) and (8) report the results from the panel regressions. In this case, instead of country and industry fixed effects, country-year and industry-year fixed effects are included.

To understand the size of the effects, Table 5 reports the coefficient from a panel regression. In this specification, to avoid several multi-collinearity, I include some of the interaction terms only. First, in this specification, the significance level is a bit weak but still the size of the coefficient of the main interaction term is similar to the previous table. The variability of the nominal exchange rate works negatively if the industry faces rigid wage. The effect is comparable to those of financial development interacted with external financial dependency (Manova, 2013), the rule of law interacted with the relationship specificity (Nunn, 2007), and the natural resource endowment interacted with the energy intensity of industry.

[22] The Appendix reports the cross-sectional estimates using other years. The results are similar.

Table 4: Determinants of country-industry-year export value

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\text{Exch}^c \times \text{Wage rigid}_i$	0.030	-0.71^{***}	-0.87^{***}	-1.32^{***}	-1.12^{***}	-1.20^{***}	-0.52^{*}	-0.53^{*}
	(0.022)	(0.19)	(0.29)	(0.37)	(0.37)	(0.37)	(0.28)	(0.28)
$\text{Inf}^c \times \text{Wage rigid}_i$		✓	✓	✓	✓	✓	✓	✓
$\text{Labor flex}^c \times \text{Wage rigid}_i$		✓	✓	✓	✓	✓	✓	✓
$\text{Exch}^c \times \text{Price flex}_i$		✓	✓	✓	✓	✓	✓	✓
$\text{Exch}^c \times \text{Sales vol}_i$		✓	✓	✓	✓	✓	✓	✓
Other comp. adv.			✓	✓	✓	✓	✓	✓
$\text{Country terms}^c \times \text{Wage rigid}_i$			✓	✓	✓	✓	✓	✓
$\text{Exch}^c \times \text{Industry terms}_i$			✓	✓	✓	✓	✓	✓
$\text{Country terms}^c \times \text{Price flex}_i$				✓	✓	✓	✓	✓
$\text{Inf}^c \times \text{Industry terms}_i$				✓	✓	✓	✓	✓
$\text{GDPpc}^c \times i\text{-dummy}$					✓		✓	
$\text{GDPpw}^c \times i\text{-dummy}$						✓		✓
Country FE	✓	✓	✓	✓	✓	✓		
Industry FE	✓	✓	✓	✓	✓	✓		
Country-year FE							✓	✓
Industry-year FE							✓	✓
Year	2013	2013	2013	2013	2013	2013	2011–15	2011–15
# Country	161	150	120	120	120	120	124	124
Obs.	7,691	7,237	5,978	5,978	5,978	5,978	29,056	29,056

Numbers in parentheses are robust standard errors for (1)–(6), and country- and industry- two-way clustered for (7)–(8). *** 1%, ** 5%, * 10%.

Table 5: Determinants of country-industry-year export value

	Stad. β	SE
Exchange rate variability^c $\times$ Wage rigidity$_i$	-0.56^*	(0.29)
Schooling^c $\times$ H-intensity$_i$	-0.066	(0.072)
K/L ratio^c $\times$ K-intensity$_i$	0.13	(0.38)
Financial development^c $\times$ External fin. dep$_i$	0.093^{**}	(0.039)
Financial development^c $\times$ Asset tangibility$_i$	-0.053	(0.11)
Rule of law^c $\times$ Rel. specificity$_i$	-0.11^{**}	(0.044)
Labor flexibility^c $\times$ Sales volatility$_i$	-0.059	(0.052)
Natural resource^c $\times$ NR-intensity$_i$	0.17^*	(0.089)
Inflation rate^c $\times$ Price flexibility$_i$	-0.0095	(0.017)
Inflation rate^c $\times$ Wage rigidity$_i$	0.55^*	(0.30)

Panel regression using 2011–2015 data. Number of observations is 29,318. Number of countries included is 124. Country-year and industry-year fixed effects are included. Industry-fixed effects interacted with log real GDP per capita are included. Other interaction terms not reported table are not included.
Numbers in parentheses are country- and industry- two-way clustered for (7)–(8). *** 1%, ** 5%, * 10%.

4.4 Robustness checks

I conduct several robustness checks. The results are available in the separate Appendix.

4.4.1 Nominal exchange rate

In the baseline, the coefficient of variation of the nominal exchange rate is the level of the variable. I also examine the coefficient of variation of the gross growth rate of the nominal exchange rate.

4.4.2 Wage

When I calculate wage rigidity, I include only wages reported as the hourly wage. If hourly wages are not observable, I supplement this by the average weekly earnings divided by the usual hours worked.

4.4.3 Number of years for calculating the country variables

In the baseline, I use eight-year (96-month) data to construct explanatory variables. The results are not largely different if I use six- or ten-year data.

