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Price Dispersion and the Stability of Trade

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Abstract: Research on trade relationships have documented a high rate of relationship breakup and churning. We use data on Norwegian exports to document two stylized facts about the stability of trade relationships. First, the probability of relationship breakup increases in the deviation of the relationship-specific price from a reference price. Second, relationship hazards follow Zipf's law. We propose a search model with limited information and search frictions to explain these facts. Reference prices provide information on outside trade options that inform optimal breakups, leading to the first stylized fact. Strong heterogeneity in breakup frictions across relationships can explain Zipf's law hazards.

Keywords: trade duration, price dispersion, transaction data, search costs.

JEL classification: C41, F10, F14

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1. Introduction

Stable long-term trade relationships are important to international trade. Monarch and Schmidt-Eisenlohr (2017) show that almost 80 percent of U.S. imports occurs in what can be defined as stable trade relationships. Still, relationship breakup and churning are prevalent (Eaton et al. 2008; Lederman, Rodríguez-Clare, and Xu 2011; Fanelli and Hallak 2015; Bernard, Bøler, and Dhingra 2018). Fanelli and Hallak (2015) document that two thirds of firms that enter a foreign market exit the market the following year. Besedeš and Prusa (2006a, 2006b) show that the median duration of trade is about one year for half of all observed trade relationships using country-to-country data. Survival times are also found to be short at the firm-country-level (Esteve-Pérez, Requena-Silvente, and Pallardó-Lopez 2013), at the firm-product-level (Görg, Kneller, and Muraközy 2012) and at the firm-product-country-level (Békés and Muraközy 2012).

The large churning of relationships combined with the importance of stable relationships suggest that breakups play an important role in trade allocation at the extensive margin. However, the empirical findings leave something of a puzzle as to why relationships should fail so frequently, and what determine breakups at the most disaggregated level, the exporter-importer-product-level. Besedeš and Prusa (2006a) hint at this challenge when noting that so many failed relationships are not expected from theory. Network theory emphasizes how fixed costs give incentives to remain in established relationships (Albornoz, Fanelli, and Hallak 2016; Bernard and Moxnes 2018). Theories focusing on uncertainty and learning also support stability (Monarch and Schmidt-Eisenlohr 2017; Bastos, Dias, and Timoshenko 2018; Timoshenko 2015; De Sousa, Disdier and Gaignè 2020).

Much of the literature has looked at trade relationships at the firm-country level. In this paper, we investigate trade stability at the firm-to-firm level. As trade is fundamentally a firm-to-firm activity, this offer potentially useful insights on the determinants of trade stability. We use firm-level customs data on Norwegian exports to document two stylized facts about the stability of firm-level trade relationships. First, we document a higher probability of relationship breakup for relationships trading in prices deviating from reference prices. This fact is consistent with Besedeš and Prusa (2006b). They use firm-country data to document that higher variation in unit values increase the hazard for homogeneous goods, but not for differentiated product. Similarly, Monarch (2018) finds that importers are more likely to terminate a trade relationship if suppliers charge higher prices. We also find that termination rates are slightly more sensitive to higher prices. However, different from Monarch (2018) we document that termination rates increase for both high and low prices relative to relevant reference prices, i.e. exporters terminate relationships when prices are too low. We propose and explore an economic mechanism that explains the termination rates. We also subject the stylized fact to various robustness checks, including a research design that controls for the endogeneity of relationship level transaction prices and which quantifies how much individual price deviations are driven by changes in reference prices.

The unconditional hazard rate for individual exporter-importer relationships is strongly declining in the age of the relationship, consistent with Aeberhardt, Buono, and Fadinger (2014) and others. Our second stylized fact shows that these exporter-importer hazard rates follow Zipf's law. Several empirical size distributions in economics and other social sciences are known to follow Zipf's law; a well-known example being firm size (Axtell 2001; Di Giovanni and Levchenko 2013; Chaney 2018). We argue that this regularity of the hazard rate can be explained by relationship level heterogeneity in unconditional breakup rates. Heterogeneity is prevalent at the firm-to-firm level. Armenter and Koren (2015) argue that since different firms encounter different sets of entry costs in export markets, several dimensions of heterogeneity are necessary when modelling transaction level data. Zipf's law provides a clue to the central role of heterogeneity, and we illustrate an intuitive generating mechanism founded on heterogeneity that produces Zipf's law hazards that match the data.

Having documented the stylized facts, we propose an economic model to jointly explain the facts. The model is grounded in the observation that commercial sales agreements are private in nature. Traders observe only their own transaction prices and a reference price. The reference price is an average across all trade relationships for the traded product and operates to aggregate private transaction prices. In the model, traders use the reference price as an imperfect signal of the outside option trade price, i.e., the price they *ex ante* can expect to obtain by switching partners. In this context, the deviation of the relationship price from the reference price becomes an observable signal of the opportunity cost of the existing relationship. Search frictions provide a threshold, such that price deviations beyond the threshold trigger termination of the relationship. In the model, price deviations and relationship churning are driven by changes in the reference price. Changes in the reference price represent the flow of pricing relevant information for the traded product. This mechanism generates the first stylized fact. By introducing time-invariant heterogeneity in search frictions across trade relationships the model reproduces Zipf's law in hazard rates. Our theory centers on the role of reference prices. It predicts that the disciplining role of reference prices should be stronger for trade relationships trading in goods with informative reference prices that reliably represents outside trade options, which can explain the finding in Besedeš and Prusa (2006b).

The observation that *ex-ante* profitability of searching for new trade partners change as perceived outside trade options change is not novel to this paper. Benguria (2021) document that as US trade tariffs to Colombia declined following a free trade agreement, US exporters disbanded existing relationships at a higher rate, consistent with improved outside options for pre-existing relationships. There has also been substantial research on the importance of search frictions and limited information on the dispersion of trade prices. Alessandria (2009) develop a model of buyer search in a market with search frictions leading firms to price discriminate across markets based on the opportunity cost of search. Allen (2014) shows how limited information about available trade partners leads to higher dispersion in the distribution of transaction prices. In recent years, improved access to firm-level trade data has also led to extensive research on search and informational frictions on the formation and stability of trade relationships (Besedeš 2008; Defever, Heid, and Larch 2010; Antras and Costinot 2011; Monarch 2014; Albornoz, Aeberhardt, Buono, and Fadinger 2014; Fanelli, and Hallak 2016; Kamal and Sundaram 2016; Chaney 2014; Startz 2016; Krolikowski and McCallum 2021). This paper provides a connection between price dispersion and the stability of trade that sheds light on the observed high rate of churning of trade relationships.

To investigate the ability of the model to reproduce the stylized facts we estimate model parameters using simulated non-linear least squares methods. The estimated models match the level of breakup rates observed across different product types in the data and is able to reproduce the stylized facts. Consistent with theory the model fit is stronger for product sections with more reference price goods. The model also underlines the important role of temporal frictions in relationship breakups. As far as we know, this friction has not been investigated in the literature. A temporal friction emerges when there is a significant time lag between the time when a trade partner delivers a notice of termination of the relationship and the partners disband. The temporal friction operates as an exit barrier that accentuates existing search costs, contributes to longer duration relationships, and allows for persistent pricing inefficiencies in the interim period of trade between notice of termination and the disbanding of the relationship. The temporal friction is plausibly related to institutional factors of trade, which determines the flexibility by which partners can enter and exist relationships. For instance, Araujo, Mion, and Ornelas (2016) show that strong institutions increase the survival of exporting firms.

2. Stability of Trade in Norwegian Exports

We analyze firm-level customs declarations data for Norwegian exports in the period 2004 to 2014. The data is provided by Statistics Norway and includes anonymous id's for both the exporting and importing firm, the 8-digit HS code for the traded products, the date of the invoice, the FOB statistical value (in NOK), the weight of the shipment (in kg), and the country of destination.

We analyze trade at the most disaggregate 8-digit product level available in the data, but for exposition purposes we report results by 2-digit HS product sections. We consider the eight largest product sections for Norwegian mainland exports (this excludes the offshore petroleum sector), which accounts for 91% of total mainland export value ($37.6B p.a.). Table 1A in the appendix describes the product sections. The eight sections differ substantially in their share of reference price and differentiated goods. According to Bernard, Moxnes, and Ulltveit-Moe (2018) the structure of Norwegian microdata for exports mirrors the structure reported for other developed countries.

The data is organized as an unbalanced panel where the unit is an individual exporter/importer trade relationship and calendar time is measured at quarterly frequencies from Q1 2004 to Q4 2014. For censoring purposes, we remove the first and last quarter of the sample. We also remove exporters and importers that trade very infrequently (less than 10 transactions over the 11-year period). This reduces total export value by 12%.

To proceed we need to operationalize the concepts of trade relationship and duration. We define an exporter-importer pair as being in a trade relationship in a quarter if they make at least one transaction that quarter. The duration of a relationship is the number of consecutive quarters of trade. Any two partners starting to trade again after more than one quarter of not trading is defined as a new trade relationship. Fanelli and Hallak (2015) argue that exporters that re-enter a market show greater survival probability due to more accumulated experience. Since such re-entry is counted as a separate trade relationship in our setup, systematic differences in survival probability conditional on reentry is absorbed, at least partially, by relationship specific fixed effects.

