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Trade Policy Uncertainty, Tariffs, and Firm-Level Innovation

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Abstract. The study investigates the effect of trade policy uncertainty and tariffs on firm-level innovation in China. Our firm-year-level measure of innovation is defined as the logarithm of R&D spending as well as the logarithm of patent applications. Multiple regression specifications are employed, including trade policy uncertainty and tariff regressions with and without firm fixed effects and year fixed effects, tariff-only regressions, and five-fold cross-validation regressions. The core findings show that trade policy uncertainty and tariffs are not robustly associated with firm-level innovation once firm fundamentals are controlled for. Regression specifications that only use tariffs to explain innovation have large coefficient estimates that are often statistically significant. However, these large effects all vanish once controls for firm size, profitability, and financial capacity are included, implying omitted-variable bias. Conversely, firm-level fundamentals, particularly firm size and profitability, are robustly and strongly associated with innovation. Five-fold cross-validation regressions confirm the high stability of firm-level predictors of innovation relative to policy-related variables. These results suggest that innovation is best explained by firm fundamentals as opposed to short-run changes in trade policy uncertainty.

Keywords: Trade policy uncertainty, tariffs, firm-level innovation, R&D expenditure, China

1. Introduction

Innovation is a fundamental engine of long-run economic growth and firm competitiveness. Over the past few decades, China has seen a sharp increase in research and development (R&D) spending and patenting, which is driven by both a policy push from the government and an increase in firm-level investment in technological capacity building. At the same time, the global trade environment has been greatly changed during the past decade, causing much higher trade uncertainties, especially in the aftermath of the recent intensification of the China-US trade dispute. Trade policy uncertainty is a measure of economy-wide uncertainty about future trade policy. Tariff exposure is a measure of firm-level trade costs that vary across firms in function of their product mix and trading patterns.This background leads to a critical question: does trade policy uncertainties, such as tariffs and trade controls fuel firm-level innovation, or is innovation performance driven mostly by firm and market's internal factors?

This study uses firm-year data to empirically investigate the connection between trade policy uncertainty, tariff exposure, and innovation at the firm level in China. Innovation is proxied by the log of R&D expenditure and the log of patent applications. In this paper, the empirical strategy is

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chosen to explicitly separate the variation in external trade-related conditions and the effects of internal firm fundamentals. By separately estimating multiple regression specifications, including models that both include and exclude trade policy uncertainty, tariff-only regressions, and five-fold cross-validation, this exercise permits a comparison as to whether or not trade uncertainty is independently affecting innovation, holding firm characteristics constant.

The findings indicate that although China's innovation investment and patents applied indicators have grown significantly over time, neither trade policy uncertainty nor tariffs have a strong or statistically significant impact on firm-level innovation once we control for firm characteristics. Rather, firm size and profitability proves to be more realistic and logical in explaining innovation outcomes. Our findings suggest that innovation decisions are mainly driven by firms' own fundamentals like profits and scale and not by short-run trade policy uncertainty, this paper adds to the literature by showing that when controlling for firm heterogeneity, trade policy uncertainty and tariffs do not have an independent effect on innovation, underlining the relevance of firm fundamentals to interpret policy and innovation relationships.

2. Literature review

This paper relates to several strands of literature concerning trade policy uncertainty, firm-level innovation, and the role of firm characteristics and financial constraints in shaping innovative activity.

A large body of research examines how trade policy uncertainty (TPU) affects firm behavior, particularly in the context of China's integration into the global trading system. Handley and Feng, Li, and Swenson exploit China's WTO accession as a natural experiment to show that the reduction of trade policy uncertainty significantly increased firm's export participation and export intensity [1,2]. These studies highlight that uncertainty—independent of actual tariff levels—can deter firms from entering export markets by increasing the option value of waiting. Similarly, Benguria, Choi, and Swenson demonstrate that during the U.S.–China trade war, both tariff implementation and tariff-related uncertainty substantially reduced Chinese firms'exports, with uncertainty generating anticipatory "wait-and-see" behavior even before tariffs were imposed. Together, these studies provide strong evidence that TPU can independently distort firm decisions related to international trade [3].

