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JEL Classification: F14, Q54

Keywords: Global value chains, Climate shocks, extreme weather

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Rikard Forslid† Mark Sanctuary ‡

December 16, 2022

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1 Introduction

This paper estimates how the 2011 Thailand flood affected importers in Sweden.[1] Sweden is a small open economy far from Thailand, and our estimates therefore speaks to the far reaching consequences of climate shocks in a world economy connected through international trade.

We use Swedish registry data on imports at the firm-product-origin level over the years 2006 to 2013. Our identification strategy rests on the assumption that the Thai flood of 2011 was an unexpected random event that affected in particular the firms importing from Thailand. The treated group are Swedish firms with an average of at least some (greater than zero) imports from Thailand in the two years prior to the flood (2009 and 2010). The control group are all other Swedish firms that import during this period.

Some firms import from both Japan and Thailand, which could pose an issue for identification because there was a major earthquake in Japan in 2011. We tag firms that import from Japan in 2011 through to 2013 and exclude them from the analysis to test the robustness of the results.

Our results show that Thai imports by Swedish firms fell by around 90 percent as a result of the flood. Our estimates suggests that in 2012, Swedish imports from Thailand were around 1.08 billion SEK lower due to the flood. We also find that the flood caused an 8% drop in 2012 sales of firms with a higher share of Thai imports in total imports. This suggests the Thai flood caused a 29.7 billion SEK drop in sales by Swedish firms. Interestingly, we find that the adverse impacts to treated firms persisted for two years through to 2013, despite the fact that Thai production had largely recovered within six months of the flood waters receding. This indicates that fixed costs in establishing links in supply networks may be substantial, and once severed, supplier-buyer relationships may be costly to re-establish (see e.g. Antras et al. (2017)). Swedish importers predominantly switched to other Asian suppliers, and we find very weak evidence of re-shoring. Another result is the role of firm size. We split the sample of treated firms at 250 employees and find that systematic evidence that larger firms were better at handling the shock, facing a smaller drop in the value of imports from Thailand than smaller firms. Geographical diversification of suppliers is also important in determining how well firms weathered the shock. We show that treated firms that import a product from more than one country are almost completely shielded from the flood. Firms that import a product from Thailand

[1] Global warming will bring about more frequent and severe extreme-weather events, Hennessy et al. (2022), which means that the risk of weather related disturbances to production and transportation will increase over time.

only, on the contrary, are unable to source alternative suppliers of the goods affected by the flood. We also find a very strong negative horizontal effect, suggesting Swedish firms cancelled orders of goods that were complementary to the goods they were unable to obtain from Thailand - firm import of other goods from other countries fall by around 80 percent.

Our paper is related to the literature in business and operations management that has suggested conditions and strategies that mitigate risks to global value chains (GVCs). This literature is vast, but relies primarily on surveys, interviews and case study examples. Several well cited studies find large and persistent negative effects of the disruptions to firm operations.[2]

Our paper is also related to the large literature on GVCs surveyed by Antras and Chor (2021), and Johnson (2018). Several of our results are consistent with previous studies in this literature. In particular we find that the fall in imports from Thailand is sticky. That is, Swedish imports do not recover in spite of a relatively fast recovery of production in Thailand, which is consistent with important fixed costs in establishing buyer-supplier links. The role of switching costs has been analyzed in connection with banking relationships by e.g. Amiti and Weinstein (2018) and Chodorow-Reich (2014), and more closely related to our paper, in connection to buyer-supplier relationships by Antras et al. (2017) and Bernard et al. (2019). We also find that the fall in firm-level imports has a relatively strong negative effect on firm exports, which is consistent with several studies documenting a close relationship between firm-level importing and firm-level exporting (Bas (2012), Bas and Strauss-Kahn (2014) and Feng et al. (2016)).

There is also closely related literature that analyses the firms-level impacts of natural disaster shocks.[3] Boehm et al. (2019) investigate how the Great East Japan Earthquake of 2011 affected subsidiaries of Japanese firms in the US. They find that output falls roughly one-for-one with declines in imports. We find here a considerably larger effect where a one dollar fall in imports lead to a 27 dollar fall in firm output - indicating imports from Thailand constitute critical components for production in Sweden. Carvalho et al. (2021) also provides a quantification of the role of input-output linkages as a mechanism for

[2]Tang (2006) studies supply chain risk management practices and suggests that diversifying suppliers (in multiple countries) to manage GVC risks maintains firm resilience during major supplier disruptions. Jüttner (2005) studies GVC risk management practices and provides a taxonomy of the sources of supply chain risk. Hendricks and Singhal (2005) is an exception in that use quantitative methods to study the stock price effects of supply chain disruptions.

[3]Weather events that are less severe than natural disasters are analyzed by Pankratz and Schiller (2021). They find that a supply-chain link is 6 to 11 percent more likely to be terminated in a given year, if the realized exposure to heat and floods exceeds proxies of customers' ex-ante expectation.

the propagation and amplification of the shock from the Great East Japan Earthquake of 2011. They find that the earthquake and its aftermath resulted in a 0.47 percentage point decline in Japan's real GDP growth in the year following the disaster. Another example of how shocks propagate thru GVCs is found in Kashiwagi et al. (2021), that document how Hurricane Sandy adversely affected companies that were not directed affected by the disaster, but were linked to affected firms. Todo et al. (2015) find that supply chain networks on balance have positive effects on the resilience of firms to the Great East Japan Earthquake in 2011. Zhu et al. (2016) employ a difference-in-difference strategy using Japanese firm-level data from 2010-2013, to show show that the Great East Japan Earthquake increased offshoring of Japanese firms. Barrot and Sauvagnat (2016) study the impact the propagation effects of firm-level shocks caused by natural disasters in the US. They find that when a firm experience a drop in sales of on average 2-3 percent when a supplier is hit by a natural disaster. In our study, importing firms in Sweden are very far away from the shock in Thailand. Imports from Thailand are also a very small share of Swedish imports. In spite of this we find very large and persistent effects on the affected firms. Production drops by on average 8 percent in our case (for the treated firms that had a higher share of Thai imports in total imports).[4] This points to the potential long-range effects of natural disasters, and it could indicate that switching costs increase with the distance to suppliers. Consistent with this we find that Swedish importers predominantly switch to suppliers in other Asian countries in response to the shock. Finally, we show a very strong mitigating effect when suppliers are geographically diversified.