TABLE 1. Descriptive Statistics Norwegian Exports, 2004-2014

Product section, HS 2-digit level	# Trade Relationships	Rate of Termination (Quarterly)	Mean Duration (Quarters)	Share of relationships in: [1] Reference goods	Differentiated products
I: Animals	30 437	34 %	2.60	75.0 %	24.2 %
V: Minerals	1 939	29 %	2.97	66.7 %	30.4 %
VI: Chemicals	12 267	27 %	3.20	23.6 %	0.40 %
VII: Plastics	17 762	34 %	2.58	33.1 %	65.0 %
X: Wood	8 442	32 %	2.86	53.9 %	46.1 %
XV: Base Metals	35 413	40 %	2.2	25.9 %	67.0 %
XVI: Machinery	158 392	52 %	1.8	0.0 %	100.0 %
XVIII:Instruments	25 268	48 %	1.87	0.0 %	100.0 %

Note: [1] We match 8-digit HS product codes to the SITC classification of goods into 1) goods traded on an organized exchange, 2) reference priced, and 3) differentiated products as provided on James E. Rauch's website https://econweb.ucsd.edu/~jrauch/rauch_classification.html. We are able to match between 60% and 99% of all 8-digit HS product codes across production sections. The table reports the share of trade relationships trading in reference price goods and differentiated products for each section for the subset of matched products.

Table 1 shows descriptive statistics by product section. The number of unique classified trade relationships range from 1 939 (Minerals) and up to 158 392 for the most heterogeneous category (Machinery). The unconditional (quarterly) rate of termination ranges from 27% for chemicals and up to 52% for machinery, with a mean relationship duration from 1.8 (Machinery) to 3.2 quarters (Minerals). These results correspond to findings in the literature showing that the survival times of established trade relationships is in general short.

The two last columns break down trade relationships in each section according to whether their main traded product, by value, can be classified as a reference price good or a differentiated product based on the classification in Rauch (1999). Rauch classifies traded products into three categories based on transaction mode (organized exchange, reference priced and differentiated products) at the three- and four-digit SITC level. We match our 8-digit HS product codes to the relevant SITC classification. As stated in Rauch (1999) "commodities at the five-digit SITC level were classified by looking them up in *International Commodity Markets Handbook* and *The Knight-Ridder CRB Commodity Yearbook* (to check for organized exchanges) and *Commodity Prices* (to check for reference prices, e.g., price quotations published in trade journals such as *Chemical Marketing Reporter*)".

The animals section has the largest share of relationships classified as trading in reference price goods. Animals is dominated by seafood, and in particular farmed salmon, a highly homogenous product. Machinery and Instruments are exclusively classified as differentiated products according to the Rauch classification.

Different product sections also vary in their share of durable product trade and bulkiness of trade. This will likely lead to differences in frequency of trade and measured duration. We address this effect by aggregating to annual levels, which extend the allowable time period between trades to one year. The regressions analysis also includes the number of quarterly transactions to account for frequency of trade effects on measured durations.

<u>Stylized fact 1</u>: The probability of termination of a relationship increases when the relationship specific transaction price deviates from the reference price.

We use the unit value of a transaction, the FOB export value of a transaction divided by the weight of the shipment, as a proxy for the transaction price. The quarterly relationship price is the equally weighted average of all relationship transaction prices that quarter, for each 8-digit level product traded. We then have relationship transaction prices for each (importer-exporter relationship, product, quarter) triplet.

The product reference prices are constructed as the equally weighted average of all product transaction prices. While the median relationship trades in only one product, around 30% of relationships trade in multiple products. This complicates the procedure of generating relationship prices and assign the relevant reference price to the relationship. Our preferred way of dealing with this is to create a product portfolio price deviation measure. Let α_{it}^{k} be the value share of product k in trade relationship i at calendar time t, and let p_{it}^{k} be the relationship price. Furthermore, let $\bar{p}_{t}^{k}$ be the corresponding reference price, constructed as the equally weighted average price of all products k transaction prices at t. The relationship i relative price r_{it} is then constructed as,

$$r_{it} = \sum_{k=1}^{N_{it}} \alpha_{it}^{k} \left(\frac{p_{it}^{k}}{\bar{p}_{t}^{k}}\right).$$

This is equal to the single product relative price if partners trade in a single product. Below we control for the potential effect of the portfolio construct by restricting the sample to single-product trade relationships. The deviation of the relationship price from the reference price is then constructed as,

$$z_{it} = |r_{it} - 1|.$$

Reference prices are constructed using the sample of all relevant transaction prices in the Norwegian customs data. As this is restricted to Norwegian transactions, the reference prices will necessarily be Norwegian reference prices. In the interpretation of reference prices as measuring outside trade options this assumes the Norwegian reference price is representative of global reference prices. We are confident this is valid for the animal's section that consists heavily of seafood and especially farmed salmon. Norway is the largest producer of farmed salmon, and salmon is highly traded with a global market in common with most other seafood products (Anderson et al., 2018).

Our hypothesis assumes that deviations from the reference price are informative about the opportunity cost of the trade relationships. However, goods at the 8-digit level are not perfectly homogenous, and price deviations necessarily also measure other things than outside trade options, such as product quality differences or relationship specific relative bargaining power. To account for time-invariant price deviations we also use the time demeaned measure[1],

$$z_{it} = \left| r_{it} - \frac{1}{T}\sum_{t=1}^{T} r_{it} \right|, \qquad \text{(\textit{time demeaned price deviation})}$$

The cost of using this measure is that we lose relationships that trade only in a single period.

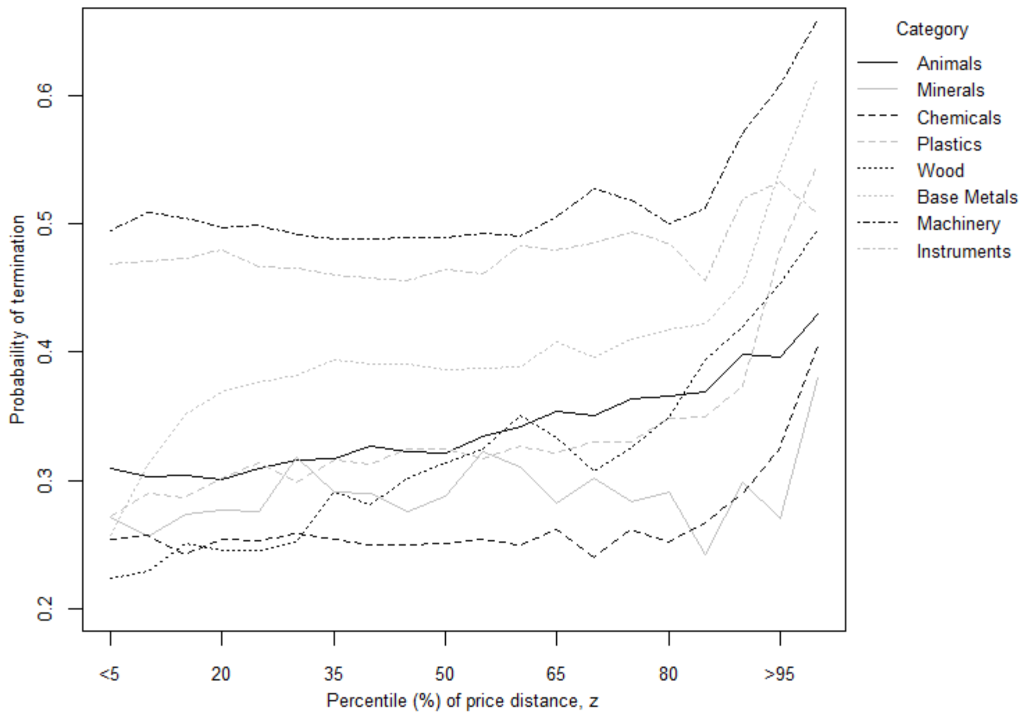
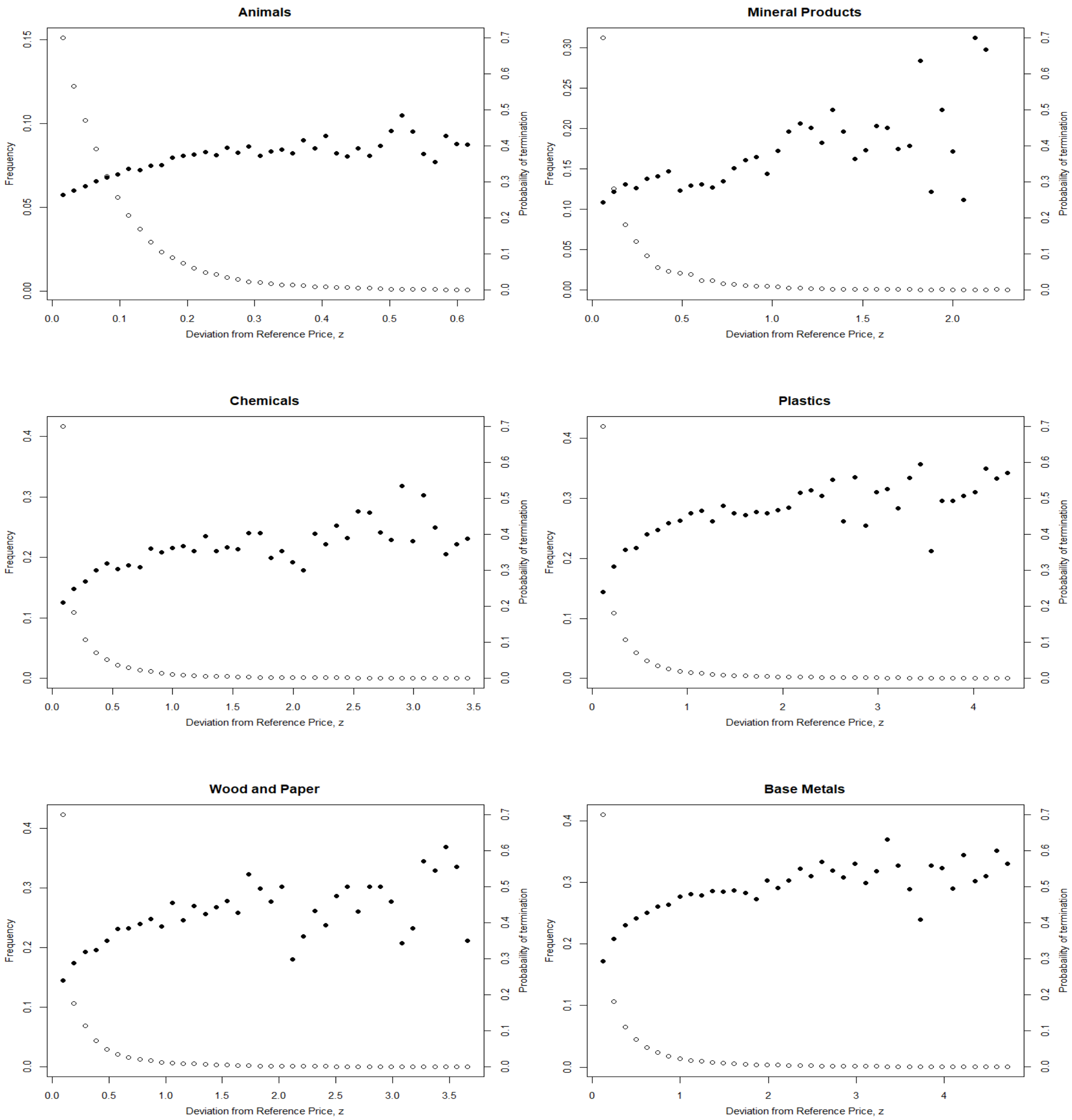