4.4.4 PPML specification

Although the data does not include so many zeros, I also run the regressions using Poisson Pseud Maximum Likelihood estimations (Santos Silva and Tenreyro, 2006). The results are essentially the same.

5 Conclusion

This paper examines the impacts of variability of the nominal exchange rate on the international trade by considering the differential impacts across sectors. Theoretically, the model implies that a country who faces more (less) volatile nominal exchange rate has a comparative advantage in industries which faces flexible (sticky) wages. Since the implication is similar to the usual statement about the comparative advantage, I then test this implication using world trade data combined with the industry-level wage rigidity measure constructed by the United States Current Population Survey data. Employing the standard identification strategy of comparative advantage, the data robustly supports the hypothesis.

The paper focuses on the nominal wage rigidity, but other mechanisms may differentiate the impacts of nominal exchange rate variability on the value of trade. One important channel is the exporting and domestic pricing strategies as suggested by Bacchetta and van Wincoop (2000). The response of prices of imported intermediate inputs also might have impacts on the exporting prices and hence productions. Future researches are expected.

References

Antràs, P. (2003): "Firms, Contracts, and Trade Structure," *Quarterly Journal of Economics*, 118, 1375–1418.

——— (2015): *Global Production: Firms, Contracts, and Trade Structure*, Princeton, NJ: Princeton University Press.

Antràs, P. and D. Chor (2013): "Organizing the Global Value Chain," *Econometrica*, 81, 2127–2204.

Auboin, M. and M. Ruta (2013): "The Relationship between Exchange Rates and International Trade: a Literature Review," *World Trade Review*, 12, 577–605.

Bacchetta, P. and E. van Wincoop (2000): "Does Exchange-rate Stability Increase Trade and Welfare?" *American Economic Review*, 90, 1093–1109.

Barattieri, A., S. Basu, and P. Gottschalk (2014): "Some Evidence on the Importance of Sticky Wages," *American Economic Journal: Macroeconomics*, 6, 70–101.

Barro, R. and J.-W. Lee (2013): "A New Data Set of Educational Attainment in the World, 1950-2010." *Journal of Development Economics*, 104, 184–198.

Becker, R., W. Gray, and J. Marvakov (2016): "NBER-CES Manufacturing Industry Database," `http://www.nber.org/nberces/`, accessed March 8, 2017.

Bélanger, D., S. Gutiérrez, D. Racette, and J. Raynauld (1992): "The Impact of Exchange Rate Variability on Trade Flows: Further Results on Sectoral US Imports from Canada," *North American Journal of Economics and Finance*, 3, 61–82.

Benigno, G. and P. Benigno (2003): "Price Stability in Open Economies," *Review of Economic Studies*, 70, 743–764.

Benigno, P. (2004): "Optimal Monetary Policy in a Currency Area," *Journal of International Economics*, 63, 293–320.

Bergin, P. R. and G. Corsetti (2016): "Beyond Competitive Devaluations: The Monetary Dimensions of Comparative Advantage," mimeo.

Bernard, A. B., J. B. Jensen, S. J. Redding, and P. K. Schott (2010): "Intra-Firm Trade and Product Contractibility," *American Economic Review*, 100, 444–448.

Bini-Smaghi, L. (1991): "Exchange Rate Variability and Trade: Why Is It So Difficult to Find Any Empirical Relationship?" *Applied Economics*, 23, 927–936.

Broda, C. and D. E. Weinstein (2006): "Globalization and the Gains from Variety," *Quarterly Journal of Economics*, 121, 541–585.

Burstein, A. and G. Gopinath (2014): "International Prices and Exchange Rates," in *Handbook of International Economics*, ed. by E. H. Gita Gopinath and K. Rogoff, Amsterdam: North-Holland, vol. 4 of *Handbooks in Economics*, chap. 7, 391–451.

Chor, D. (2010): "Unpacking Sources of Comparative Advantage: A Quantitative Approach," *Journal of International Economics*, 82, 152–167.

Clark, P. B. (1973): "Uncertainty, Exchange Risk, and the Level of International Trade," *Economic Inquiry*, 11, 302–313.

Corsetti, G. and P. Pesenti (2005): "International Dimensions of Optimal Monetary Policy," *Journal of Monetary Economics*, 52, 281–305.

Costinot, A. (2009a): "An Elementary Theory of Comparative Advantage," *Econometrica*, 77, 1165–1192.

——— (2009b): "On the Origins of Comparative Advantage," *Journal of International Economics*, 77, 255–264.

Cuñat, A. and M. J. Melitz (2012): "Volatility, Labor Market Flexibility, and the Pattern of Comparative Advantage," *Journal of the European Economic Association*, 10, 225–254.