2 The 2011 Thailand Flood

The flooding began in July of 2011. It inundated 9.1 percent of the total land area of Thailand, affecting close to 13 million people, with 728 deaths. It caused an estimated total damage of USD 46.5 billion. Damaged areas were dispersed in 69 provinces in every region of the country, and Bangkok and its vicinity were paralyzed for two months (Poapongsakorn and Meethom (2013)). The flood hit the manufacturing sector especially hard, accounting for an estimated USD 32 billion of the total damages (Haraguchi and Lall (2015)). METI (2012) report, for instance, production losses of 84 percent in transport machinery, 77 percent in office equipment, and 73 percent in information and

[4]Firms in the top 50th percentile had imports from Thailand worth at least 7000 USD (51 272 SEK) in 2010.

communication equipment. The time to recover differed between sectors, but also among individual firms depending on their location. In the automotive industry Toyota required 42 days to partly resume operations, while Honda required 174 days. Thailand produced approximately 43 percent of the world's hard disk drives in 2011, and recovery was somewhat slower than in the automobile sector. Many companies had facilities in Ayutthaya, where industrial parks were heavily inundated, Haraguchi and Lall (2015). However, overall Thai industry recovered within months and had made important progress within six months. Production in March 2012 was 10 percent lower than that in March 2011, which may be compared to the maximal loss of 77 percent in November 2011, METI (2012).

3 Data Sources

This section provides summary information on our data provided by Statistics Sweden. The data includes annual firm-level observations between 2006-2013. The flood occurred in the summer of 2011, and in 2014 Thailand suffered a coup d'etat, hence 2013 is the last year included in the sample. We also observe customs data for each firm's imports by product at the Combined Nomenclature 8-digit level (CN8) $\times$ country of origin. Thus for each firm, we observe the CN8 product imported by the firm and the country, or countries, from which the product is imported from.

We focus on manufacturing firms in NACE sectors 13-33[5], and observe firm-level balance sheet data that is matched with customs trade data. This means our data includes annual observations at the firm-origin-product level. We employ a unbalanced panel that contains data for all of Sweden's importing firms per year. There were a total of 3651 importing firms in Sweden in 2010. For that same year this translates to: 61171 observations at the firm-origin level; 116317 observations at the firm-product level; and 357921 observations at the firm-product-origin level. 265 Swedish firms imported from Thailand in 2011, and these constitute the treated group. The sector composition of Swedish imports from Thailand is shown in Figures 1 and 2. Machinery and equipment (sector 28) and computer and electronic products (sector 26) are particularly important import sectors in terms of both value and number of importers.

Summary statistics of all variables is provided in Table 1. The upper panel shows all firms and the lower panel only the treated ones.

[5]Thus, excluding food in sectors 10-12.

Figure 1: The distribution of Swedish imports from Thailand across SNI 2007 2-digit sectors - value of imports in 2010

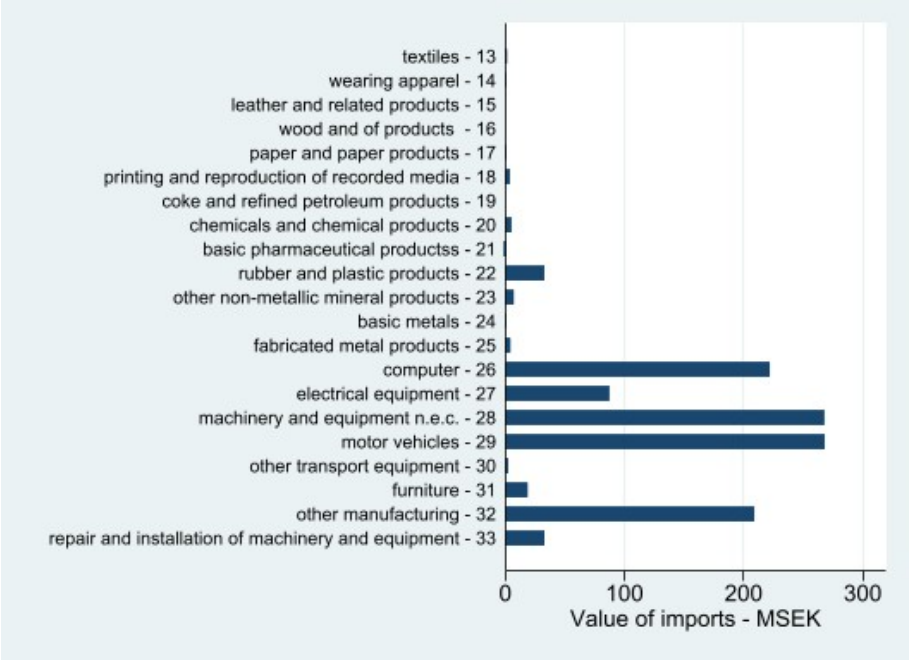


Figure 2: The distribution of treated Swedish firms by SNI 2007 2-digit sector - number of firms in 2010