FIGURE 1. *Percentiles of the non time demeaned price deviations and the probability of relationship termination.*

[1] Note that this demeaning will not be removed by relationship specific fixed effects in a regression model at the relationship level. This is because $|r_{it} - 1| - \overline{|r_{it} - 1|}$ is not in general equal to $|r_{it} - \overline{r_{it}}|$.

A relationship terminates at calendar time t if t is the last period of consecutive observed trade. Figure 1 plots the probability of termination at different percentiles of the non time demeaned price deviation measure. For all product sections, the probability of termination increases as relationship prices deviate from the reference price. The level differences in the curves align with the different baseline rates of termination in table 1.



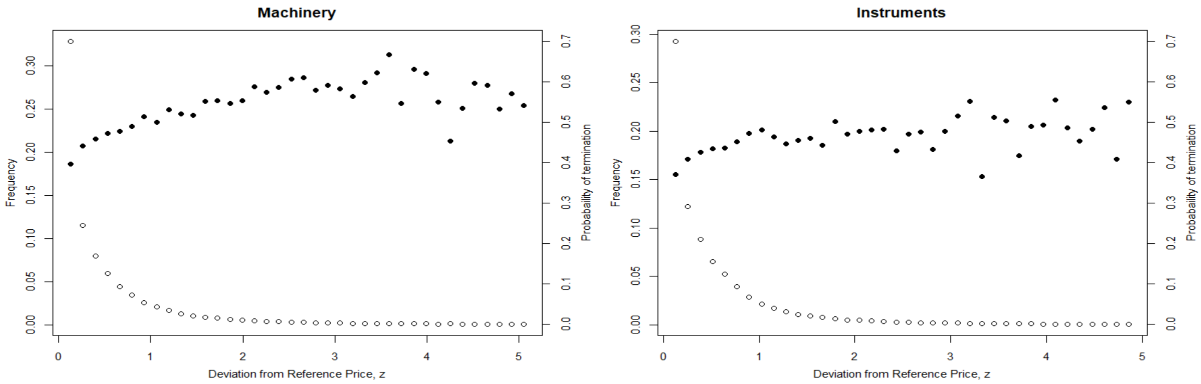


FIGURE 2. *Time-demeaned price distance measure and probability of relationship termination (black dots, right axis). Open dots (left axis) show the empirical frequency distribution of the price distance.*

Figure 2 provides an alternative perspective and plots the empirical frequency distribution of the time demeaned price deviations (the open dots, left y-axis) together with the associated termination probabilities (black dots, right y-axis). The different scales of the x-axis illustrate the differences in price deviations across product sections. Animals, the most homogenous reference price good category has lowest dispersion, with the more differentiated product sections having larger deviations. As in figure 1, all sections display a pattern of increasing probability of termination with price deviation. The variation in the termination probability increases as we move into the tails of the distribution due to fewer data points in the tails.

<u>Stylized Fact 2:</u> The hazard rate is proportional to $(\mathbf{1}+\boldsymbol{n})^{-\mathbf{1}}$, where $\mathbf{n}$ is the number of consecutive quarters traded (Zipf's Law)

Our next stylized fact relates to the hazard rate. The hazard rate of a trade relationship is the probability that a relationship terminates after n periods, having persisted up to n periods. Figure 3 shows hazard rates by product sections.

