KIEL CENTRE FOR GLOBALIZATION

KCG Working Paper

Technological Sophistication Made in China? – New Insights from Germany's Evaluation of COVID-19 Antigen Rapid Tests

Silas Dreier and Wan-Hsin Liu

No. 30 | November 2023

Technological Sophistication Made in China? – New Insights from Germany's Evaluation of COVID-19 Antigen Rapid Tests

Silas Dreier and Wan-Hsin Liu

Abstract: By analyzing a unique dataset from Germany's evaluation of COVID-19 antigen rapid tests, we show that Chinese firms can excel under today's global competition and produce tests at quality levels higher than China's income level would suggest. We find these achievements are positively associated with China's rising innovation capability and robust industrial base. Further strengthening China's innovation and industrial base to support Chinese firms' future accomplishments is what the Chinese government clearly aims for. This would intensify the challenges facing Western economies that strive for technological sovereignty and eagerly seek to de-risk their economic relations with China.

Keywords: China, product quality, technological sophistication, trade, COVID-19

JEL Classification: F10, O10, O30

Silas Dreier
University of Würzburg and
Kiel Institute for the World Economy
Kiellinie 66
D24105 Kiel, Germany
Email: silas.dreier@ifw-kiel.de

Wan-Hsin Liu (corresponding author)
Kiel Institute for the World Economy and
Kiel Centre for Globalization
Kiellinie 66,
D24105 Kiel, Germany
Email: wan-hsin.liu@ifw-kiel.de

Acknowledgement: This is a working paper version of the article that is accepted for publication in Economics Bulletin. We would like to thank the editors and the reviewer for their very helpful comments. We want to thank Micha C. Nübling from the Paul-Ehrlich-Institut for sharing valuable background information related to the PEI evaluation study. We are also grateful to Frank Bickenbach, Eckhardt Bode, Robert Gold, Holger Görg, Cecília Hornok, Markus Pape and participants at the Kiel China Initiative Workshop on Aug. 24, 2022, for their helpful comments and suggestions.

About the Kiel Centre for Globalization (KCG): KCG, initiated by Christian-Albrechts University of Kiel and Kiel Institute for the World Economy, works on an interdisciplinary research agenda that evaluates the proliferation of global supply chains as an important aspect of globalization. To this end, KCG brings together researchers from economics, ethics and management science. More information about KCG can be found here: www.kcg-kiel.org.

1 Introduction

In the current geopolitical competition, China and the United States (US) race to out-innovate each other in the critical technologies they provide to the world. While the US leads in multiple regards, studies using product-level trade data already postulate that the technological sophistication of Chinese exports has increased over time. China's technological sophistication level is also found to be higher than what its income level would suggest (e.g., Rodrik 2006; Schott 2008).

However, using product-level trade data for analyzing technological sophistication has two main weaknesses. First, they are not value-added export data. An increase in technological sophistication of Chinese exports may just be a result of China's successful processing trade (Amiti and Freund 2010; Girma and Görg 2021; Xing and Detert 2010), where foreign firms have played an important role (Xu and Lu 2009).

Second, the product categories of trade data, even in HS 10-digit, are broadly defined. Same-category products can still differ in characteristics, including quality. Although several attempts utilize product prices to better proxy quality (e.g., Schott 2004; Xu 2010; Hallak and Schott 2011; Khandelwal et al. 2013), the problem cannot be fully solved since product prices can be affected by factors other than quality (e.g., Kneller and Yu 2016; Lin et al. 2021).

This means that measuring technological sophistication in exports based on trade data cannot appropriately reflect product quality. To help fill this gap, our paper presents evidence on quality in Chinese exports based on the example of COVID-19 antigen rapid tests (Ag-RTs). In an age where technology defines geopolitics (Schmidt 2023), accurately grasping the quality of Chinese exports is crucial for assessing China's capabilities in technological competition.

The remainder is structured as follows: Section 2 introduces the data. Section 3 presents the empirical analysis and results. Section 4 concludes.