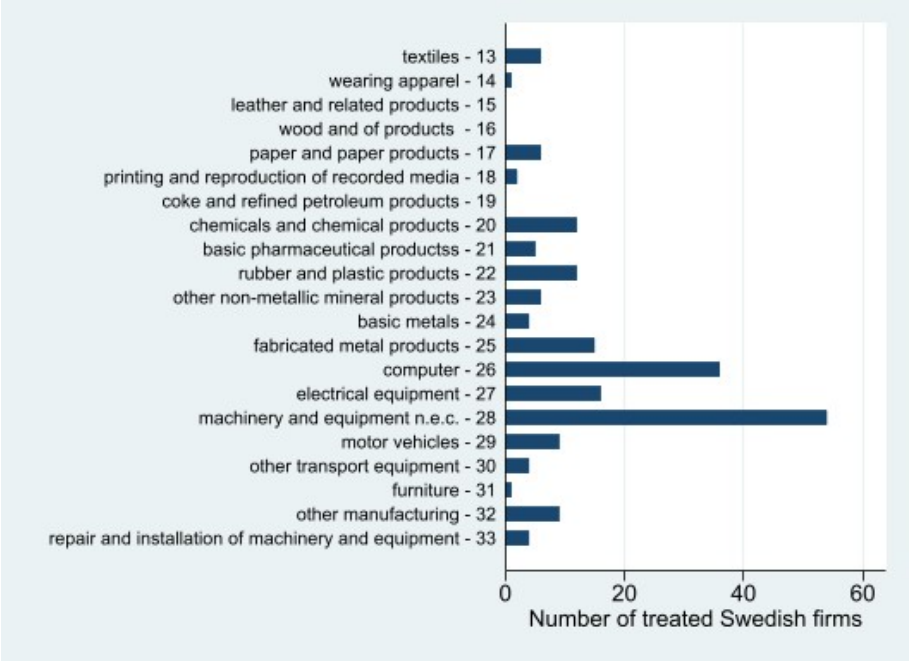


Table 1: Summary statistics regression sample of firms, Sweden 2006-2015

	Variable	Mean	Std. Dev.	Min.	Max.	N
Full sample, all years						
Y_{it}	Sales, M Kr.	241.71	2183.17	5	109 856	45 751
VA_{it}	Value added, M Kr.	69.43	637.42	-3574	39 204	45 751
X_{it}	Export revenue, M kr.	123.48	1379.44	0	72 1335	45 751
w_{it}	Wages, M kr.	31.10	218.72	0	11 110	45 751
L_{it}	Employees	80.87	462.45	10	20 492	45 751
M_{ict}	Value imports per origin, M. kr.	4.65	146.52	0	49 124	453 601
M_{ipt}	Value product imports, M. kr.	2.61	135.29	0	89 056	952 093
Q_{ipt}	Quantity product imports, thousands, units vary	148	23 835	0	15 784 390	952 093
$M_{ipt}^{TH'}$	Value product imports excl. TH, M. kr.	2.54	147.04	0	89 056	868 089
$Q_{ipt}^{TH'}$	Quantity product imports excl. TH, units vary	213	262 521	0	15 784 390	868 089
Indicator variables for:						
D_i^{JP}	Imports from Japan	0.04	0.18	0	1	45 751
Sample treated firms in 2011						
Y_{it}	Sales, M Kr.	2370.56	9907.08	5.91	109 856	265
VA_{it}	Value added, M Kr.	698.72	2824.15	-1694	29 795	265
X_{it}	Export revenue, M kr.	1465.98	6232.32	0	64 229	265
w_{it}	Wages, M kr.	267.38	946.11	1.37	10 538	265
L_{it}	Employees	586.11	1934.23	10	19 310	265
Indicator variables for:						
E_i^{hi}	High share of Thai imports in imports	0.51	0.50	0	1	265
E_{ic}^{big}	250 or more employees	0.05	0.22	0	1	1574
E_{ip}^{sole}	Sole origin (from TH only)	0.05	0.07	0	1	4145
E_{ip}^{TH}	Product imported from Thailand	0.13	0.33	0	1	4145

The table presents summary statistics on the sample used in regressions reported in Tables 5 column 1 for firm × year observations, Table 4 column 1 for firm × country × year and Table 6 column 1 for firm × product × year observations.

4 Estimation

4.1 Effects of the Thai flood on Swedish firm imports

We use a difference-in-difference specification to estimate the causal effect of the Thai flood on Swedish firms. With this approach, we can control for other factors that may confound the estimated effects, including for instance movements in the Swedish business cycle that could also affect import flows from Thailand. We designate all other Swedish importers as the control group in all regressions. That is, the control group consists of Swedish importers that do not import from Thailand.

A potential threat to this identification strategy is that firms in the control group could be indirectly affected in various ways, for instance if suppliers of control group suppliers were affected by the Thai flood. This would bias our results towards zero. Alternatively, if a firm in the control group happens to export a good that is hit by the flood, it would face increasing demand for it's output, and therefore possibly increase imports. This would give a bias towards larger results in our regressions (in absolute value). However, the control group used here is very large. It consists of all Swedish 3386 importing firms in 2010, which may be compared to the 265 firms that import from Thailand in the same year. Thai imports constituted less than one percent of firm imports in Sweden in 2010.[6] This means that the aforementioned potential spillovers to other firms will be practically negligible .

Furthermore the treatment and control groups may differ in their observable and unobservable characteristics, but the estimation of the causal impact will be unbiased only if this difference is constant over time prior to treatment Angrist and Pischke (2008). Figure 3 shows highly parallel trends for the treatment and control group once a linear time trend has been removed.[7] All regressions are based on the detrended data.