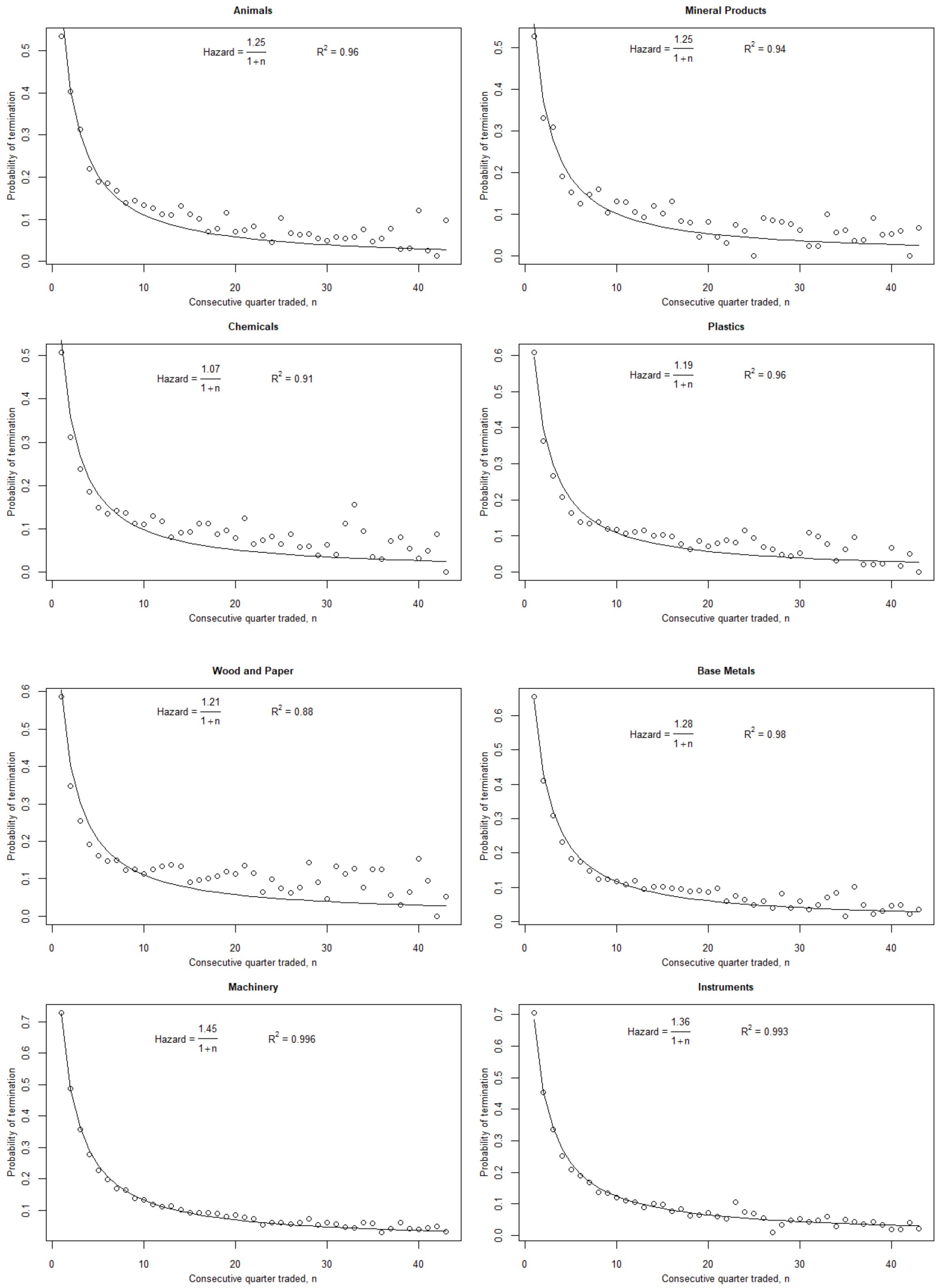


FIGURE 3. *Unconditional Hazard Rates by 2-digit Product Sections.*

Similar to findings for French exports, hazards are strongly declining in relationship age (Aeberhardt, Buono, and Fadinger 2014). The solid line shows the fit of the parametric hazard function $\alpha(1+n)^{-1}$, where α is an estimated factor of proportionality. This simple function describes the hazard rates well.

The parametric function implies that a good guess for the probability of termination after one quarter of trade is $\alpha/2$, after two quarters, $\alpha/3$, and so on. This pattern of regularity is known as Zipf's Law. Zipf's law occurs in several social science and economic data, such as firm size (Chaney 2018). Table 5A in the appendix shows that Zipf's law provides similar fits to an unrestricted power law, and a substantially better fit than an exponential law.

2.1. Regression Analysis and Results

We investigate the robustness of the stylized facts using regression analysis. The dependent variable of interest is y_{it}, a binary variable taking a unit value if calendar time t is the last trade quarter. Our baseline regression model is the binary discrete choice model,

$$y_{it} = 1[\alpha_i + \alpha_t + \beta_z z_{it} + \beta_n n_{it} + \boldsymbol{X}_{it}\boldsymbol{\beta} + \varepsilon_{it} > 0],$$

where α_i is a relationship specific fixed effect controlling for baseline differences in termination probability, and α_t is a time fixed effect. The variable n_{it} is a count variable of consecutive number of quarters traded (the age of the relationship). $\boldsymbol{X}_{it}$ is a vector of additional explanatory variables to be discussed below, and ε_{it} is a possibly heteroskedastic error term. Let $prob_{it} = Prob(y_{it} = 1|z_{it}, n_{it}, \boldsymbol{x}_{it}, \beta_z, \beta_n, \boldsymbol{\beta}, \alpha_i, \alpha_t)$ denote the conditional probability of termination at time t. The probability of breakup at calendar time t is modelled using the logistic transfer function[2]. The regression

[2] We tested other transfer functions, such as the Probit, but found that overall the logistic function provided better explanatory power. The model is estimated using the unconditional logit estimator with bias-corrected average partial effects to account for possible incidental parameters biases (Hahn and Newey 2004). The unconditional logit estimator uses dummy variables to filter fixed effects, which becomes computationally demanding for large

model can also be seen as a "one-step-ahead" prediction model on the presence of a trade relationship the next quarter.

The stylized facts are captured by the signs of β_z and β_n in (1). Specifically, $\beta_z > 0$, implies larger price deviations predict higher relationship termination probability. Increasing (decreasing) hazard rate is given by $\beta_n > 0$ (< 0).

Relationship fixed effects control for heterogeneity in time-invariant termination probabilities across relationships, for instance due to different preferences for longer or shorter sales contracts, or time invariant differences in search frictions. The association between price dispersion and relationship termination is identified by within-relationship variation in the price deviation measure during the lifetime of the relationship. Relationship level fixed effects reduce the sample to trade relationships that are terminated during the sample period. Below we investigate the possible distorting effects of this sampling effect using different fixed effects and samples.

We include a set of control variables that might affect the joint relationship between relationship termination, price dispersion and relationship age. These are,

- *Number of quarterly transactions*. Partners that make frequent transactions within a quarter, for instance trade in perishable goods or low bulk trade, are more likely to continue transactions beyond the quarter and have lower measured termination probability. Number of transactions is also a measure of the strength and experience of the relationship. Albornoz, Fanelli, and Hallak (2016) argue that trade experience is positively associated with exporter survival.
- *Product diversification in the relationship*, measured by one minus the product Herfindahl index of trade across different products in the relationship. The measure tends to unity for

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panel data. To overcome this, we apply the pseudo-demeaning approach in Stammann, Heiss, and McFadden (2016).

increasingly specialized product trade in the relationship. The stability of relationships trading in many different products might possibly behave differently from very specialized trade.

- *The degree of exporter and importer investment or commitment in the relationship,* measured as the Herfindahl index of trade value across the exporters or importers trading partners. The measure is unity if the exporter (importer) is exclusively trading with the given importer (exporter) and tends to zero as the exporter or importer distributes their trade across many other trading partners. More committed relationships are expected to have lower termination rates as the relative value impact of disbanding is larger. Note that this measure is only partial for the importer as we do not know the importers partners in other countries.
- *Exporter and importer number of trade partners.* Several exporters and importers trade with multiple partners, while our analysis focuses on single trade relationships in isolation from the whole partner portfolio. The network literature on trade suggests that traders use their existing trade network to overcome informational frictions and reduce search costs, thus having access to more partners might reduce search costs. This measure is also only partial for importers.
- *Number of total exporters and importers for the main product.* Looking at the main product traded (in terms of value) in a relationship, we count how many other exporters and importers trade in the same product. This is a measure intended to control for bargaining power and the availability of outside options for trade in the same product.

The above controls do not necessarily exhaust all possible relevant confounders. While time invariant quality differences are controlled for by using the time demeaned deviation measure, changes in product quality within relationships over time might lead to price deviations not related to outside trade options but might affect breakup probabilities. Breaking down the analysis by product sections provides some control for the effect of product heterogeneity. Below we will also include exporter market share as a measure of competitive product quality.

Individual relationship prices, and price deviations, are potentially endogenous to duration. In the robustness section below, we address this concern by using the absolute value of the quarterly change in the reference price, a model predicted driver of price deviation and breakup, as an instrument for individual price deviations.

Effect of Price Dispersion and Age of Relationship on Termination Probability

We estimate the binary choice model with and without relationship specific fixed effects. This is done to assess the impact of relationship-specific heterogeneity. Furthermore, to facilitate the comparison of estimated price deviation parameters across product sections with different levels of mean deviations, we divide price deviation measures in each section by 100 times the mean deviation for that section. The coefficient then represents the marginal effect of a mean deviation times 100.

Tables 2 shows the estimation results (average partial effects on probability of termination) using the scaled time-demeaned price distance measure. Table 2A in the appendix shows the estimates for the control variables.

TABLE 2. Average Partial Effects Binary Choice Model, Price Deviation and Age of Relationship

	Dependent Variable: Termination of Trade Relationship, y_{it}					
	Model 1:			*Model 2:*		
	Price Deviation	*Age of Relationship*	R^2	*Price Deviation*	*Age of Relationship*	R^2
Product sections, HS 2 digit level:	Est (S.E.)	Est (S.E.)		Est (S.E.)	Est (S.E.)	
I Animals	0.393	-0.016	0.138	0.977	0.020	0.246
	(0.075)	(0.001)		(0.123)	(0.001)	
V Minerals	0.562	-0.019	0.144	0.508	0.007	0.226
	(0.195)	(0.001)		(0.293)	(0.001)	
VI Chemicals	0.289	-0.016	0.128	0.362	0.013	0.239
	(0.042)	(0.001)		(0.055)	(0.001)	
VII Plastics	0.385	-0.020	0.162	0.297	0.012	0.246
	(0.052)	(0.001)		(0.065)	(0.001)	
X Wood & Paper	0.357	-0.018	0.133	0.339	0.014	0.251
	(0.071)	(0.001)		(0.083)	(0.001)	
XV Base Metals	0.509	-0.026	0.160	0.229	0.018	0.236
	(0.067)	(0.001)		(0.073)	(0.001)	
XVI Machinery	0.462	-0.032	0.159	0.238	0.0105	0.216
	(0.078)	(0.001)		(0.062)	(0.001)	
XVIII Instruments	0.020	-0.027	0.182	0.150	0.0085	0.223
	(0.068)	(0.001)		(0.099)	(0.001)	

Fixed Effects:		
Time	YES	YES
Relationship	NO	YES

Note: Estimated by the unconditional logit estimator Stammann, Heiss, and McFadden (2016) implemented in R by the BIFE package. Standard errors are estimated as the square-root of the diagonal of the concentrated inverse hessian, $V = (\sum_{i=1}^{N} \sum_{t=1}^{T} \overline{\boldsymbol{x}}'_{\boldsymbol{it}} \overline{\boldsymbol{x}}_{\boldsymbol{it}})^{-1}$, where $\overline{\boldsymbol{x}}_{\boldsymbol{it}}$ is the vector of demeaned weighted regressors $\tilde{\boldsymbol{x}}_{\boldsymbol{it}} = \sqrt{p_{it}(1-p_{it})}\boldsymbol{x}_{\text{it}}$. R^2 is the McFadden pseudo-R^2 based on deviances. Estimation of standard errors based on a linear approximation (delta method). Price deviation measure for each section is scaled by the mean absolute deviation multiplied by 100.