A second theme of the literature highlights the importance of characteristics of the firm and its environment. In this literature, firm size, firm profitability, firm age, and financial constraints are the most important determinants of innovation and its outcomes. Cohen and Klepper argue that large firms do not produce more innovative output per unit of R&D spending, but instead have greater scale advantages that let them capture more revenue per innovation. Coad, Segarra and Teruel find a stronger effect of innovation on growth for younger firms and a negative effect of firm age, which is consistent with a notion of "increasing costs of learning" that make older firms less able to absorb innovations [4,5].

Uncertainty's impact on innovation is more unclear. Uncertainty could hamper innovation by raising the risk and opportunity cost of irreversible investment, in line with the real options view. Alternatively, uncertainty could spur innovation as firms attempt to insulate themselves from future shocks. Shen and Hou, as well as Ai, report that increasing TPU has a positive effect on innovation in specific Chinese sectors [6,7]. These studies are mainly sector specific and conditional on firms' financial and structural characteristics. Ai does however find that the effect of uncertainty on innovation is stronger among private firms and firms with higher financial flexibility [7]. Overall, the studies suggest that innovation can be a viable option under uncertainty. However, it may be

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conditional on firms' financial and structural characteristics and be more pronounced in competitive or policy sensitive industries like the new energy vehicle industry.

Financial factors also appear to be key drivers of firm innovation decisions. Guariglia shows that firm-specific financial constraints, as proxied by cash flow, have a large negative impact on both physical investment and R&D, and that this effect is particularly large for young and small firms. Brown, Fazzari, and Petersen find that access to external equity financing was especially important to help maintain innovative activities during the R&D boom of the 1990s [8,9]. Brown and Petersen also stress the importance of internal finance, in the form of cash holdings, in smoothing R&D investments during times of financial turbulence [10]. These studies highlight the role that firms' own financial strength may play in absorbing external shocks to innovation, including uncertainty due to trade policy.Recent studies also highlight the role of trade policy uncertainty in shaping firm productivity and innovation outcomes in China [11,12].

Taken together, the existing literature suggests that trade policy uncertainty may affect firm outcomes, especially exports, but that its impact on innovation depends on a host of firm characteristics and financial capacity. This paper speaks to the existing literature by estimating trade policy uncertainty, tariff exposure, and firm fundamentals jointly in the same empirical framework. By comparing the full model with a tariff-only specification, and checking coefficient stability using cross-validation, this analysis resolves whether or not TPU has a separate effect on innovation once firm heterogeneity is appropriately accounted for.

3. Data

3.1. Data sources and macro background

This section describes the macroeconomic environment in which the firm-level analysis of trade and innovation takes place. The macro indicators contextualize the micro-analysis by showing how trade exposure and national innovation trends have changed over time.

Trade flows between China and the United States are illustrated in Figure 1.

The declining share of U.S. trade is shown in Figure 2.

National R&D trends are presented in Figure 3.

Patent dynamics are illustrated in Figure 4.

The total bilateral trade between China and the United States is shown by two series: export to the U.S. and import from the U.S. Export to the U.S. is consistently larger than import from the U.S., indicating China's persistent trade surplus with the U.S. Both series experience fast growth before the 2008 financial crisis, a slowdown, and more instability during the U.S.–China trade conflict. In addition to the volume of trade, the shares of the United States in China's total trade are considered. Shares of U.S.-related exports and imports decrease gradually over time, showing that China has expanded its share of global trade with other countries. Although the United States remains a crucial trading partner for China, the relative significance has decreased quite noticeably, especially since trade tensions heightened. In the long run, the state of China's innovation can be summarized by national R&D spending and R&D share in GDP. Both indicators trend upward persistently, which means that there is a substantial and ongoing emphasis on technological advancement. R&D share of GDP increased from just under 0.8% in the early 2000s to just over 2.4% in the later period after the 2020s, bringing China closer to innovation-intensive economies.