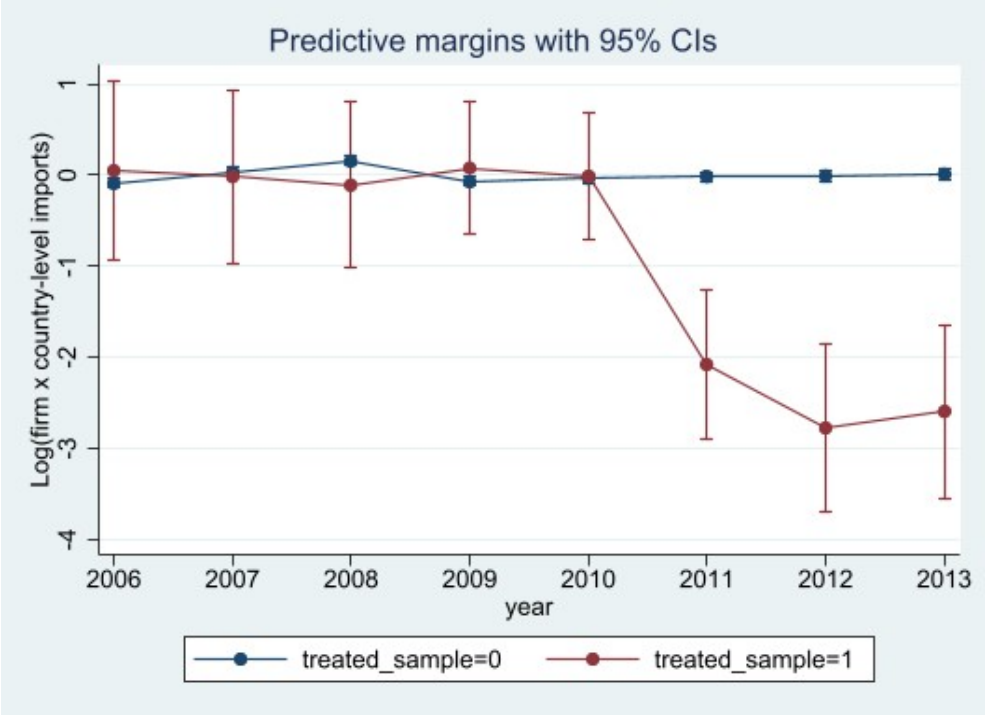
For a first look at the effects of the flood on imports, We use the following difference-in-difference specification with firm × country fixed effects and year fixed effects:

$$\begin{aligned} \ln M_{ict} =& \beta_1(E_{ic} \times D_{2011}) + \beta_2(E_{ic} \times D_{2012}) + \beta_3(E_{ic} \times D_{2013}) \\ &+ \alpha_0 + \alpha_{ic} + D_t + \epsilon_{ict} \end{aligned} \tag{1}$$

[6] Total imports by manufacturing firms (the entire sample of firms in our data) in 2010 amounted to 284 billion Swedish kr, whereas total imports by treated firms amounted to 1.2 billion Swedish kr the same year.

[7] The confidence interval for the large control group is to small to be visible in the figure.

Figure 3: The impact of the 2011 Thai flood on the imports from Thailand



M_{ict} is the value of imports by firm i from country c at time t, α_{ic} is a firm $\times$ country fixed effect, D_t is a time fixed effect, and β_j measures the effect on treated firms year j. E_{ic} indicates firm imports from Thailand and is equal to 1 for a firm that imports from Thailand and equal to zero otherwise. $[D_{2011}, D_{2012}, D_{2013}]$ are indicators for the years 2011, 2012, and 2013, and ϵ_{ict} is an error term.

The result of the difference-in-difference regression is shown in Table 2. Column (1) shows that treated firms experience 89 percent drop in their imports in 2011, increasing to 95 percent in 2012 and 2013. In column (2) all firms that import from Japan are dropped, to purge the results from confounding effects of the tsunami that occurred in Japan later in 2011. Results remain highly similar in these regressions.

We next turn to the issue of which firms that were most affected by the flood. As a first test, we show that effects were stronger for smaller or medium sized firms. We divide the sample of treated firms into larger firms ($\geq$250 employees) and smaller firms ($<$250 employees). 81 treated firms fall into the larger firm category and 184 firms fall into the smaller firm category. We the define E_{ic}^{big}, which indicates a large firm $\times$ country import from Thailand and E_{ic}^{small} for the small firms.

The results in Table 3 reports point estimates that suggest smaller firms saw the

Table 2: Effects of the 2011 Thailand flood on Swedish firm imports from Thailand.

	(1) $ln(M_{ict})$	(2) $ln(M_{ict})$
$(E_{ic} \times D_{2008})$	-0.420 (0.286)	-0.380 (0.295)
$(E_{ic} \times D_{2009})$	0.183 (0.382)	0.235 (0.390)
$(E_{ic} \times D_{2010})$	0.004 (0.465)	0.081 (0.462)
$(E_{ic} \times D_{2011})$	-2.230 (0.558)***	-2.051 (0.550)***
$(E_{ic} \times D_{2012})$	-3.093 (0.452)***	-2.836 (0.443)***
$(E_{ic} \times D_{2013})$	-3.101 (0.515)***	-2.989 (0.514)***
Sample		No Japan
Observations	453601	429420
R^2	0.032	0.031

Dependent variable: Log of firm imports by country (Millions of Swedish Crowns). * p<0.10,** p<0.05,*** p<0.01. Standard errors in parentheses, clustered at the 3-digit sector level.
Specifications include firm × country fixed effects, and year fixed effects. Observations over the years 2006-2013.

largest percentage decrease in imports from Thailand.[8] A few coefficients in column (2), where importers from Japan are dropped, loose significance. However, 66 of the 81 "large" treated firms import from both Thailand and Japan whereas 79 of the 184 "small" treated firms import from both Thailand and Japan. It means that we identify our results on just 15 large firms when we drop all the Japanese importers.

Table 3: Effects of the 2011 Thailand flood on Swedish firm imports from Thailand divided into larger firms ($\geq$ 250 employees) and smaller firms (<250 employees).

