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The impact of price variability on US imports of homogeneous inputs

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HIGHLIGHTS

- I develop a model of homogeneous input sourcing decisions under price uncertainty.
- I estimate the impact of price variability on US imports of homogeneous inputs.
- A country's share of US imports decreases in the level and the variance of its price.

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ABSTRACT

In this paper, I quantify the impact of price variability on homogeneous intermediate goods imports. In product-level data, I find a country's share of US imports is decreasing in the level and the variance of its unit price. This finding is consistent with a model of sourcing decisions in which risk averse final-goods firms choose the optimal distribution of intermediate inputs demand across suppliers.

1. Introduction

The unit values of US manufacturing imports vary substantially across countries even within narrowly defined homogeneous intermediate product categories. For the 16 year period from 1990 to 2005, the median high-to-low unit value ratio is 5.7 across all such products.[1] This observation is inconsistent with the criterion of expected cost minimization for input demand which predicts that firms will buy exclusively from the least-expected-price supplier. In this paper, I develop a model of homogeneous input demand under cost uncertainty which rationalizes the observed distribution of import demand across exporting countries. I then confront the model's main predictions with the data. The empirical results suggest that price uncertainty is a key determinant of import decisions that has been largely ignored in the literature.

In the theoretical model, risk-averse firms choose the optimal allocation of input demand across suppliers to maximize the expected utility of profits — a function of the expectation *and* the variance of profits. The analysis shows that the optimal demand is decreasing in the price and in the price variability of a supplier. These results are similar to those of portfolio diversification in theoretical finance: an increase in the number of geographically diverse suppliers reduces the variability of input costs, much like an increase in the number of assets with imperfectly correlated returns reduces the variance of a portfolio's return (e.g., Markowitz, 1952; Sharpe, 1964). I test the model's predictions in product-level data on US imports. The empirical results provide support for the main predictions of the theoretical model. I find that the share of US imports is larger for low-expected-costs, low-variance countries.

Recent studies investigate the effects of demand uncertainty on the trade decisions of firms, the production location decisions of multinational enterprises, and the effect of trade on income volatility (e.g., Caselli et al., 2015; Cukrowski and Aksen, 2003; de Sousa et al., 2015; Ramondo et al., 2013). By contrast, because intermediate products account for as much as 75% of the value of aggregate trade flows (e.g., Johnson and Noguera, 2012), this paper focuses on the impact of input price uncertainty on import decisions.

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[1] The estimated mean is about 9.4, which is much lower than the value of 24 reported in Schott (2004) for a broader sample that includes all manufacturing imports for 1994.

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This paper is closely related to Wolak and Kolstad (1991) which estimates a portfolio model of demand using data on Japanese imports of coal from 5 countries for the period 1983 to 1987. There are two main differences with my work. First, I extend the theoretical and empirical analysis to include trade costs. Second, I estimate the model using US imports data on more than 2,000 homogeneous intermediate products, originating from 113 countries over a 16 year period.

2. Theoretical framework

Consider an economy with a mass of perfectly competitive firms producing a homogeneous final good using a combination of labor (L) and materials (M). The constant returns to scale technology is given by $Q = F(L, M)$, where Q denotes total physical output. Firms can buy their homogeneous materials from N sources so that $M = \sum_{i=1}^{N} M_i$, where M_i denotes materials purchased from supplier i. The output price (p) and the wage rate (w) are known *ex ante* but the costs of materials are stochastic. I assume input prices are independent draws from country-specific distributions with expectation μ_i and variance σ_i^2. Supplies of materials must be contracted before the realization of the cost uncertainty.

Firms preferences have the exponential form $U(\Pi) = \exp(-\beta\,\Pi)$, where Π denotes firm profits and β is the Arrow–Pratt index of absolute risk aversion. Because profits are not known *ex ante*, risk-averse firms maximize the expected utility of profits.[2] For simplicity, I assume that forecasting errors have a normal distribution such that utility depends only the expectation and variance of profits (e.g., Sargent, 1987). Firms can reduce risk by substituting away from the risky input or by diversifying across multiple suppliers. The firm's problem can be expressed as

$$\max_{L,\{M_i\}_{i=1}^{N}} \mathbb{E}(\Pi) - (\beta/2)\mathrm{Var}(\Pi). \tag{1}$$

As in Wolak and Kolstad (1991) and Gervais (2015), I assume that the coefficient of risk aversion is invariant to scale (i.e., $\beta M = \eta$). Together with the constant returns to scale assumption, this specification implies that firm scale has no impact on the optimal distribution of demand across suppliers, which simplifies the analysis.

The optimization problem can be solved in two stages. In the second stage, firms choose the optimal material–labor ratio, $m^* = M/L$, conditional on the distribution of the total input demand over suppliers. Profits per unit of material conditional on the optimal material–labor ratio are given by

$$\pi(m^*) = r(m^*) - w/m^* - \sum_{i=1}^{N} s_i\,\mu_i, \tag{2}$$

where $r(m^*)$ is the revenue per unit of material and $s_i = M_i/M$ is the share of total input purchased from supplier i.