2 Data

Our analysis is based on a unique dataset from a systematic and objective evaluation of Ag-RTs carried out by the German Paul-Ehrlich-Institut (PEI), an official agency of the German Federal Ministry of Health (PEI 2022). The PEI randomly selected Ag-RTs from a list of tests officially approved for the German market for evaluation using uniform virus sample sets.

We focus on Ag-RTs and this dataset for four reasons. First, the development and production of COVID-19 Ag-RTs, which did not exist before the pandemic, require a specific level of technological sophistication.[1] Second, China shared the genetic sequence of COVID-19 with the World Health Organization as early as January 2020, enabling global access to the key information for developing diagnostic kits (WHO 2020). All firms wishing to serve the enormous market demand thus had similar

[1] The first general-use COVID-19 antigen test was approved for US emergency use in May 2020 (Hahn 2020). In late 2020, Christian Drosten, a leading German virologist whose team also tried to develop a detection test, dubbed antigen tests an "extreme breakthrough in diagnostics" for their rapid results (Frisch 2020).

challenges and time to develop the tests. Third, the focus of the dataset on one sales market, Germany, reduces the targeted market bias in product quality. Fourth, as the evaluation directly measures quality in terms of test sensitivity,[2] neither a price factor nor subjective consumer preferences influence the quality assessment.

Besides the total sensitivity, the PEI tested the sensitivity of each Ag-RT under evaluation with virus sample pools with Quantification Cycle values (Cq values) ≤25, between 25-30, and ≥30, respectively. The Cq values are lower in samples with higher viral loads. Ag-RTs generally perform better when the viral load is high (Pavia and Plummer 2021). The PEI evaluation also indicates whether tests could detect the then-latest COVID-19 variant, Omicron.

Until May 30, 2022, the PEI evaluated 252 Ag-RTs. 204 of them (81%) passed the minimum sensitivity criterion defined as 75% sensitivity for using the sample pools with Cq ≤25 for evaluation (hereafter: "good" tests). Among them, 77% (158 tests) can detect the Omicron variant ("top" tests).

The PEI evaluation results also provide the test name, id, and manufacturer name. Using these, we traced the manufacturers' home countries. For Chinese firms, we additionally traced home provinces and gathered information on firm ownership, founding year, and type of firm (manufacturing or trading firm).

3 Empirical analysis and results

Of the 252 evaluated tests, 159 are from China (63%).[3] The share of Chinese tests among the "good" tests (67%) is statistically significantly larger than the share of Chinese tests among those below the minimal sensitivity criterion (48%). China even accounts for 69% of the "top" tests, significantly larger than China's share of non-top tests (53%).

Considering the fact that 18 of the 21 sourcing economies (86%) of the 252 evaluated tests are advanced economies and they are responsible for 84% of non-Chinese tests, the findings above suggest that the quality (sensitivity) of the Ag-RTs from China should be higher than what would be expected from China's income level.

We study this by estimating a fractional probit regression model since the test sensitivity, our direct product quality measure, is a bounded variable with values from 0 to 1 (0-100%). Following Schott (2008) and Xu (2010), we consider two covariates for the estimation: GDPpc and CN_dm, with the former referring to the GDP per capita in 2019 using constant prices and at purchasing power parity for the home country of the test and the latter being a China dummy. A brief description of the variables is presented in Table 1. Estimation results measured as average marginal effects / semi-

[2] Test sensitivity is a key performance index of Ag-RTs, referring to the percentage of cases positive by a standard PCR test that are detected also as positive by the Ag-RT under evaluation (WHO 2021).

[3] The share is not significantly different from the share of Chinese tests (66%) among all tests (ever) listed as reimbursable by the German Federal Institute for Drugs and Medical Devices (BfArM 2022; Version: May 26, 2022, plus tests not meeting the minimum criterium in the PEI evaluation and thus removed from the latest BfArM list).

elasticities on tests' total sensitivity[4] are presented in Table 2. Col. (1) is the baseline model. Col. (2) additionally considers a time dummy variable for the test (Testyr_dm) since the test sensitivity may generally rise over time.[5] Col. (3)-(4) use alternative GDPpc variables to better consider the income inequality within countries, particularly in China for robustness checks.[6] Col. (5)-(6) consider the "good" and "top" tests, respectively.