	(1) $ln(M_{ict})$	(2) $ln(M_{ict})$
$(E_{ic}^{big} \times D_{2011})$	-1.350	-1.348
	(0.787)*	(1.121)
$(E_{ic}^{small} \times D_{2011})$	-2.664	-2.203
	(0.486)***	(0.513)***
$(E_{ic}^{big} \times D_{2012})$	-2.529	-1.550
	(0.625)***	(1.074)
$(E_{ic}^{small} \times D_{2012})$	-3.366	-3.087
	(0.413)***	(0.435)***
$(E_{ic}^{big} \times D_{2013})$	-2.658	-2.624
	(0.983)***	(0.980)***
$(E_{ic}^{small} \times D_{2013})$	-3.310	-3.226
	(0.431)***	(0.457)***
Sub-sample		No Japan
Observations	453601	429420
R^2	0.003	0.003

Dependent variable: Log of firm imports by country (Millions of Swedish Crowns). * p<0.10,** p<0.05,*** p<0.01. Standard errors in parentheses, clustered at the 3-digit sector level.
All specifications include firm fixed x country effects, and year fixed effects. Observations over the years 2006-2013.

As a second test, we examine if firms that have a higher share of Thai imports in total imports were better or worse at securing Thai imports. We split the sample of treated firms down the median into two buckets, one with firms that have a high share of Thai imports and another with firms that have a low share of Thai imports, denoted with E_{ic}^{hi}

[8]The difference between the 2011 point estimates for large and small firms is significant at the 15% level, and the corresponding significance levels are lower for 2012 and 2013.

and E_{ic}^{low} respectively.

The results in Table 4 Column (1) report the results for the group of high and low share of Thai imports. The point estimates suggest that firms with a higher share of Thai imports in total imports were somewhat better at securing Thai imports. The estimates under Column (1) suggest that firms with a "high" share of Thai imports saw Thai imports drop by 82%, 93% and 93% in 2011, 2012 and 2013, respectively. Firms with a "low" share saw an even larger drop. The point estimate for 2012 suggests that in aggregate, the flood caused a drop in Swedish imports from Thailand by 1.08 billion SEK.

The results are not sensitive to excluding firms that import from Japan, in Column (2).

Table 4: Effects of the 2011 Thailand flood on Swedish firm imports from Thailand divided into firms with a high share and a low share of Thai imports.

	(1) $ln(M_{ict})$	(2) $ln(M_{ict})$
$(E_{ic}^{hi} \times D_{2011})$	-1.696	-1.766
	(0.529)***	(0.496)***
$(E_{ic}^{lo} \times D_{2011})$	-2.794	-2.420
	(0.570)***	(0.837)***
$(E_{ic}^{hi} \times D_{2012})$	-2.705	-3.087
	(0.508)***	(0.489)***
$(E_{ic}^{lo} \times D_{2012})$	-3.487	-2.607
	(0.598)***	(0.691)***
$(E_{ic}^{hi} \times D_{2013})$	-2.648	-2.570
	(0.644)***	(0.646)***
$(E_{ic}^{lo} \times D_{2013})$	-3.558	-3.490
	(0.620)***	(0.634)***
Sub-sample		No Japan
Observations	453601	429420
R^2	0.003	0.003

Dependent variable: Log of firm imports by country (Millions of Swedish Crowns). * p<0.10,** p<0.05,*** p<0.01. Standard errors in parentheses, clustered at the 3-digit sector level.
All specifications include firm fixed x country effects, and year fixed effects. Observations over the years 2006-2013.

4.2 The impact of the flood on the aggregate output and export of Swedish firms

The effect of the large drop in imports from Thailand on firm-level variables such as output and value added would naturally depend on how important this import is for a particular firm, and we have therefore split the sample in the middle according to the import share from Thailand.

We estimate the impact of the flood on firm-level output using a specification with firm fixed effects and year fixed effects:

$$\begin{aligned} \ln Y_{it} =& \beta_1(E_i \times D_{2011}) + \beta_2(E_i \times D_{2012}) + \beta_3(E_i \times D_{2013}) \\ &+ \alpha_0 + \alpha_i + D_t + \epsilon_{it} \end{aligned} \tag{2}$$

Y_{it} denotes the detrended output of the firm, and the specifications for value added and exports are analogous. E_i indicates that a firm imports from Thailand and is equal to 1 for a firm that imports from Thailand and is equal to zero otherwise.

Table 5 shows the effects on output, value added and export among the treated firms, where we have split the sample in the middle according to the import share from Thailand. "Hi" denotes the top 50th percentile of import share from Thailand. However, note that even firms with the lowest import share in the "Hi" sample have a share of less than one percent. Thus, the import share in the "lo" sample is extremely low and no significant effects are registered for this sub sample of treated firms.

Whereas we have recorded large immediate effects on imports in 2011, the first effects on production are visible in 2012. Firms were able to maintain production for some period following the flood, but large effects on output are seen in 2012 and 2013 when output falls by 8 percent among the 50th percentile of importers with higher import share. This translates into a 29.7 billion SEK drop in the annual output for these firms. Recall that in 2012 the flood caused a drop in Swedish imports from Thailand that amounted to 1.08 billion SEK for these same firms (with a high Thai import share). This is a striking result. It suggests that each 1 SEK loss by Thai suppliers translated into over 27 SEK loss in output by Swedish firms.[9] Barrot and Sauvagnat (2016) find similar, albeit much smaller magnification effects. In their study of natural disasters in the US, they find that

[9]The 95-percent confidence interval of the point estimates translates to a loss of output of between 7,7 SEK and 51,7 SEK per 1 SEK loss of imports.

a 1 USD loss by a supplier translates into a 3.6 USD loss in sales.

Furthermore there is a weakly significant effect on exports of treated firms that fall by 16 percent in 2013. This is consistent with the fact that we find effects on imports all thru 2013, and it indicates a relatively low degree of resilience among the Swedish importers.

Table 5: Effects on firm output, value added and export.