Both models show a significant positive effect of price deviation on termination rate across all product sections. For instance, the fixed effects model shows that for the animal section a mean deviation drift away from the reference price raises termination probability by around 1 percentage point.

The ranking of the effect size across product sections conforms to the ranking of the share of reference price goods in table 1. This is in line with the finding in Besedeš and Prusa (2006b) of higher price sensitivity for hazard rates in reference price goods.

Following the literature, and stylized fact 2, the model without relationship fixed effects shows a strongly declining hazard with age. However, when controlling for relationship fixed effects the effect changes sign and becomes slightly positive. This sign reversal is not due to the fixed effects estimator dropping relationships that do not end during the period; using the fixed effects sample for the non-fixed effects estimator still retains the strongly negative hazard. The reason for the documented declining hazard in the literature is relationship level heterogeneity in baseline termination rates.

We only briefly discuss the results for the additional explanatory variables. Table 2A in the appendix shows the estimates. The termination probability decreases as the number of transactions made within a quarter increases. This finding is robust and stable across product sections. A higher degree of product diversification is weakly positively related with a higher termination rate, suggesting that more specialized trade relationships are more stable. All importer and exporter commitment measures are consistently negative, meaning that more committed and invested relationships are more stable. In other words, if the trade relationship takes up only a small share of the exporter or importers total trade, a termination of the relationship is more likely. Having more trade partners is associated with a lower breakup rate. This applies to both the exporter and importer, and does not support the hypothesis that larger trade networks reduce frictions in acquiring new partners. The association between total number of exporters and importers for the main product and relationship stability is more mixed. For Norwegian exporters competing with other Norwegian exporters for the same product, six out of the eight product sections show a positive association between number of exporters and relationship breakup rate. For importers the effect is oppositive, six out of the eight show negative association. It is beyond the scope of this paper to dig into the details of these findings, and we leave this for future research.

Robustness

Table 3A and 4A in the appendix presents estimation results for some alternative model specifications. The stylized facts remain robust to using log price deviations, looking only at single-product trade relationships, which define relationships as exporter-importer-product triplets, and to allowing for differential effects conditional on relationship prices being above or below the reference price. The asymmetry results support a somewhat greater termination probability for prices above the reference price, which supports the findings in Monarch (2018). However, both directional price deviations are associated with a significantly larger termination rate.

We also estimate models with importer, exporter, and product specific fixed effects. A notable effect here is that the negative hazard rate does not vanish when considering these alternative fixed effects, pointing to the importance of relationship specific heterogeneity to account for the negative hazard.

To control for potential censoring effects and sample stability we estimate the models by cutting the latter half of the sample, and by cutting the first half of the sample period. Results remain robust to these truncations.

To distinguish potential time varying differences in product quality we estimate a model that includes the exporters share of the Norwegian export market as an explanatory variable. We find that exporters with larger market shares, potentially a proxy for product quality, have more stable trade relationships than exporters with smaller market shares. Otherwise, results are robust.

To check robustness to our operational definition of relationship duration we estimate the model on annual data where trade duration is defined as consecutive years traded. The results are robust to this alternative definition of duration. We also estimate the regression models using the Heise (2018) maximum gap time definition of relationship breakup. In short, the maximum gap time for a product is the 95th percentile of the distribution of gap times between trades. A relationship terminates if their durations between trades exceeds the relevant maximum gap times, and no new products are traded within the gaps. Results are presented in table 6A in the appendix and shows robustness to this alternative definition of breakup time.

To check robustness of the reference price as an equally weighted average across relationship prices, we create the reference price as the relationship trade value weighted average of relationship prices. Results remain robust to this alternative measure of the reference price.

To allow for clustered standard errors we re-estimate models using a linear probability model. Results are shown in table 5A where we cluster by exporter, importer and by trade relationship. The linear model estimates are close to the average partial effects of the logit model suggesting that linearity does not substantially bias results. Results are robust to clustering the standard errors.

Finally, we evaluate a design aimed to control for the potential confounding effects of endogenous price deviations. The economic model discussed below predicts that price deviations triggering relationship termination are driven by changes in the reference price. We instrument relationship price deviations using the quarterly change in the reference price. The assumption here is that no single relationship substantially affects the reference price. We consider the sample of relationships trading in a single product. In the first stage we estimate $z_{it} = \mu + \beta \Delta \bar{p}_t + \varepsilon_{it}^1$, where $\Delta \bar{p}_t = |\log \bar{p}_t - \log \bar{p}_{t-1}|$ is the absolute value of the log quarterly change in the reference price for the product traded in relationship i, and ϵ_{it}^{1} is an error term. z_{it} is the scaled time demeaned price deviation measure used in table 2. The predicted deviation $\bar{z}_{it} = \mu + \beta\Delta\bar{p}_t$ is equal for all relationships i trading the same product at the same time t. This removes a considerable amount of information in the price deviation measure. In the second stage, we estimate the simple binary choice model with relationship fixed effects, $y_{it} = 1[\alpha_i + \beta_z\bar{z}_{it} + \varepsilon_{it} > 0]$. Table 3 reports the results.

TABLE 3. An IV Design for Endogenous Individual Relationship Price Deviations

	Product sections, HS 2 digit:							
	I Animals	V Minerals	VI Chemicals	VII Plastics	X Wood & Paper	XV Base Metals	XVI Machinery	XVIII Instruments
	First stage regressions $z_{it} = \mu + \beta\Delta\bar{p}_t$							
	Est. (SE)	Est. (SE)	Est. (SE)	Est. (SE)	Est. (SE)	Est. (SE)	Est. (SE)	Est. (SE)
β	0.180	0.188	0.206	0.278	0.359	0.240	0.128	0.177
	(0.003)	(0.009)	(0.007)	(0.010)	(0.011)	(0.007)	(0.007)	(0.022)
F-stat	4504	417	861	802	1097	1103	317	64
R^2	0.083	0.037	0.016	0.018	0.043	0.019	0.0027	0.0025
	Second stage regressions, Binary Choice model $y_{it} = 1[\alpha_i + \beta_z\bar{z}_{it} + \varepsilon_{it} > 0]$.							
	Est. (SE)	Est. (SE)	Est. (SE)	Est. (SE)	Est. (SE)	Est. (SE)	Est. (SE)	Est. (SE)
β_z	1.264	-0.199	0.882	1.754	0.893	1.588	7.340	3.617
	(0.408)	(1.075)	(0.433)	(0.464)	(0.490)	(0.492)	(1.216)	(2.713)

Note: Sample consists of trade relationships trading in a single product. The F-stat is the F statistics for the exclusion of the independent variable.

All product sections predict a positive relationship between the percentage change in the reference price and individual price deviations. The explanatory power of the reference price varies across sections. The effects is strongest for the animal section and is in general declining for the more differentiated product sections. Second stage results largely confirm the positive impact of price deviations on relationship termination probability presented in table 2. While the marginal effects differ somewhat in size from results in table 2, except for the animal sections, breakup rates increase following larger changes in the reference price, suggesting the documented effect is not due to endogenous price deviations.

3. Economic Model

We now present an economic model to explain the observed stylized facts. The model is inspired by search models in labor markets (see e.g. Rogerson, Shimer, and Wright (2005)) in which employers and employees meet and bargain over wages.[3] In our model, buyers and sellers meet in a trade relationship and bargain over transactions prices. Our interest is not the process by which buyers and sellers meet and match (for this process, see for instance the trade network literature discussed in the introduction), but the rational decisions to terminate existing relationships.