[Table 1 about here]

Estimation results show that GDPpc and the China dummy are significantly and positively correlated with the Ag-RT's total sensitivity in all models. The test sensitivity increases by 0.149 with a 1% increase in GDP per capita.[7] It increases by 0.235 if the test is from China (Col. (2) as an example). The China effect on test sensitivity is here roughly equal to the effect caused by a 1.6% increase in GDP per capita.

Our results suggest a positive and significant China effect when looking at product quality directly without any price or market influence. Chinese firms can export such products with a sensitivity level higher than expected from China's income level.

[Table 2 about here]

What factors might affect the quality of the Ag-RTs from China is the next question that we try to explore by again estimating fractional probit regression models. As covariates, we consider the provincial income level (PGDPpc), industrial strength (IND), innovation capability (INNO), openness (EXP), and the average industrial firm size (INDENTSize) (Table 1). We also control for the test time dummy as above. Estimation results are presented in Table 3 with Col. (1) for the baseline model for all Chinese tests, and Col. (2)-(3) for the Chinese good and top tests, respectively. Col. (4)-(6) consider only the Chinese tests from Chinese domestic manufacturers[8] with Col. (5)-(6) focusing on their good and top tests.

Estimation results show that INV and INNO are significantly and positively associated with the total sensitivity of Chinese tests in all models. The test sensitivity increases by 0.028 with one percentage

[4] More concretely, marginal effects and semi-elasticities refer to changes in test sensitivity with one unit change and 1% change in explanatory variables considered, respectively.

[5] Only two evaluated tests are from 2022.

[6] As further robustness checks, we consider, in addition to the China dummy, country dummies for the US, Germany, South Korea and Turkey, respectively. These countries are ranked behind China according to their number of tests under PEI evaluation. Our findings are robust and the other country dummies are not found to be significant for the Ag-RT's total sensitivity. Moreover, we consider as alternative explanatory variable the test sensitivity with different virus sample pools for the baseline estimation. Results hardly change here either.

[7] Using GDPpc_top20p as alternative per-capita income variable leads to a similar relative increase in per-capita income for the majority of countries (mostly between 80% to 100%), changing the correlation between per-capita income levels and test sensitivity only slightly. As a result, the estimated semi-elasticities, i.e., change in test sensitivity by 1% increase in per-capita income, are not much different from that of the baseline model.

Using GDPpc_cneast as our second alternative per-capita income variable means a higher level of per-capita income for China considered in the regressions with the income level for other countries left unchanged. This makes the high test quality for Chinese tests less striking given its now higher per-capita income level. This is reflected mainly in the reduction of the parameter for the China dummy – which remains statistically significant, however – allowing the parameter of the per-capita income variable to change only little.

[8] The 159 Chinese tests are provided by 139 Chinese firms, of which 122 are domestic manufacturers, 11 are manufacturers with foreign stakes, and 6 are domestic trading firms (PEI 2022; Baidu 2023).

point increase in the industrial share of GDP and by 0.391 when the number of invention patent applications per billion (RMB) of GDP increases by 1% in the baseline model (Col. (1)).[9] Results of other province-specific characteristics, including the provincial income level, openness, and industrial entities' average size, are not significant or not robust.

[Table 3 about here]

4 Conclusions

Analyzing the unique dataset from Germany's evaluation of COVID-19 Ag-RTs shows that Chinese firms can develop and produce technologically sophisticated new products under today's global competition. Moreover, they can do so with a product quality exceeding that suggested by China's income level. China's success in providing Ag-RTs of higher quality is found to be strongly associated with its home province's industrial strength and innovation capability.

Naturally, the development and production process of COVID-19 Ag-RTs is technologically less sophisticated than that of COVID-19 vaccines. Nevertheless, the development of Ag-RTs was considered a major breakthrough in diagnostics. Our analysis using a direct "quality" measurement without price or market bias thus provides additional evidence reiterating the relative technological sophistication of Chinese exports. Our results not only show that Chinese firms are highly capable of producing technologically advanced products like Ag-RTs but that they can do so at a comparatively high quality.