	(1) $ln(Y_{it})$	(2) $ln(\text{VA}_{it})$	(3) $ln(X_{it})$
$(E_i^{hi} \times D_{2011})$	-0.040	0.013	-0.019
	(0.027)	(0.031)	(0.099)
$(E_i^{low} \times D_{2011})$	-0.005	0.050	0.092
	(0.029)	(0.041)	(0.074)
$(E_i^{hi} \times D_{2012})$	-0.082	-0.069	-0.120
	(0.038)**	(0.048)	(0.120)
$(E_i^{low} \times D_{2012})$	0.019	-0.001	0.032
	(0.025)	(0.060)	(0.073)
$(E_i^{hi} \times D_{2013})$	-0.069	-0.035	-0.183
	(0.041)*	(0.037)	(0.107)*
$(E_i^{low} \times D_{2013})$	0.006	-0.006	-0.026
	(0.031)	(0.062)	(0.115)
Observations	45751	45361	33668
R^2	0.059	0.040	0.007

Dependent variable: Log of firm output, value added and exports (Millions of Swedish Crowns). * p<0.10,** p<0.05,*** p<0.01. Standard errors in parentheses, clustered at the 3-digit sector level.
All specifications include firm fixed effects, and year fixed effects and the dependent variables are de-trended.
Data over the period 2006-2013.

4.3 Substitution across inputs to production

Firms may be able to compensate for the loss of inputs from Thailand by using substitute suppliers from other countries, or by using other other similar products.

Table 6: Effects on imports of the affected products from other source countries.

	(1) $ln(M_{ipt})$	(2) $ln(Q_{ipt})$
$(E_{ip}^{TH} \times D_{2011})$	0.722	0.491
	(0.196)***	(0.142)***
$(E_{ip}^{TH} \times D_{2012})$	0.647	0.388
	(0.337)***	(0.223)*
$(E_{ip}^{TH} \times D_{2013})$	0.695	0.443
	(0.248)***	(0.155)**
Observations	868089	868089
R^2	0.001	0.002

Dependent variable: Firm imports by product (Millions of Swedish Crowns). * p<0.10,** p<0.05,*** p<0.01. Standard errors in parentheses, clustered at the 3-digit sector level.
All specifications include firm × product fixed effects, and year fixed effects and the dependent variables are de-trended.
Data over the period 2006-2013.

4.3.1 Substituting suppliers

We start by investigating to what extent the treated firms managed to increase their imports of the affected products from other source countries. For this purpose we use observations at the firm-product-year level. We estimate the impact of the flood on firm imports at the product-level using a specification with firm × product fixed effects and year fixed effects:

$$\begin{aligned} \ln M_{ipt} =& \beta_1(E_{ip} \times D_{2011}) + \beta_2(E_{ip} \times D_{2012}) + \beta_3(E_{ip} \times D_{2013}) \\ &+ \alpha_0 + \alpha_{ip} + D_t + \epsilon_{ipt} \end{aligned} \tag{3}$$

M_{ipt} denotes the detrended value of product-level imports of the firm for a given year. E_{ip}^{TH} is an indicator that is equal to 1 for a firm × product import where some positive share of the product p is sourced from Thailand and zero otherwise. The specification for quantity exported, Q_{ipt} is analogous.

Column (1) of Table 6 shows how the imported value from other sources almost doubled during 2011 to 2013. The effect is significant at the 1 percent level. The imported

quantity also increased, but only by around 50 percent, which is consistent with rising world market prices of these goods due to the drop in supply from Thailand. There is in this respect a difference between large and small firms. Table 7, reports the results from dividing treated firms into large and small firms, and the point estimates suggest that large firms manage to double the imported quantity from other suppliers at a moderately higher cost. Small and medium sized firms, on the contrary, were much less successful in increasing imports from other sources.

Relative to the small firms, the point estimates for large firms suggests they maintained higher import levels from other source countries during the entire period 2011-2013, which is consistent with a permanent switch of suppliers.

Table 7: Effects on imports of the affected products from other source countries divided into larger firms ($\geq$ 250 employees) and smaller firms (<250 employees).

	(1) $ln(M_{ipt})$	(2) $ln(Q_{ipt})$
$(E_{ip}^{TH,big} \times D_{2011})$	0.828 (0.255)***	0.686 (0.212)***
$(E_{ip}^{TH,small} \times D_{2011})$	0.600 (0.359)*	0.267 (0.214)
$(E_{ip}^{TH,big} \times D_{2012})$	0.821 (0.356)**	0.547 (0.278)*
$(E_{ip}^{TH,small} \times D_{2012})$	0.428 (0.422)	0.189 (0.232)
$(E_{ip}^{TH,big} \times D_{2013})$	0.938 (0.271)***	0.642 (0.211)***
$(E_{ip}^{TH,small} \times D_{2013})$	0.381 (0.409)	0.188 (0.258)
Observations	868089	868089
R^2	0.001	0.002

Dependent variable: Firm imports by product (Millions of Swedish Crowns). * p<0.10,** p<0.05,*** p<0.01. Standard errors in parentheses, clustered at the 3-digit sector level.
All specifications include firm × product fixed effects, and year fixed effects and the dependent variables are de-trended.
Data over the period 2006-2013.

4.3.2 Re-shoring

Another issue is to which suppliers the Swedish importers switch. A possible response would be to switch to suppliers that are geographically closer, so called re-shoring, for instance to suppliers located in the European union. To investigate this we use annual observations at the firm $\times$ product $\times$ region level for four regions: Asia, EU, North America and Other. 'Asia' includes all countries in Asia except Thailand, while 'EU' includes all 27 members of the European Union plus the UK. 'NA' captures North America, and 'Other' captures all other countries of origin. The regions are denoted by the subscript $r \in (Asia, EU, NA, Other)$, and Table 8 reports the results. The table reveals that importers predominantly switched to other Asian suppliers, whereas only smaller and marginally significant increases are seen from the EU. The fact that Swedish importers where not able to find other nearby suppliers could help explaining the large effects of the flood. That supply from North America decreased, is consistent with increased international competition for components supplied by Thailand such as hard-disks. No significant effects were found for the group of Other countries.