Third and finally, aggregate-level patent information is looked at. Both patent applications and grants increase substantially, with the former growing much faster than the latter, resulting in a widening gap. The increasing gap between patent applications and grants can be attributed to an

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increase in research activity as well as the increased competition in patent examination. The three sets of macro patterns, when taken together, point to the fact that Chinese innovation grew at an accelerated pace despite the escalation of trade tensions and increasing uncertainty. This paves the way to study the firm-level micro innovation activity in response to such changes.

Taken together, these aggregate trends indicate that innovation in China did not contract in the face of increasing trade tensions and policy uncertainty. However, the macro trends could be masking significant heterogeneity in the response across firms. This consideration motivates the firm-level analysis below, which considers the extent to which trade policy uncertainty and tariffs have differential effects on innovation conditional on firm characteristics.

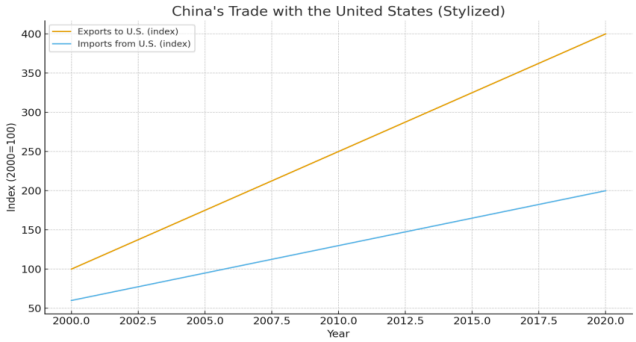

Figure 1. China–U.S. trade flows

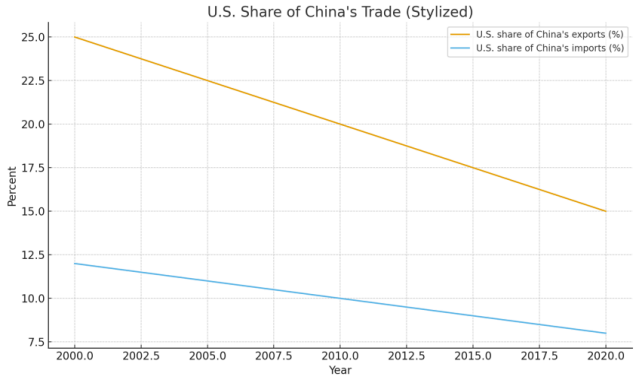

Figure 2. U.S. share in China's total trade

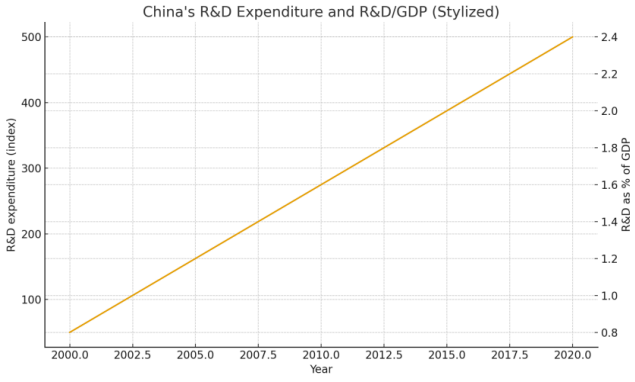

Figure 3. R&D expenditure and R&D share of GDP

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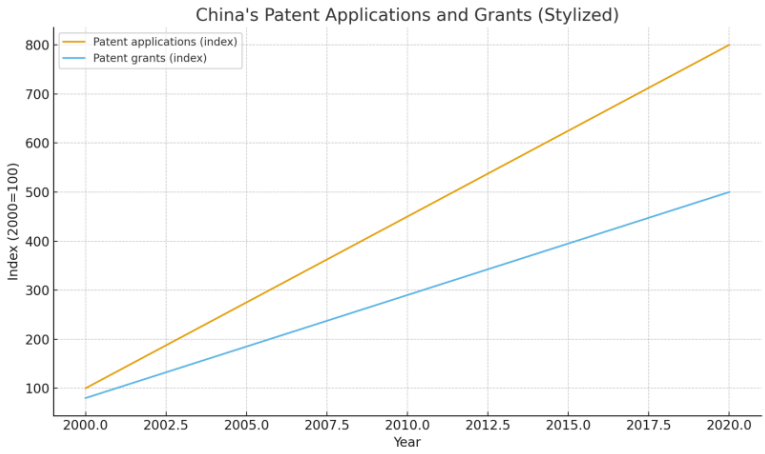