Devereux, M. B. and C. Engel (2003): "Monetary Policy in the Open Economy Revisited: Price Setting and Exchange-rate Flexibility," *Review of Economic Studies*, 70, 765–783.

Druant, M., S. Fabiani, G. Kezdi, A. Lamo, F. Martins, and R. Sabbatini (2012): "Firms' Price and Wage Adjustment in Europe: Survey Evidence on Nominal Stickiness," *Labour Economics*, 19, 772–782.

Erceg, C. J., D. W. Henderson, and A. T. Levin (2000): "Optimal Monetary Policy with Staggered Wage and Price Contracts," *Journal of Monetary Economics*, 46, 281–313.

Ethier, W. (1973): "International Trade and the Forward Exchange Market," *American Economic Review*, 63, 494–503.

Feenstra, R. C., R. Inklaar, and M. P. Timmer (2015): "The Next Generation of the Penn World Table," *American Economic Review*, 105, 3150–3182.

Flood, S., M. King, R. Rodgers, S. Ruggles, and J. R. Warren (2018): "Integrated Public Use Microdata Series, Current Population Survey: Version 6.0," `https://doi.org/10.18128/D030.V6.0`.

Frankel, J. (2010): "The Estimated Trade Effects of the Euro: Why Are They below Those from Historical Monetary Unions among Smaller Countries?" in *Europe and the Euro*, ed. by A. Alesina and F. Giavazzi, University of Chicago Press, 169–212.

Frankel, J. and A. K. Rose (2002): "An Estimate of the Effect of Common Currencies on Trade and Income," *Quarterly Journal of Economics*, 117, 437–466.

Glick, R. and A. K. Rose (2002): "Does a Currency Union Affect Trade? The Time-series Evidence," *European Economic Review*, 46, 1125–1151.

Ishise, H. (2019): "Inflation as a Source of Comparative Advantage," mimeo.

Johnson, N. L., S. Kotz, and N. Balakrishnan (1994): *Continuous Univariate Distributions*, New York: John Wiley & Sons, second ed.

Levchenko, A. A. (2007): "Institutional Quality and International Trade," *Review of Economic Studies*, 74, 791–819.

Manova, K. (2008): "Credit Constraints, Equity Market Liberalizations and International Trade," *Journal of International Economics*, 76, 33–47.

——— (2013): "Credit Constraints, Heterogeneous Firms, and International Trade," *Review of Economic Studies*, 80, 711–744.

Matsuyama, K. (2005): "Credit Market Imperfections and Patterns of International Trade and Capital Flows," *Journal of the European Economic Association*, 3, 714–723.

McKenzie, M. D. (1998): "The Impact of Exchange Rate Volatility on Australian Trade Flows," *Journal of International Financial Markets, Institutions and Money*, 8, 21–38.

——— (1999): "The Impact of Exchange Rate Volatility on International Trade Flows," *Journal of Economic Surveys*, 13, 71–106.

Nakamura, E. and J. Steinsson (2008): "Five Facts about Prices: A Reevaluation of Menu Cost Models," *Quarterly Journal of Economics*, 123, 1415–1464.

Nunn, N. (2007): "Relationship-specificity, Incomplete Contracts, and the Pattern of Trade," *Quarterly Journal of Economics*, 122, 569–600.

Nunn, N. and D. Trefler (2014): "Domestic Institutions as a Source of Comparative Advantage," in *Handbook of International Economics*, ed. by G. Gopinath, E. Helpman, and K. Rogoff, Oxford and Amsterdam: Elsevier, vol. 4, chap. 63, 263–315.

Nurkse, R. (1944): *International Currency Experience: Lessons of the Inter-War Period*, Geneva: League of Nations.

Obstfeld, M. and K. Rogoff (1996): *Foundations of International Macroeconomics*, Cambridge, MA: MIT Press.

——— (2000): "New Directions for Stochastic Open Economy Models," *Journal of International Economics*, 50, 117–153.

——— (2003): "Risk and Exchange Rates," in *Economic Policy in the International Economy: Essays in Honor of Assaf Razin*, ed. by E. Helpman and E. Sadka, New York: Cambridge University Press, chap. 4, 74–120.

Rivera Drew, J. A., S. Flood, and J. R. Warren (2014): "Making Full Use of the Longitudinal Design of the Current Population Survey: Methods for Linking Records across 16 Months," *Journal of Economic and Social Measurement*, 39, 121–144.

Romalis, J. (2004): "Factor Proportions and the Structure of Commodity Trade," *American Economic Review*, 94, 67–97.

Santos Silva, J. and S. Tenreyro (2006): "The Log of Gravity," *Review of Economics and Statistics*, 88, 641–658.

Schmitt-Grohé, S. and M. Uribe (2016): "Downward Nominal Wage Rigidity, Currency Pegs, and Involuntary Unemployment," *Journal of Political Economy*, 124, 1466–1514.