The Ag-RT case demonstrates China's current achievements in catching up technologically. Combining rising innovation capabilities with a robust industrial base enables Chinese firms to provide technologically sophisticated products, and they do so, in general, at lower prices. Further developing such a strong industrial and innovation base to support Chinese companies' future accomplishments is what the Chinese government clearly aims for, in order to strengthen its leading position as an export nation. Together, this would intensify the challenges facing Western economies that strive for technological sovereignty and eagerly seek to de-risk their economic relations with China.

[9] We run several robustness checks by (1) using the GDP for the whole secondary industry, including the construction sector in addition to the mining sector, manufacturing sector and the sector of electricity, gas and water production and supply, as base to measure the industrial strength and the average size of industrial firm, (2) using total patent applications to measure innovation capability, (3) using total non-invention patent applications to measure innovation capability, (4) using the average GDPpc of neighboring provinces to measure the provincial income level and (5) controlling for the founding year of the firm in addition. The positive and significant findings for the province-level industrial strength (IND) and innovation capability (INNO) for the AG-RT's total sensitivity are robust. Moreover, we consider as alternative explanatory variable the test sensitivity with different virus sample pools for the baseline estimation. Results hardly change here either.

References

Amiti, M., and C. Freund (2010). The Anatomy of China's Export Growth. In *China's Growing Role in World Trade* by J. Feenstra and S.-J. Wei, Eds., University of Chicago Press: Chicago, pp. 35–56.

Baidu (2023). Aichicha – Professional Firm Search Platform (Accessed: September 2022 – April 2023).

BfArM, Bundesamt für Arzneimittel und Medizinprodukte (2022). Antigen-Tests auf SARS-CoV-2, die Gegenstand des Anspruchs nach §1 Satz 1 Coronavirus-Testverordnung (TestV) sind (Accessed: June 28, 2022).

DGBAS, Directorate-General of Budget, Accounting and Statistics from Taiwan (2020-2022). *Report on the Survey of Family Income and Expenditure 2019-2021*, DGBAS: Taipei.

Frisch, J. (2020). Die Krux der hilfreichen Corona-Antigen-Schnelltests. *ÄrzteZeitung* (Accessed: October 31, 2022).

Girma, S., and H. Görg (2021). Productivity Effects of Processing and Ordinary Export Market Entry: A Time-varying Treatments Approach. *Review of International Economics* 30(3): 836–853.

Hahn, S.M. (2020). Coronavirus (COVID-19) Update: FDA Authorizes First Antigen Test to Help in the Rapid Detection of the Virus that Causes COVID-19 in Patients. *FDA Statement* (Accessed: October 31, 2022).

Hallak, J.C., and P.K. Schott (2011). Estimating Cross-country Differences in Product Quality. *Quarterly Journal of Economics* 126(1): 417–474.

IMF, International Monetary Fund (2022). World Economic Outlook Database – GDP per capita (Accessed: October 31, 2022).

Khandelwal, A.K., P.K. Schott and S.-J. Wei (2013). Trade Liberalization and Embedded Institutional Reform: Evidence from Chinese Exporters. *American Economic Review* 103(6): 2169–2195.

Kneller, R., and Z. Yu (2016). Quality Selection, Sectoral Heterogeneity and Chinese Exports. *Review of International Economics* 24(4): 857–874.

Lin, Y., S. Lin, X. Wang and J. Wu (2021). Does Institutional Quality Matter for Export Product Quality? Evidence from China. *The Journal of International Trade & Economic Development* 30(7): 1077–1100.

NBSC, National Bureau of Statistics China (2020). China Statistical Yearbook 2020 (Accessed: March 1, 2023).

PEI, Paul-Ehrlich-Institut (2022). Vergleichende Evaluierung der Sensitivität von SARS-CoV-2-Antigenschnelltests / Comparative Evaluation of the Sensitivities of SARSCoV-2 Antigen Rapid Tests (Accessed: July 15, 2022).