4.3.3 Imports of other goods - horizontal propagation

The drop of imports from Thailand may spill over to imports of other goods not directly affected by the flood. Firms may increase imports of other goods from other countries as they seek substitutes to the goods they are not able to obtain from Thailand. Alternatively, firms may decrease imports of other goods from other countries that were complements to the goods they are not able to obtain from Thailand. To capture these effects, we examine the imports of products by treated firms that are sourced from countries other than Thailand, which we denote with the complement of Thailand superscript TH', in $E_{ip}^{TH'}$.

Table 9 shows a large reduction in the imported quantity of all other goods from non-Thai origins, which is consistent with these goods being complements on average. The reduced demand for complement goods leads to a sizeable fall in the price of these imports as seen by the fact that the value of imports fall by a much larger percentage than the quantity of imports. Quantities are, however, less precisely estimated. Again the effect is seen all the years 2011-2013.

Table 8: Effects on re-shoring in response to the Thailand flood.

	(1) $ln(M_{iprt})$	(2) $ln(Q_{iprt})$
$E_{ipr}^{Asia} \times D_{2011}$	1.356 (0.671)**	0.687 (0.398)*
$E_{ipr}^{Asia} \times D_{2012}$	1.320 (0.632)**	0.584 (0.358)
$E_{ipr}^{Asia} \times D_{2013}$	1.209 (0.545)**	0.522 (0.4102)
$E_{ipr}^{EU} \times D_{2011}$	0.457 (0.262)*	0.225 (0.213)
$E_{ipr}^{EU} \times D_{2012}$	0.384 (0.314)	0.178 (0.215)
$E_{ipr}^{EU} \times D_{2013}$	0.467 (0.270)*	0.115 (0.238)
$E_{ipr}^{NA} \times D_{2011}$	-0.286 (0.575)	-0.063 (0.293)
$E_{ipr}^{NA} \times D_{2012}$	-0.761 (0.639)	-0.291 (0.304)
$E_{ipr}^{NA} \times D_{2013}$	-1.210 (0.400)***	-0.546 (0.196)***
$E_{ipr}^{Other} \times D_{2011}$	-0.046 (0.621)	-0.014 (0.385)
$E_{ipr}^{Other} \times D_{2012}$	-0.072 (0.605)	0.030 (0.354)
$E_{ipr}^{Other} \times D_{2013}$	-0.618 (0.553)	-0.316 (0.393)
Observations	1450445	1450445
R^2	0.001	0.001

Dependent variable: Firm imports by product and by region (Millions of Swedish Crowns). * p<0.10,** p<0.05,*** p<0.01. Standard errors in parentheses, clustered at the 3-digit sector level.
All specifications include firm × product × region fixed effects, and year fixed effects and the dependent variables are de-trended.
Data over the period 2006-2013.

Table 9: Effects on imports of complementary products in response to the Thailand flood.

	(1) $ln(M_{ipt})$	(2) $ln(Q_{ipt})$
$(E_{ip}^{TH'} \times D_{2011})$	-1.652	-0.626
	(0.451)***	(0.358)*
$(E_{ip}^{TH'} \times D_{2012})$	-1.692	-0.626
	(0.444)***	(0.342)*
$(E_{ip}^{TH'} \times D_{2013})$	-1.819	-0.695
	(0.442)***	(0.347)**
Observations	950641	950641
R^2	0.017	0.006

Dependent variable: Firm imports by product (Millions of Swedish Crowns). * p<0.10,** p<0.05,*** p<0.01. Standard errors in parentheses, clustered at the 3-digit sector level.
All specifications include firm × product fixed effects, and year fixed effects and the dependent variables are de-trended.
Data over the period 2006-2013.

4.3.4 Diversification by using multiple suppliers

It has been suggested that supply chains would be more robust to shocks if firms diversify suppliers: firms could reduce their risk by having more than one supplier of an input. Our data at the firm-country-product level does not distinguish if a firm has several suppliers in the same country. However, we can investigate the importance of having suppliers in more than one country. We investigate this by running a regression were we divide the treated firms into firms that import at least one CN8 good from Thailand only and firms that import the good from several countries before the flood. Each group of treated firms is compared to the control group used in the rest of the paper. Table 10 shows the result. Firms that do source a given input from other countries do not have any significant drop in imports. Rather they increase imports in 2011, possibly to hedge against future shortages of the affected products. Firms that import from Thailand only have a large and consistent drop in imports. Quantities seem, somewhat surprisingly, to fall less than values. It is possible that importers switch to inputs of lower qualities. However, quantities are quite imprecisely estimated.

Table 10: Comparing firms sourcing a product from multiple countries to firms sourcing a product from Thailand only.

	(1) $ln(M_{ipt})$	(2) $ln(Q_{ipt})$
$(E_{ip}^{sole} \times D_{2011})$	-1.214	-0.332
	(0.333)***	(0.245)
$(E_{ip}^{diverse} \times D_{2011})$	0.476	0.425
	(0.146)***	(0.102)***
$(E_{ip}^{sole} \times D_{2012})$	-1.273	-0.333
	(0.590)**	(0.252)
$(E_{ip}^{diverse} \times D_{2012})$	0.243	0.282
	(0.220)	(0.111)**
$(E_{ip}^{sole} \times D_{2013})$	-1.303	-0.392
	(0.348)***	(0.188)**
$(E_{ip}^{diverse} \times D_{2013})$	0.335	0.399
	(0.163)*	(0.094)***
Observations	952093	952093
R^2	0.001	0.003

Dependent variable: Log of firm inputs at the CN8 level. * p<0.10,** p<0.05,*** p<0.01. Standard errors in parentheses, clustered at the 3-digit sector level.

All specifications include firm × product fixed effects, and year fixed effects - treatment and control groups time de-trended.

The sample includes all importing Swedish firms between the years 2006 and 2013, inclusive.

4.4 Conclusion

We use a difference-in-difference specification to estimate the effect of the 2011 Thai flood on Swedish firms that import from Thailand.