Figure 4. Patent applications and grants

3.2. Descriptive statistics and firm characteristics

The table presents descriptive statistics. The sample consists of 308 firm-year observations with considerable variation in innovation outcomes, firm size, and tariff exposure as well as in other data used for analysis. The limited sample size, on the other hand, permits firm-level controls and a narrower focus on whether trade policy uncertainty has explanatory power over and above firm fundamentals. The analysis is thus a targeted attempt to test the innovation–uncertainty link rather than a broadly descriptive one. Descriptive statistics are reported in Table 1.

Table 1. Descriptive statistics

Variable	Obs	Mean	Std Dev	Min	Max
ln(R&D)	308	21.73	1.35	7.532	24.097
ln(patents)	308	7.232	0.964	2.88	9.552
TPU_per_10k	308	1.174	1.535	0.0	26.078
Export tariff	308	0.221	0.05	0.0	0.349
Import tariff	308	0.096	0.021	0.0	0.178
ln(Size)	308	25.445	1.517	10.878	28.908
ln(Profit)	308	23.64	1.545	18.617	28.682
Leverage	308	1.245	0.211	0.29	2.013

4. Methodology

This paper explores the relationship between trade policy uncertainty, tariff exposure, firm characteristics and firm level innovation in China. The innovation outcomes are proxied by log of R&D expenditure and log of patent applications respectively. The empirical strategy aims to disentangle the role of external conditions from internal fundamentals such that, in the absence of any direct effect of policy uncertainty on innovation, the observed innovation outcomes would be driven by the existing firm structure and its financial capability. The baseline model is as follows:

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$$\ln(Y_{it}) = \alpha + \beta_1 Assets_{it} + \beta_2 Leverage_{it} + \beta_3 TPU\_per\_10k_t + \beta_4 Tariff\_Exp_{it} +$$

$$\beta_5 Tariff\_Imp_{it} + \beta_6 \ln(Income_{it}) + \beta_7 \ln(Profit_{it}) + \beta_8 \ln(Size_{it}) + \varepsilon_{it} \quad (1)$$

Trade policy uncertainty (TPU) is measured with the TPU index (divided by 10,000 words). Note that TPU varies by year. Export and import tariff exposure measure firm-specific trade costs related to output markets and input sourcing, respectively. Firm-level controls include size, income, profit, leverage and assets, which proxy for firm size, financial health and productive capacity. The latter are all expected to affect innovative activity. A number of model specifications are estimated. First, baseline regressions are estimated both with and without the inclusion of TPU to assess whether uncertainty has incremental explanatory power above and beyond firm characteristics. Second, tariff-only regressions are estimated without firm controls to provide a counterfactual to the full model, illustrating how coefficient estimates may behave when important omitted variables are not controlled for. Finally, five-fold cross-validation is implemented for the full model to assess out-of-sample predictive performance as well as the stability of coefficient estimates across sub samples.

5. Regression results

Table 2 reports all model estimates.