Monarch (2018) studies breakups in US-China trade relationships. Consistent with our model, he finds that high costs of switching partners impedes the allocation of importers from high to low-cost exporters. Importers paying the highest prices are more likely to change their exporting partner. Different from our setting, he models exporters as passive and only importers make switching decisions. Furthermore, he assumes full information so that importers know what prices were paid by other firms in previous periods. A key feature of our mode is that trade partners only observes their own price and a reference price. Transaction prices are private information. Kleshchelski and Vincent (2009) develop a model where buyers face switching frictions between different suppliers. In their model, suppliers realize that raising prices will increase the likelihood that buyers terminate the relationship. As in Monarch (2018), their model does not assume that suppliers can also terminate relationships. Similar to our model, Alessandria (2009) document that search frictions leads to deviations from the law of one price, leading to price dispersion. Price setting in our model takes the form of bargaining over trade prices. This aligns our paper with Krolikowski and McCallum (2021), which investigate Nash price

[3] This is a market with several similarities where heterogenous workers with different opportunity costs bargain with heterogenous employers in an employment relationship. In the trade setting, heterogenous firms and importers with different opportunity costs bargain over prices in trade relationships.

bargaining with search costs. They show how search costs affect the negotiated price due to changes in relative bargaining position. We show a similar pattern in our model, but in contrast to their setting we do not assume a fixed separation rate, but rather focus on how the separation rates relates to price deviations. Heise (2018) uses transaction-level U.S. import data to study the responsiveness of trade relationship prices to exchange rate changes. He finds a relative low exchange rate pass-through suggesting a relative high degree of pricing rigidity within trade relationships.

The Value of a Trade Relationship

A buyer and seller in a relationship trade at a price p. For now, we drop relationship specific subscripts and focus on a generic trade relationship. The value of the product is c for the seller and v for the buyer. The model is set in continuous time and partners are assumed to continuously trade a unit of the product. Let r be the instantaneous discount rate applied to the valuation of the trade relationship.

The trade price p can be renegotiated. Renegotiation occurs at a rate λ, where λ is the arrival rate of a Poisson process. There is a fixed cost $f \geq 0$ associated with such renegotiations. The renegotiation rate λ defines the partners' preferences for trading at fixed or floating prices. A relationship with a high renegotiation rate will update prices frequently. The limit of continuously renegotiated prices defines a spot-price relationship. As the renegotiation rate tends to zero, the price becomes fixed over the lifetime of the relationship.

Let $\bar{p}(t)$ be the partners' assessed outside option price. This is the price the buyer and seller expect to be able to trade at, *a priori,* in a new trade relationship. When partners renegotiate the price, $\bar{p}(t)$ is the *a priori* expected renegotiated price. In other words, it serves as the focal point for renegotiated prices. We present the bargaining process below and show that this is the consistent expected renegotiated price as long as search costs are symmetric across the buyer and seller.

The following two equations define the value of trade relationships in terms of the value of trade necessary to balance the opportunity cost of participating in trade. The value of the relationship at current price p combined with the expected outcome from renegotiations gives the seller and buyer asset equations for the trade relationship,

$$rV_s\big(p,\bar{p}(t)\big) = (p-c) + \lambda\left(\frac{1}{r}(\bar{p}(t)-c) - f - V_s\big(p,\bar{p}(t)\big)\right), \tag{1a}$$

$$rV_b\big(p,\bar{p}(t)\big) = (v-p) + \lambda\left(\frac{1}{r}\big(v-\bar{p}(t)\big) - f - V_b\big(p,\bar{p}(t)\big)\right), \tag{1b}$$

where subscript s refers to the seller, and b to the buyer. Consider the sellers valuation, (1a). The asset equation states that the required value of the trade relationship, $rV_s\big(p,\bar{p}(t)\big)$, must cover the immediate benefit of trading, $p-c$, plus the expected value from renegotiations, $\lambda\left(\frac{1}{r}(\bar{p}(t)-c) - f - V_s\big(p,\bar{p}(t)\big)\right)$. The latter term is expected "capital gains" due to future renegotiations. When the renegotiation rate tends to zero, the value of the trade relationship reduces to the present value of perpetual trade at the existing price, $\frac{1}{r}(p-c)$, i.e., a fixed price contract.

The Outside Trade Option

The buyer and seller can both decide to terminate the relationship to find a new partner. This incurs a fixed search cost $s_s \geq 0$ for the seller, and $s_b \geq 0$ for the buyer. Search costs are the expenses involved in establishing a trade relationship, tweaking the product, or logistics to the client's requirements and negotiating the legal contract. We assume the buyer and seller can always find a new partner, but doing so takes $\tau \geq 0$ periods. This temporal friction implies that if any partner decides to terminate today, they will have to wait τ periods before termination takes effect and they start trading with a new partner.

The following two equations give the assessed gross value (not including the search cost) of the outside trade options for the seller and buyer,

$$O_s\big(p,\bar{p}(t)\big) = \left(\frac{1-exp(-\tau r)}{r}\right)(p-c) + \left(\frac{exp(-\tau r)}{r}\right)(\bar{p}(t)-c), \tag{2a}$$

$$O_b(p,\bar{p}(t)) = \left(\frac{1-exp(-\tau r)}{r}\right)(v-p) + \left(\frac{exp(-\tau r)}{r}\right)(v-\bar{p}(t)). \quad (2b)$$

The first term on the right-hand sides is the present value of the remaining period of the current relationship, whereby they trade at price p for a duration of τ periods due to the temporal friction. The second term is the expected present value of the new relationship following termination. Note that both parties take $\bar{p}(t)$ as the relevant parametric price for all future outside trade relationships.

Seller and Buyer Minimum Acceptable Prices

The minimum price the seller requires to stay in the current relationship is the price $p_{min}(t)$ that equates the value of the existing trade relationship with the outside option. Specifically, solving $V_s(p_{min}(t),\bar{p}(t)) = O_s(p_{min}(t),\bar{p}(t)) - s_s$ for $p_{min}(t)$ gives the seller's minimum price,

$$p_{min}(t) = \bar{p}(t) - \left(\frac{r+\lambda}{1-\left(\frac{r+\lambda}{r}\right)(1-exp(-\tau r))}\right)\left(s_s - \frac{\lambda}{r+\lambda}f\right). \quad (3a)$$

Equivalently, the buyer's maximum acceptable trade price is,

$$p_{max}(t) = \bar{p}(t) + \left(\frac{r+\lambda}{1-\left(\frac{r+\lambda}{r}\right)(1-exp(-\tau r))}\right)\left(s_b - \frac{\lambda}{r+\lambda}f\right). \quad (3b)$$

The traders can agree on a price whenever $p_{max}(t) \geq p_{min}(t)$. Formally, this is satisfied when 1) $\frac{r}{r+\lambda} > 1 - exp(-\tau r)$, and 2) $s_b - \frac{\lambda}{r+\lambda}f > 0$ and $s_s - \frac{\lambda}{r+\lambda}f > 0$. The first condition ensures that a within-relationship price increase raises the value of the relationship for the seller relative to the outside option, and equivalently for a within-relationship price decrease for the buyer. The second condition states that the search cost must exceed the present value of expected future renegotiation costs. These conditions jointly ensure that $p_{max}(t) \geq p_{min}(t)$ such that a mutually acceptable price can be found. If not, partners will disband the relationship as soon as possible to search for new partners. We assume the conditions hold for observed relationships.

When the difference between $p_{max}(t)$ and $p_{min}(t)$ increases, the range of acceptable within-relationship pricing heterogeneity increases, expanding the scope of price negotiations. Higher search costs and higher temporal friction raise the cost of switching partners and so increase the range of within- relationship acceptable pricing. The cost of switching also increases in the renegotiation rate. Intuitively, for relationships with high renegotiation rates revising prices within the relationship reduces the benefit of terminating and seek for a new trade relationship.

Price Bargaining and Consistency

At the initiation of a trade relationship and during renegotiations the buyer and seller bargain to determine the price. We assume Nash-bargaining as in Goldberg and Tille (2016) for currency invoicing, and Krolikowski and McCallum (2021) for trade bargaining. The sellers threat point is her minimum acceptable price $p_{min}(t)$, and the buyers threat point is her maximum acceptable price $p_{max}(t)$. The outcome of the bargaining process is the price,

$$p(t) = \bar{p}(t) + \left(\frac{r+\lambda}{1-\left(\frac{r+\lambda}{r}\right)(1-exp(-\tau r))}\right)\frac{1}{2}(s_b - s_s). \tag{4}$$

Equation (4) makes it clear that if search costs are equal, $s_b = s_s$, bargaining positions are symmetric and the only acceptable trade price is the outside option price, $\bar{p}(t)$. Note that this outcome is consistent with the prior assumed expected renegotiation price in the above expressions for trade values (equations 1a-b) and resulting equations (3a-b)

If search costs differ, the partner with the lower search cost can exploit her favorable bargaining position to negotiate a better price than the outside option price. If this is the case, our assumed expected renegotiation price in equations (1a-b) will not be consistent with the outcome of price bargaining (equation 4). Iterating on equations (1a-b) with updated bargained prices gives the consistent fixed-point trade price with asymmetric search costs as,

$$p(t) = \bar{p}(t) + \varphi\left(\frac{r+\lambda}{1-\left(\frac{r+\lambda}{r}\right)(1-exp(-\tau r))}\right)\frac{1}{2}(s_b - s_s), \tag{5}$$

$$\varphi = \frac{r+\lambda}{1-\left(\frac{r+\lambda}{r}\right)(1-exp(-\tau r))+\frac{\lambda}{r}},$$

where the proportional adjustment term φ is due to partner's realizing their differences in bargaining power when renegotiating prices and reassessing the value of their trade relationships. With asymmetric search costs, the latter term on the right-hand side in the expression for $p(t)$ above should be added to $\bar{p}(t)$ in equations 1a-b for consistency. The net effect of different search costs is to adjust the price and to reduce (increase) the buyer's maximum (seller's minimum) price when $s_b > s_s (s_b < s_s)$. This will generate asymmetry in the sensitivity of termination to high and low-price deviations relative to the reference price.