We find large effects on imports as well as sizeable effects on the output of firms that were dependent on Thai imports. Imports from Thailand dropped by about 90% on average. Output by the 50th percentile of importers with a higher share of Thai imports in total imports dropped by 8% (by value) in 2012. In aggregate, this translates into a 1.08 billion SEK drop in Thai imports for these firms, which translated into over 29.7 billion SEK in lost sales. The magnitude of the amplification effect is striking, suggesting that firms were systematically ill prepared to deal with this shock to their supply chains. The effects on Swedish importers were visible through the year of, and years following, the flood up to 2013 inclusive. Effects on imports and other aspects of firm operations lasted trough 2013, despite the fact that many Thai based producers seem to have resumed production already after six months. This is consistent with the idea that there are substantial fixed costs associated with establishing links between firms in global value chains (se eg. Antras et al. (2017)). We also find that large firms were better at handling the shock. First, point estimates for larger firms suggest they were better at obtaining inputs from Thailand and saw a smaller drop in their imports from Thailand. Second, larger firms managed to increase imports from other countries but were able to keep import prices in check. In contrast, smaller firms faced significant price increases when importing from other sources. A particularly important factor was whether a treated firm had suppliers outside Thailand before the shock. Firms that obtained inputs from multiple sources were to a large degree isolated from the shock, which shows the importance of diversifying suppliers in a value chain. Finally, there are very weak indications of re-shoring. Swedish importers instead switched to other Asian suppliers. The fact that the importers where not able to find substitute European suppliers could help explaining the large effects of the flood.

References

Amiti, M. and Weinstein, D. E. (2018). How much do idiosyncratic bank shocks affect investment? evidence from matched bank-firm loan data. *Journal of Political Economy*, 126(2):525–587.

Angrist, J. D. and Pischke, J.-S. (2008). Mostly harmless econometrics. In *Mostly Harmless Econometrics*. Princeton university press.

Antras, P. and Chor, D. (2021). Global value chains. Working Paper 28549, National Bureau of Economic Research.

Antras, P., Fort, T. C., and Tintelnot, F. (2017). The margins of global sourcing: Theory and evidence from us firms. *American Economic Review*, 107(9):2514–64.

Barrot, J.-N. and Sauvagnat, J. (2016). Input specificity and the propagation of idiosyncratic shocks in production networks. *The Quarterly Journal of Economics*, 131(3):1543–1592.

Bas, M. (2012). Input-trade liberalization and firm export decisions: Evidence from argentina. *Journal of Development Economics*, 97(2):481–493.

Bas, M. and Strauss-Kahn, V. (2014). Does importing more inputs raise exports? firm-level evidence from france. *Review of World Economics*, 150(2):241–275.

Bernard, A. B., Moxnes, A., and Saito, Y. U. (2019). Production networks, geography, and firm performance. *Journal of Political Economy*, 127(2):639–688.

Boehm, C. E., Flaaen, A., and Pandalai-Nayar, N. (2019). Input linkages and the transmission of shocks: Firm-level evidence from the 2011 tōhoku earthquake. *Review of Economics and Statistics*, 101(1):60–75.

Carvalho, V. M., Nirei, M., Saito, Y. U., and Tahbaz-Salehi, A. (2021). Supply chain disruptions: Evidence from the great east japan earthquake. *The Quarterly Journal of Economics*, 136(2):1255–1321.

Chodorow-Reich, G. (2014). The employment effects of credit market disruptions: Firm-level evidence from the 2008–9 financial crisis. *The Quarterly Journal of Economics*, 129(1):1–59.

Feng, L., Li, Z., and Swenson, D. L. (2016). The connection between imported intermediate inputs and exports: Evidence from chinese firms. *Journal of International Economics*, 101:86–101.

Haraguchi, M. and Lall, U. (2015). Flood risks and impacts: A case study of thailand's floods in 2011 and research questions for supply chain decision making. *International Journal of Disaster Risk Reduction*, 14:256–272.

Hendricks, K. B. and Singhal, V. R. (2005). An empirical analysis of the effect of supply chain disruptions on long-run stock price performance and equity risk of the firm. *Production and Operations management*, 14(1):35–52.

Hennessy, K., Lawrence, J., and Mackey, B. (2022). Ipcc sixth assessment report (ar6): Climate change 2022-impacts, adaptation and vulnerability: Regional factsheet australasia.

Johnson, R. C. (2018). Measuring global value chains. *Annual Review of Economics*, 10:207–236.

Jüttner, U. (2005). Supply chain risk management: Understanding the business requirements from a practitioner perspective. *The international journal of logistics management*.

Kashiwagi, Y., Todo, Y., and Matous, P. (2021). Propagation of economic shocks through global supply chains—evidence from hurricane sandy. *Review of International Economics*, 29(5):1186–1220.

METI (2012). White paper on international economy and trade 2012. *Ministry of Economy Trade and Industry (METI) Tokyo, Japan*.

Pankratz, N. and Schiller, C. (2021). Climate change and adaptation in global supply-chain networks. In *Proceedings of Paris December 2019 Finance Meeting EUROFIDAI-ESSEC, European Corporate Governance Institute–Finance Working Paper*, number 775.

Poapongsakorn, N. and Meethom, P. (2013). Impact of the 2011 floods, and flood management in thailand. *ERIA Discussion Paper Series*, 34:2013.

Tang, C. S. (2006). Perspectives in supply chain risk management. *International journal of production economics*, 103(2):451–488.

Todo, Y., Nakajima, K., and Matous, P. (2015). How do supply chain networks affect the resilience of firms to natural disasters? evidence from the great east japan earthquake. *Journal of Regional Science*, 55(2):209–229.

Zhu, L., Ito, K., and Tomiura, E. (2016). *Global sourcing in the wake of disaster: Evidence from the Great East Japan Earthquake*. RIETI.