In the first stage, firms choose the optimal share of input demand for each country to maximize profits per unit of material. By definition, shares should satisfy the following conditions: $\sum_{i=1}^{N} s_i = 1$ and $s_i \geq 0$, $\forall i = 1, \ldots, N$. From Eqs. (1) and (2), the first stage problem can be expressed as

$$\max_{\{s_i\}_{i=1}^{N}} \mathscr{L}(\pi(m^*)) = r(m^*) - w/m^* - \sum_{i=1}^{N} s_i\,\mu_i - \frac{\eta}{2}\sum_{i=1}^{N} s_i^2\sigma_i^2 - \lambda\left(1 - \sum_{i=1}^{N} s_i\right), \tag{3}$$

where λ is the shadow value of the constraint.

Because I am only interested in the distribution of input demand across suppliers, I focus on the first stage. From the first order conditions of problem (3), the optimal share of demand for each supplier is given by

$$s_i^* = \frac{\lambda - \mu_i}{\eta\sigma_i^2}, \quad \forall\, i = 1, \ldots, N,$$
$$\text{with } \lambda = \left(\sum_{i=1}^{N}\frac{1}{\sigma_i^2}\right)^{-1}\left[\eta + \sum_{i=1}^{N}\left(\frac{\mu_i}{\sigma_i^2}\right)\right]. \tag{4}$$

The condition that $s_i > 0$ implies that firms will only buy inputs from suppliers with expected costs lower than the shadow value of the constraint (i.e., $c_i < \lambda$), which I assume is the case for all suppliers $i = 1, 2, \ldots, N$.

Eq. (4) implies that the optimal share of demand is decreasing in the expected price and the variance of price:

$$\frac{\partial s_i^*}{\partial \mu_i} = \frac{1}{\eta\sigma_i^2}\left(\frac{\partial\lambda}{\partial\mu_i} - 1\right) < 0, \quad \text{and} \quad \frac{\partial s_i^*}{\partial\sigma_i^2} = -\frac{s_i^*}{\sigma_i^2} < 0, \tag{5}$$

where the first inequality follows from the fact that $\partial\lambda/\partial\mu_i < 1$. As one would expect, these results suggest that firms prefer to source from low-cost, low-variance suppliers and trade off price for variability when choosing the allocation of input demand across suppliers. Because this is a representative firm model, the distribution of aggregate imports (defined as the sum of imports across all firms) across sources is also described by Eq. (4), such that the predictions described in Eq. (5) remain valid for aggregate imports. In the next sections, I confront these predictions with product-level data on US imports.

3. Econometric strategy

To estimate the model, I need to formalize firms' expectations about the evolution of prices over time. Suppose prices have two main components: the factory gate price charged by foreign suppliers ($c_{i,t}$) and *ad valorem* trade costs ($\tau_{i,t}$) so that $p_{i,t} = \tau_{i,t}c_{i,t}$, where i and t index countries and time, respectively, and, as traditional in the international trade literature, $\tau_{i,t} \geq 1$. For simplicity, I assume that trade costs are deterministic but that factory gate prices follow a random walk: $c_{i,t} = c_{i,t-1} + e_{i,t}$ with $e_{i,t} \sim N(0, \tilde{\sigma}_i^2)$.[3] I further assume firms have rational expectations about future prices so that the expected level and variance of input prices (at time $t-1$) are, respectively,

$$\mathbb{E}_{t-1}(p_{i,t}) = \tau_{i,t}c_{i,t-1} \quad \text{and}$$
$$\mathbb{E}_{t-1}\left(\sigma_{i,t}^2\right) = \frac{t}{t-1}\sum_{s=1}^{t-1} e_{i,s}^2 = t\tilde{\sigma}_i^2. \tag{6}$$

2 An extensive literature shows that moral hazard and adverse selection issues create divergence between managers' and shareholders' interest and provide an incentive to shareholders to tie the value of managers' compensation to the value of their firms. This type of compensation scheme prevents managers from diversifying firm-level risk to the extent that shareholders can (e.g., Lambert et al., 1991; or Murphy, 1999). Empirical studies provide evidence that companies are controlled by imperfectly diversified owners and, as a result, are risk-averse (e.g., Faccio et al., 2011; Heaton and Lucas, 2000; Lyandres et al., 2013, and references therein).

3 Assuming prices follow an AR1 process does *not* affect the general form of the estimating equation or the interpretation of the main estimated coefficients. After taking logs, the additional constant terms (which depend on the autocorrelation of prices) will be captured in the regression model's constant term. In my sample, the autocorrelation of prices is 0.77 which suggests that past prices contain useful information on future prices and that a random walk (or AR1) is a reasonable approximation.