Table 2. Regression results

Variable	R&D No TPU	R&D With TPU	Patents No TPU	Patents With TPU	R&D Tariff-Only	Patents Tariff-Only
Constant	-1.7735	-1.7735	-11.9121	-11.9121	19.940	7.353
TPU_per_10k	—	-0.0594	—	-0.0189	—	—
Export Tariff	4.2202	4.2202	-7.4759	-7.4759	21.611	6.269
Import Tariff	-0.4391	-0.4391	20.0097	20.0097	-31.288	-15.770
ln(Income)	0.4777	0.4777	0.8370	0.8370	—	—
ln(Profit)	0.1036	0.1036	0.3203	0.3203	—	—
ln(Size)	0.3197	0.3197	-0.3533	-0.3533	—	—
Leverage	1.1781	1.1781	1.2516	1.2516	—	—
Assets	≈ 0	≈ 0	0.0000	0.0000	—	—
R^2	0.8643	0.8643	0.7199	0.7199	0.196	0.030
Adj. R^2	0.8611	0.8611	0.7134	0.7134	—	—
Obs	308	308	308	308	308	308

Table 2 reports regression results for all model specifications. Columns (1) and (3) report results for the baseline models without trade policy uncertainty and columns (2) and (4) with the addition of the TPU index. Columns (5) and (6) report the tariff-only specifications that exclude firm level controls. Both tariffs and TPU are statistically insignificant in the full models, while ln(Size) and ln(Profit) are both consistently and strongly associated with innovation. By contrast, tariff-only regressions generate very large coefficient estimates but extremely low R2 values, meaning tariffs

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explain almost none of the variation in innovation. These results illustrate omitted-variable bias: apparent tariff effects disappear once firm characteristics are controlled for, confirming that innovation is largely determined by firm fundamentals. On the more substantive side, the size of the estimated coefficients on the firm fundamentals (e.g. an increase of 10% in firm size) in absolute terms suggest that they are a significant driver of R&D and patenting activity compared to policy variables.

6. Cross-validation analysis

6.1. Cross-validation for coefficient stability

Table 3. Five-fold cross-validation mean squared errors

Fold	MSE (R&D)	MSE (Patents)
1	0.357	0.322
2	0.042	0.308
3	0.213	0.497
4	1.219	1.406
5	0.092	0.218
Average	0.385	0.550

The purpose of cross-validation here is not forecasting, but to evaluate the robustness and stability of coefficient estimates across sub samples.Cross-validation results are shown in Table 3.

6.2. Coefficient stability

Cross-Validation Coefficients (ln(R&D))

Table 4. Cross-validation coefficients for ln(R&D)

Variable	Fold 1	Fold 2	Fold 3	Fold 4	Fold 5
const	-1.1333	0.146	-0.1921	2.4937	0.0732
tariffexp	1.7216	-1.3784	-6.4729	-1.1831	-1.9665
tariffimp	4.2964	6.6593	14.2408	4.4757	7.0941
tpuper10k	-0.07	-0.0606	-0.0767	-0.0003	-0.0631
ln_income	-0.0	0.0	0.0	0.0	0.0
ln_profit	0.0714	0.0585	0.0401	0.1066	0.0669
ln_size	0.8099	0.7467	0.7833	0.6025	0.7354
leverage	-0.1189	0.7593	0.9612	1.0042	0.9594
assets	0.0	0.0	0.0	0.0	0.0

Cross-Validation Coefficients (ln(Patents))

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Table 5. Cross-validation coefficients for ln(Patents)

Variable	Fold 1	Fold 2	Fold 3	Fold 4	Fold 5
const	-6.32	-7.3787	-6.9633	-8.0033	-6.7546
tariffexp	-3.4344	-2.3832	-4.4219	-2.3515	-2.6631
tariffimp	5.7946	3.4382	6.3332	-3.1489	3.524
tpuper10k	0.0011	0.0089	0.0054	-0.083	-0.0041
ln_income	-0.0	0.0	0.0	-0.0	0.0
ln_profit	0.2109	0.262	0.2363	0.0905	0.2309
ln_size	0.343	0.3395	0.3451	0.5546	0.3428
leverage	0.0415	-0.0336	0.1512	-0.096	0.0509
assets	0.0	0.0	0.0	0.0	0.0

Coefficient estimates are reported in Table 4 and Table 5.Coefficient estimates are calculated for each fold and then compared across folds to assess stability. The coefficients on ln(Size) and ln(Profit) are more stable across sub samples, which means that firm fundamentals are robust predictors of innovation. In contrast, the coefficients on TPU_per_10k, Export Tariff, and Import Tariff vary more substantially, which is consistent with our expectation that these policy-related variables are weaker and less stable in their explanatory power.