Since asymmetry is not the primary focus of our paper and the adjustment does not affect the primary mechanism of trade termination we proceed with the assumption of symmetric search costs such that bargained prices are set equal to the outside trade price, $p(t) = \bar{p}(t)$. We also note that since time-invariant asymmetric costs lead to a fixed price deviation from the reference price, the above regression analysis with time demeaned price deviations control for time-invariant asymmetric search costs.

Termination of Trade Relationship

The transaction price in the trade relationship is discontinuous. The current price equals the bargained price, $p(t) = \bar{p}(t^*)$, where $t^* < t$ is the date of the most recent price setting. Immediately following the establishment of a new trade relationship or a price renegotiation, the price changes to $p(t) = \bar{p}(t)$.

The seller will optimally terminate the relationship if $p(t) < p_{min}(t)$. The buyer will optimally terminate if $p(t) > p_{max}(t)$. The following equation gives the criteria for optimal termination in terms of price deviation from the outside option price. Using the minimum and maximum acceptable prices in (3a-b), a trade relationship breakup occurs when,

$$|p(t) - \bar{p}(t)| > \left(\frac{r+\lambda}{1-\left(\frac{r+\lambda}{r}\right)(1-exp(-\tau r))}\right)\left(s - \frac{\lambda}{r+\lambda} f\right), \quad (6)$$

where the left-hand side is the deviation of the within-relationship price from the outside option price, and s is the symmetric search cost. Intuitively, the left-hand side measures the opportunity cost of the trade relationship, i.e., what one of the partners expect to gain by changing partners. The right-hand side measures the direct cost of terminating and establishing a new trade relationship.

Relationship prices change and relationships terminate due to changes in the reference price $\bar{p}(t)$, where changes in the reference price represents flow of price relevant information for the traded product. We treat the cost parameters comprising the composite cost term on the right-hand side of (6) as fixed over time within each trade relationships. In theory, prices could also change, and relationships terminate due to changes in the cost parameters over time. For instance, one could imagine a change in trade policy that reduces search costs and improves opportunities for higher quality partner matching. We focus only on relationship termination due to perceived improvements in outside options of trade as measured by the price deviation from the reference price. Empirically this allows us to focus on the observable left-hand side of (6) and its relation to stability.

Information and Econometric Analysis

Equation (6) provides a connection between price dispersion and the decision to terminate a relationship. It suggests that within-relationship price deviations and relationship churning are disciplined by the reference price.

Heterogeneity in the parameters defining the cost of terminating and establishing new trade relationships will naturally lead to heterogeneity in termination behavior across trade relationships. To formalize this, we denote the composite cost term on the right-hand side of equation (6) by π_i for trade relationship i. Observationally, $\pi_i \sim dG_\pi$ will be a stochastic variable generated by some CDF G_π that defines the relationship level heterogeneity in costs. If $y_i(t)$ is a binary variable equal to unity if t is the last observed trade period for relationship i, then equation (6) together with G_π implies the probabilistic expression,

$$Prob(y_i(t) = 1) = G_\pi(|p_i(t-\tau) - \bar{p}(t-\tau)|),$$

which by equation (6) is increasing in price deviation $|p_i(t-\tau) - \bar{p}(t-\tau)|$.

Customs data will not contain data on the outside option price, $\bar{p}(t)$, which makes the above exact probability statement empirically infeasible. In the appendix we prove that the cross-sectional average transaction price is an informative proxy for the outside option price whenever the average renegotiation rate across trade relationships is non-zero. For trade partners, this means such an observed reference price can be used to assess the outside trade option and discipline pricing and bargaining. For the investigator, it establishes the empirical validity of using the cross-sectional average across all transaction prices as a measure of $\bar{p}(t)$.

Heterogeneity and the Hazard Rate

While the explanation for the first stylized fact does not require heterogeneity in costs across trade relationships, stylized fact 2 does. Heterogeneity in cost parameters generates heterogeneity in unconditional breakup rates. We show how such heterogeneity provides a plausible explanation for stylized fact 2. Let q_i denote the relationship specific unconditional termination rate. Assume a continuum of relationships, where $k_i \in [0,1]$ define a relationship type with termination rate $q_i = q(k_i) = k_i$. Relationship types are uniformly distributed, and we assume a unit mass of relationships.

The hazard rate is the probability that a relationship terminates after n periods conditional on having survived up to n periods. From the uniform distribution of types, after one period ($n = 1$) we will have that $\int_0^1 q(k)dk = \frac{1}{2}$ of the relationships have terminated. The density of surviving partners is $1 - q(k_i)$. The share of partners that terminate in the second period ($n = 2$) is then the mass of relationships that terminate in the second period relative to the mass that survived into the second period, $\frac{\int_0^1 (1-q(k))q(k)dk}{\int_0^1 (1-q(k))dk} = \frac{1}{3}$. The mass of partners that survive two periods becomes $\left(1 - q(k)\right)^2$. Continuing this process leads to the parametric hazard function $(1 + n)^{-1}$, or Zipf's law. The law emerges because the hazard conditions on already having survived up to period n. Since this selects for trade relationships with lower unconditional breakup rates, declining hazard follows.

This argument suggests that investigating stability of relationships at the firm-to-firm level using the hazard rate is prone to selection bias due to relationship heterogeneity. While there are plausible economic arguments why relationship stability might increase with age, such that learning (Monarch and Schmidt-Eisenlohr 2017) or a weeding out unreliable partners (Aeberhardt, Buono, and Fadinger 2014), inference need to account for the selection bias due to heterogeneity. This point was also made by Aeberhardt, Buono, and Fadinger (2014) for French exporters

4. Confronting the Model with the Stylized Facts

The model can theoretically account for the stylized facts. In this section we confront the model with data to investigate to what degree it can empirically replicate the observed patterns. The estimation strategy consists of simulating "customs" data from the model and match model predicted and empirical stylized facts.

To confront the model with the customs data some assumptions are necessary. The customs data is observed at discrete sampling frequencies. To obtain exogenous stochastic variation in the reference price, we model the outside option price as a discrete time Gaussian random walk process, $\bar{p}_{t+1} = \bar{p}_t + \sigma_P \varepsilon_{t+1}$, where $\varepsilon_t \sim N(0,1)$. This is understood as exogenous variation in marginal cost and/or marginal valuation for the product impacting exporter and importer assessment of the current transaction price.

We assume symmetric search costs such that in the first period of a new trade relationship partners set a price equal to the outside option, $p_{it} = \bar{p}_t$. At the start of any period partners renegotiate prices with probability λ_i. The renegotiated price is set equal to the outside option price. With no renegotiation partners trade at the previously negotiated price. Following this, partners evaluate their trade relationship using the relationship specific price bound condition (equation (6)), reproduced here with relationship specific costs,

$$|p_{it} - \bar{p}_t| \leq \pi_i. \tag{7a}$$

$$\pi_i = \left(\frac{r+\lambda_i}{1-\left(\frac{r+\lambda_i}{r}\right)(1-exp(-\tau_i r))}\right)\left(s_i - \frac{\lambda_i}{r+\lambda_i} f_i\right) \tag{7b}$$

If the bound is violated at time t, a notice of termination is filed, and $t + \tau_i$ is the observed termination date, the last period they are recorded to transact. Given discrete sampling τ_i will be specified and measured as quarters. At time $t + \tau_i + 1$ a new random trade relationship is generated such that we always keep a fixed number of trade relationships active. The econometrician observes identified trade relationships over time together with the transaction prices.

Prices are unit free and to fix the scale we set $\bar{p}_1 = 100$ and $\sigma_P = 5.$ We further set the interest rate at an annual 15%. While this rate is above risk-free rates, it is consistent with annual required rates of returns for risky ventures (see for instance Imhof, Seavey & Smith (2017)). In any case, the level of the interest rate only scales (7b) for all trade relationships and will not affect the overall fit to the stylized facts.

This leaves relationship renegotiation rates, λ_i, temporal friction τ_i, search cost s_i and renegotiation cost f_i. Since we only observe price deviations, and these are compared to the composite cost expression, separate parameters are not all independently identified. For instance, any changes in s_i or f_i can almost always be matched by a change in λ_i to maintain the same composite cost. Experimentation shows there is little information added in estimating f_i or s_i together with the renegotiation rates, λ_i. As such we fix $f_i = 1$ and $s_i = 10$ and focus on estimating the distribution of renegotiation rates, λ_i. We assume a beta distribution, $\lambda_i \sim Beta(a, b)$, which is continuous and bounded between 0 and 1.