Pavia, C.S., and M.M. Plummer (2021). The Evolution of Rapid Antigen Detection Systems and Their Application for COVID-19 and Other Serious Respiratory Infectious Diseases. *Journal of Microbiology, Immunology and Infection* 54(5): 776–786.

Rodrik, D. (2006). What's so Special about China's Exports?. *China & World Economy* 14(5): 1–19.

Schott, P.K. (2008). The Relative Sophistication of Chinese Exports. *Economic Policy* 23(53): 5–49.

Schott, P.K. (2004). Across-product versus Within-product Specialization in International Trade. *Quarterly Journal of Economics* 119(2): 647–678.

Schmidt, E. (2023). Innovation Power. *Foreign Affairs* 102(2): 38–52.

WHO, World Health Organization (2020). COVID-19 – China (Accessed: January 10, 2023).

WHO (2021). Antigen-detection in the Diagnosis of SARS-CoV-2 Infection (Accessed: January 10, 2023).

World Bank (2023). World Development Indicators – Income Share held by highest 20% (Accessed: March 1, 2023).

Xing, Y., and N. Detert (2010). How the iPhone widens the United States trade deficit with the People's Republic of China. ADBI Working Paper 257. Asian Development Bank Institute: Tokyo.

Xu, B. (2010). The Sophistication of Exports: Is China Special?. *China Economic Review* 21(3): 482–493.

Xu, B., and J. Lu (2009). Foreign Direct Investment, Processing Trade, and the Sophistication of China's Exports. *China Economic Review* 20: 425–439.

Table 1. Description and basic statistics of key variables

Variable	Description	Mean	Std. Dev.	Min.	Max.	Obs.
Sensitivity[1]						
Sen_tt	Total sensitivity	0.50 (0.53)	0.25 (0.24)	0 (0)	1 (1)	252 (159)
Sen_Cq≤25	Sensitivity with sample pools with Cq≤25	0.84 (0.87)	0.28 (0.26)	0 (0)	1 (1)	252 (159)
Sen_Cq25-30	Sensitivity with sample pools with Cq between 25-30	0.40 (0.44)	0.34 (0.35)	0 (0)	1 (1)	252 (159)
Sen_Cq≥30	Sensitivity with sample pools with Cq ≥30	0.08 (0.09)	0.19 (0.21)	0 (0)	1 (1)	252 (159)
Omicron[1]	Test being able to detect Omicron variant (1) or not (0)	0.63 (0.69)	0.48 (0.47)	0 (0)	1 (1)	252 (159)
GDPpc[2]	Country-level GDP per capita, 2019, constant price at purchasing power parity (international dollar)	27396	16774	10132	70662	252
China_dm	Test from China (1) or not (0)	0.63	0.48	0	1	252
GDPpc_top20p[3]	Country-level GDP per capita for the top 20% earners, 2019, constant price at purchasing power parity (international dollar)	59065	34168	21733	146681	252
GDPpc_cneast[24]	For China: GDPpc for the Chinese eastern region (international dollar) Other countries: GDPpc	30852	14442	10132	70662	252
Testyr_dm[1]	Test approved in 2020 (0) or later (1)	0.53 (0.62)	0.50 (0.49)	0 (0)	1 (1)	252 (159)
PGDPpc[5]	GDP per capita, 2019, current price (RMB), Chinese province-level	(106509)	(28771)	(43578)	(164212)	(159)
IND[5]	Industrial share of GDP (%), Chinese province-level	(32.76)	(8.16)	(11.99)	(38.14)	(159)
INNO[5]	Number of invention patent applications per billion (RMB) GDP, Chinese province-level	(18.31)	(7.93)	(5.58)	(36.73)	(159)
EXP[5]	Export to GDP ratio (%), Chinese province-level	(27.51)	(14.97)	(3.10)	(46.13)	(159)
INDENTSize[5]	Average industrial GDP size per industrial entity, Chinese province-level (million RMB)	(8.92)	(4.41)	(4.84)	(18.34)	(159)

Notes: [1]from PEI (2022). [2]from IMF (2022). [3]calculated based on IMF (2022), World Bank (2023), and DGBAS (2020-2022). [4]calculated based on IMF (2022) and NBSC (2020). [5]calculated based on NBSC (2020). Numbers in parentheses in the table are for Chinese tests only.