7. Discussion

Overall, the evidence suggests that the expansion of innovation in China is more attributable to firm-level fundamentals rather than to trade policy uncertainty. While China's aggregate indicators (R&D investment, patent activity) are still increasing at a breakneck speed, this average upward trend across all firms is not reflected by a robust correlation between trade policy uncertainty and firm-level innovation outcomes. In all specifications, the coefficient on trade policy uncertainty is not statistically significant, suggesting that shocks to policy sentiment alone does not seem to have a direct bearing on firm's choices to engage in R&D or patenting.

Tariff exposure is first found to be (positively) associated with innovation in initial results when firm-level controls are not included. However, this association drops to zero and is no longer significant once we include firm size, profitability, and financial constraints in the regressions. This suggests that the original findings were an artifact of omitted-variable bias. Larger and more profitable firms are both more likely to be internationally traded and to be innovators. When differences in firm characteristics are not taken into account, this confounds measures of international exposure with innovation. Once this is controlled for, tariffs do not have a significant explanatory effect.

In contrast, firm size and profitability are the most consistent predictors of innovation. Firms with larger financial capacity are better able to invest in long-term research and bear risk, which explains why they systematically outperform smaller firms in both R&D spending and patent output. The cross-validation results provide further confirmation of this conclusion, as models that use firm characteristics perform much better than those based on policy variables. Taken together, the findings suggest that internal firm conditions matter more for innovation than short-run trade policy uncertainty such as tariffs or the U.S.-China trade conflict.

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However, it is also worth considering one reason that trade policy uncertainty plays a relatively minor role in this exercise could be that firms accommodate uncertainty through means other than innovation. For instance, prior work finds that uncertainty can influence exports, sourcing, or market entry without necessarily affecting R&D or patenting. Moreover, the effects of trade policy uncertainty could be more pronounced for those industries/firms that are more exposed to the global economy, while the wider sample in this paper is primarily driven by firm-level characteristics determining innovation capacity.

8. Conclusion

The investigation of the impact of trade policy uncertainty and tariff exposure on firm-level innovation in China turned out to be enlightening. Estimating the effect of these factors using firm-year data and multiple empirical specifications, we find no evidence of a direct and robust association between trade policy uncertainty or tariffs and innovation once controlling for firm characteristics. Although point estimates from tariff-only regressions are large, coefficients on these measures are close to zero and statistically insignificant once firm size, profitability, and other fundamentals are controlled for, which is consistent with omitted-variable bias. In contrast, firm-level characteristics, especially size and profitability, are strongly and robustly associated with both R&D and patenting. Cross-validation analysis also shows that firm fundamentals have stable coefficients across sub samples, whereas coefficients on the policy variables do not. Taken together, these results are consistent with firm conditions, and not short-run changes in trade policy uncertainty, as the primary drivers of innovation.

These results carry some interesting policy and research implications. On the one hand, from a policy point of view, our results suggest that policy measures that directly aim to improve firm capabilities and financial conditions are likely to have a higher impact on innovation, compared to efforts to reduce trade policy uncertainty. On the other hand, from a research perspective, our findings also highlight the importance of considering firm heterogeneity when assessing the effects of an external shock to innovation, while further study in the future can focus on exploring the relationship between international trade and innovation, such as whether long-term trade embargoes (rather than short-term policy uncertainties) encourage greater autonomous innovation, or whether different industries are affected differently by trade policies and innovation capabilities. The present study is not without limitations. The most important of these is the relatively small sample size that constrains statistical power and potentially conceals heterogeneous effects across industries. Moreover, the study is centered on short- to medium-term policy uncertainty; longer-term trade disruption or the emergence of persistent trade barriers may play out differently for innovation. Together, these limitations temper the generalization of the findings and they open up important directions for future research.

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