The temporal friction is empirically relevant and identifiable. This parameter is identified by modifying the slope and shape of the curve defining the relationship between model predicted termination rates and price deviation. For instance, as τ_i increases, observed termination can be flat in some range of deviation from the reference price, before starting to increase at sufficiently high deviations. To allow for flexibility in the temporal friction, we assume that a share $1 - \omega$ of trade relationships have temporal friction $\tau_i = 0$, while the remaining share ω has $\tau_i = 1$. Experimentation suggests that the upper bound $\tau_i = 1$ is empirically sufficient.

These parameters jointly determine the composite cost term, equation 7b. Costs vary across trade relationships but are fixed over time. The composite cost term is meaningfully interpreted relative to the scale of the reference price.

For each parameter vector $\theta = [a, b, \omega\ ]$, we simulate data using fixed seed random numbers. To ensure stationary sampling, we simulate 3000 trade relationships over 3000 periods, discarding the 200 first periods. We apply the Nelder-Mead algorithm to minimize the squared deviation between model prediction and data. The data on the probability of termination contains 20 observations, one for each 5th percentile of the price deviation. To match the hazard rate, we match the 20 first observations (consecutive trade from 1 to 20 quarters) so that each data series of stylized facts to match has 20 observations each, leaving 40 data points to match for the model.

To derive parameter standard errors, we approximate the Hessian of the objective function using the Jacobian. Specifically, let y be the data vector, and $\hat{y}(\theta)$ the equivalent vector predicted by the model. The objective function to minimize is $r(\theta) = \sum_{i=1}^{40}\left(y_i - \hat{y}_i(\theta)\right)^2$. The estimated parameter vector is $\hat{\theta} = arg\,min\, r(\theta)$. The covariance matrix of the estimator is calculated as $\hat{\Sigma} = \hat{\sigma}^2\left(\widehat{H}^{-1}\right)$, where $\hat{\sigma}^2 = \frac{r(\hat{\theta})}{40-3}$, and the Hessian is approximated by $\widehat{H} = J\left(\hat{\theta}\right)' J\left(\hat{\theta}\right)$ where $J\left(\hat{\theta}\right)$ is the Jacobian of $r(\theta)$ evaluated at $\hat{\theta}$.

Table 4 reports model parameter estimates, implied net search costs (equation 7b), and model prediction fit to the data. Results suggest the model is able to replicate the unconditional mean breakup rates by product section well. Stylized fact 1 is also well predicted by the model, with a few exceptions. The fit to the termination probability for minerals, machinery, and instruments is weaker, while for the animal section, where reference pricing appear most important, show a strong fit. This supports movements in reference pricing disciplining relationship turnover. The estimated models also replicate stylized fact 2. Agents in our model are risk neutral and there is no learning effects over time, the strongly negative hazard with relationship age emerges purely from heterogeneity in costs. In table 5A in the appendix we report the adjusted R^2 fits of Zipf's law to model predicted hazards. The appendix also shows plots of all the model predicted and empirical stylized facts for each product section.

TABLE 4. Estimation Results for the Economic Model

	Product sections, HS 2 digit:							
	I Animals	V Minerals	VI Chemicals	VII Plastics	X Wood & Paper	XV Base Metals	XVI Machinery	XVIII Instruments
	Estimated Model Parameters							
a	2.20	2.44	2.50	2.30	1.94	1.79	1.27	1.13
	(0.12)	(0.09)	(0.06)	(0.21)	(0.05)	(0.03)	(0.07)	(0.08)
b	3.78	4.39	4.14	4.67	3.39	4.16	4.38	3.32
	(0.44)	(0.07)	(0.46)	(0.56)	(0.21)	(0.21)	(0.06)	(0.04)
ω	0.77	0.98	0.98	0.86	0.66	0.68	0.74	0.59
	(0.59)	(0.14)	(0.42)	(0.13)	(0.50)	(0.17)	(0.09)	(0.10)
	Implied mean (std) of net search costs, π_i, equation (7b)							
π_i,	1.45	1.51	1.68	1.20	1.39	1.04	0.72	1.45
	(1.72)	(2.20)	(1.83)	(1.09)	(1.86)	(2.52)	(0.85)	(1.44)
	Model estimated mean quarterly breakup rates							
	29 %	28 %	26 %	33 %	32 %	40 %	51 %	46 %
	Correlation between model predicted and empirical stylized fact 1							
$corr(\hat{y}_i(\theta), y_i)$	0.99	0.42	0.90	0.96	0.98	0.91	0.81	0.63
	Correlation between model predicted and empirical stylized fact 2							
$corr(\hat{y}_i(\theta), y_i)$	0.98	0.97	0.96	0.97	0.95	0.97	0.98	0.99

Note: Values in parenthesis for model parameter estimates refers to asymptotic standard errors of estimates. $corr(\hat{y}_i(\theta), y_i)$ is the correlation between model prediction and data for the stylized fact.

We observe informative inference on the a and b parameters, with strong evidence for heterogeneity in costs across trade relationships. The temporal friction parameter is less precisely estimated. This parameter is primarily identified by the mapping between the probability of termination and price dispersion. Experimenting with a temporal friction set to zero suggests that it is empirically important to explain the shape of the mapping. The temporal friction raises the cost of switching partners, and since it leads to interim period of trade after termination decisions, it allows for larger price dispersion. Experimenting with setting $\omega = 0$ leads to an average doubling in quarterly breakup rates suggesting that it contributes significantly to the economic search costs.

The mean net search cost across product categories is between 14% to 34% of the standard deviation of quarterly changes in reference prices (set to a scale of 5). There is substantial variation across trade relationships in terms of costs, which leads to Zipf's law hazards. Higher search costs maps to lower breakup rates so that estimated cost differences across product sections correspond to section differences in mean quarterly breakup rates.

The model is simple and highly stylized and focuses on one mechanism of relationship breakups. The estimated parameters from the model should be interpreted with care. The main takeaway is that the proposed mechanism is able to reproduce the empirically robust relationship between breakup rates and price deviations in the data, the strong Zipf's law result in observed hazard rates, and the overall unconditional rate of relationship breakup across product sections.

5. Concluding Remarks

The literature on the duration and stability of trade relationships has shown that long-term stable relationships account for a considerable share of trade. However, short-lived relationships, representing a considerable turnover rate in relations, are an important part of the dynamics of trade. Using firm level data on Norwegian exports from 2004-2014, this paper documents a robust empirical relationship between the dispersion of transaction prices and the stability of trade. As relationship prices deviate from market reference prices, the probability of breakup increases. Empirically, the result is robust across different product sections, different sample periods, different measures of price deviations, asymmetry in price deviations, and endogeneity in trade relationship prices. The asymmetry results show that termination is responsive to both high and low prices relative to the reference price. However, as in Monarch (2018) we find evidence of somewhat more aggressive termination in response to higher prices. Theoretically, this is consistent with buyers having relativity lower search cost.

The effect size is larger for product sections with more trade in reference price goods. We also show the hazard rate for relationship breakups is strongly declining in relationship age, and conforms to Zipf's law. We argue that this effect can be explained by strong heterogeneity in relationship level breakup rates. Controlling for relationship level fixed effects, the negativity of the hazard rate vanishes, and evidence rather favors that breakup probability is slightly increasing with age.

We develop a simple search theoretic model with fixed search costs and temporal frictions in the breakup process as a plausible economic explanation of the stylized facts. In the model, price deviations from reference prices are observable measures of the opportunity costs of existing trade relationships. Search costs and temporal frictions in the breakup process bounds the acceptable price deviations such that sufficiently high price deviations make it optimal to terminate the existing trade relationship.

Our findings suggest that informational frictions due to the private nature of commercial sales agreements leaves an important role for reference prices in disciplining pricing and guiding relationship turnover and trade allocation. This is predicted by the model and consistent with the regression results. A short duration is consistent with firms seeking to optimize partner matches in such a limited information environment.

When investigating trade relationships at the firm level, heterogeneity remains prominent. We show how heterogeneity in baseline termination rates at the relationship level is sufficient to generate the Zipf's law hazard rates observed in the data. Conditioning on relationship age introduces a selection bias in favor of more durable trade relationships with lower breakup rates, leading to a strong negative empirical hazard rate. The lesson here is that analysis of the stability of trade relationships needs to consider the importance of of heterogeneity in the relationships.

The economic model is estimated using simulated non-linear least squares to match the observed stylized facts. While the model is simple and focuses only on the role of price deviations in determining relationship breakups, the model can successfully replicate both of the stylized facts as well as the unconditional breakup rates in the data. The estimation results support strong heterogeneity in switching costs, as well as an empirically relevant temporal friction in the relationship breakup process. Though the model is simple, we take this result as corroborative evidence for the role of reference prices in disciplining trade relationships. Besedeš and Prusa (2006) document higher hazard rates for reference price good trade relationships compared to differentiated products. We add to this by showing how reference prices through their role of measuring outside trade options contributes to churning of relationships.

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