Table 2. Estimation results for total sensitivity: Average marginal effects / semi-elasticities

	(1)	(2)	(3)	(4)	(5)	(6)
	All	All	All	All	All Good	All Top
GDPpc	0.147***	0.149***			0.126***	0.116**
	(0.054)	(0.055)			(0.042)	(0.045)
China_dm	0.255***	0.235***	0.233***	0.205***	0.171***	0.142**
	(0.064)	(0.067)	(0.065)	(0.058)	(0.051)	(0.059)
Testyr_dm		0.090***	0.087***	0.090***	0.085***	0.083***
		(0.029)	(0.029)	(0.029)	(0.024)	(0.027)
GDPpc_top20p			0.157***			
			(0.057)			
GDPpc_cneast				0.167***		
				(0.062)		
Obs.	252	252	252	252	204	158
Wald Chi2	17.62***	24.53***	25.16***	24.53***	26.18***	15.60***

Notes: Results for China_dm and Testyr_dm are marginal effects, i.e., change in total sensitivity with one-unit change (from zero to one) in the respective dummy variable. Results for GDPpc, GDPpc_top20p and GDPpc_cneast are semi-elasticities, i.e., change in total sensitivity with 1% increase in the per-capita income variable considered. Fractional probit regression models with robust estimator of variances are estimated. All explanatory variables are country-level data except for the test-level “Testyr_dm” variable. *** p<0.01, ** p<0.05, * p<0.1. Numbers in parentheses are delta-method standard errors.

Table 3. Estimation results for total sensitivity: Average marginal effects / semi-elasticities (For Chinese tests only)

	(1)	(2)	(3)	(4)	(5)	(6)
	CN	CN Good	CN Top	CN	CN Good	CN Top
PGDPpc	-0.121	-0.091	-0.040	-0.094	-0.057	-0.005
	(0.120)	(0.093)	(0.106)	(0.127)	(0.097)	(0.106)
IND	0.028***	0.019***	0.018***	0.026***	0.018***	0.016***
	(0.007)	(0.006)	(0.006)	(0.007)	(0.006)	(0.006)
INNO	0.391***	0.266***	0.229**	0.362***	0.235**	0.193**
	(0.113)	(0.091)	(0.099)	(0.119)	(0.091)	(0.098)
EXP	-0.004*	-0.002	-0.003	-0.004*	-0.002	-0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
INDENTSize	0.193**	0.130**	0.087	0.161*	0.100	0.057
	(0.084)	(0.065)	(0.074)	(0.086)	(0.065)	(0.072)
Testyr_dm	0.129***	0.124***	0.115***	0.102***	0.102***	0.093***
	(0.035)	(0.028)	(0.031)	(0.038)	(0.030)	(0.033)
Focus on tests from CN domestic manufacturers	No	No	No	Yes	Yes	Yes
Obs.	159	136	109	139	118	96
Wald Chi2	25.63***	28.30***	21.56***	20.04***	22.28***	17.83***

Notes: Results for IND, EXP and Testyr_dm are marginal effects, i.e., change in total sensitivity with one percentage point increase in industrial share of GDP, one percentage point increase in Export-to-GDP ratio, and a one-unit change from zero to one in the test year dummy variable, respectively. Results for PGDPpc, INNO and INDENTSize are semi-elasticities, i.e., change in total sensitivity with 1% increase in the provincial per-capita GDP, in number of invention patent applications per billion GDP, in average industrial size per entity, respectively. Fractional probit regression models with robust estimator of variances are estimated. All explanatory variables are province-level data except for the test-level "Testyr_dm" variable. *** p<0.01, ** p<0.05, * p<0.1. Numbers in parentheses are delta-method standard errors.