GTAP Trade Policies Simulations: When Does "Firm Heterogeneity" Need to be Considered?

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1. The Effects of Firm Heterogeneity in Trade Policy

1.1 Policy Effects of "Firm Heterogeneity" Vary Theoretically

Melitz (2003) set up a trade model of firm heterogeneity incorporating firm-level productivity differences where firms enter an industry when their productivity is above a threshold value and then become exporters when their productivity is higher than an another threshold, also known as the endogenous selection of heterogenous firms.

Although the firm heterogeneity trade model helps understand many micro firm-level behaviours, Arkolakis et al. (2012) believed that firm heterogeneity implications had little impact on aggregate welfare gain, and that only two macro variables are sufficient: the share of total expenditure on domestic goods and the elasticity of imports with respect to trade costs[1]. Therefore, they argued welfare changes from trade policy could be calculated based on the estimates of the above two statistics alone, summarizing the firm heterogenous was 'not much' different than the firm homogeneity in terms of explaining welfare gains.

Since the welfare equations of Arkolakis et al. (2012) (ACR) were confined to three macro-level restrictions, Melitz and Redding (2015) moved beyond these parameter restrictions and extended the ACR's approaches, noting that welfare gains in firm heterogeneity model are not only affected by domestic trade share and trade elasticity, also prone to production and trade costs on micro structure. Small departures as such

[1] *Welfare is defined as a function of real income. To simplify the analysis, the wage is numeriare to 1. Welfare becomes a function of a country's overall price level and then a function combining the price of domestic goods and imports (a function of labour and trade cost) through the elasticity of imports, as price changes of domestic goods and imports are reflected in the share of expenditure on domestic goods and imports.*

would affect the number of firms engaged in production and export in an economy, underscoring the endogenous selection of heterogenous firm model would have a substantial impact on aggregate welfare gains. Compared with homogeneous firm model, they concluded that in heterogenous firm model, more firms would export for the case of reductions in trade costs, implying greater welfare gains, whereas increases in trade costs would make fewer firms export, but also incurred fewer additional trade costs, implying smaller welfare losses.

1.2 Is it Necessary to Incorporate "Firm Heterogeneity" into Trade Policy Practice?

In general trade policy practices, "firm heterogeneity" is reflected by a firm's behaviours at the micro level, namely the impact of firm entry and exit on policy effectiveness, especially on welfare. The practice of trade policies raises two noteworthy questions:

(i) Would all trade policies affect firm entry and exit, or only particular trade policies would?

(ii) Is there a threshold value defining the impact of trade policies on firm entry and exit? In other word, to what extent will trade policies start affecting firm entry and exit?

1.3 Research Question in This Paper

GTAP model has been widely applied in trade policy simulation. The standard GTAP model (Hertel and Tsigas, 1997; Corong et. al, 2017) has matured after decades of development. Akgul et al. (2016) introduced "firm heterogeneity" based on the standard GTAP model and developed the GTAP-HET model. Thus, when GTAP model is employed to analyse trade policies, the same problem would arise: for which policy simulation, the standard GTAP model could solve the problem, which would be necessary to include the GTAP-HET model, so as to be able to grasp the effect of firm heterogeneity?

This paper intended to employ both standard GTAP model and the GTAP-HET model, to simulate tariff and non-tariff policies separately, and to answer above question through comparative analysis.

2. GTAP Model: Amington v.s. Firm Heterogeneity

3. Scenarios and Data

As of July 2018, the United States has imposed a 25% tariff on part of Chinese products – as punitive measures on Chinese products based on the decisions of the "Section 301 investigation". As U.S. and China placed retaliatory tariffs on more goods, some multinational companies had to reschedule production network, close down parts of plants located in China, and shift overseas. This changing process is a typical example of how firms' behaviour reacted to the trade policy.

This paper will focus on this aspect and analyse the impact of firm behaviours on the effectiveness in the implementation of trade policies. Scenarios analyses are conducted based on three conditions:

(i) To simplify the analysis, this paper divided the manufacturing industry into light manufactures, technology-intensive manufactures and other manufactured products (refer to Table 2 for specific industry division);

(ii) Tariffs levied by the U.S. on Chinese products are all set to 25%, and 10% would be set in the robustness analysis;

(iii) To analyse the impact of "firm heterogeneity" on policy simulations, this paper also set scenarios for comparison to reflect the differences between tariff policies and non-tariff policies when "firm heterogeneity" is introduced.

Specific data and scenarios are as follows:

3.1 Data

3.1.1 Basedata

Based on the aforementioned analysis, basedata from GTAP Data Base (Version 10) were divided into 13 economies and 6 economic sectors in this paper. Specific division is as follows:

Table 1: Division of Economies

Economy	ASEAN	Australia	Canada	China	EU (27)	Japan	Rest of World
	South Korea	Mexico	New Zealand	Switzerland	the United Kingdom	the United States	

Source: data organized in accordance with GTAP 10 Data Base.

Table 2: Division of Economic Sectors

Economic Sector	GTAP Classification No.	Market Structure
Agriculture, forestry and fishing	No.1-14	Perfectly competitive
Mining and quarrying	No.15-18	Imperfectly Competitive
Light-Manufactures	No.19-31、35、36	Perfectly Competitive
Tech-intensive Manufactures	No.34, 40, 42-44	Imperfectly Competitive
Other Manufactured Products	No.32, 33, 37-39, 41, 45	Perfectly Competitive
Service Industry	No.46-65	Perfectly Competitive

Source: data organized in accordance with GTAP 10 Data Base.

3.1.2 Parameters of "Firm Heterogeneity"

Referring to the standard GTAP model, the GTAP-HET model requires additional parameters, including: (i) the elasticity of substitution between varieties, *SIGMA*; and (ii) Shape parameter for Pareto distribution, *SHAPE*. Referring to Akgul et al. (2016) to determine these two parameters.

3.2 Scenarios

Scenario A: Tariff policies, would "firm heterogeneity" lead to significant differences in the effect of tariff policies in perfectly competitive sector?

A1. the U.S. imposed a 25% tariff on China's light industry (perfectly competitive) in GTAP-HET model (Melitz).

A2. the U.S. imposed a 25% tariff on China's light industry in standard GTAP model (Amington).

Scenario B: Tariff policies, would "firm heterogeneity" lead to significant differences in the effect of tariff policies in imperfectly competitive sector?

B1. the U.S. imposed a 25% tariff on China's tech-intensive industry (imperfectly competitive) in GTAP-HET model (Melitz).

B2. the U.S. imposed a 25% tariff on China's tech-intensive industry in standard GTAP model (Amington).

Scenario C: Non-tariff policies, would "firm heterogeneity" lead to significant differences in the effect of non-tariff policies in perfectly competitive sector?

C1. the production costs of China's light industry exporting to the U.S. increased by 25%

in GTAP-HET model (Melitz).
C2. the production costs of China's light industry exporting to the U.S. increased by 25% in standard GTAP model (Amington).

Scenario D: Non-tariff policies, would "firm heterogeneity" lead to significant differences in the effect of non-tariff policies in imperfectly competitive sector?
D1. the production costs of China's tech-intensive industry exporting to the U.S. increased by 25% in GTAP-HET model (Melitz).
D2. the production costs of China's tech-intensive industry exporting to the U.S. increased by 25% in standard GTAP model (Amington).

Scenario E: Non-tariff policies, the role of trade cost variables in GTAP-HET model.
E1. the set-up costs in tech-intensive industry exporting to the U.S. increased by 25% in GTAP-HET model (Melitz).
E2. the fixed trading costs of China's tech-intensive industry exporting to the U.S. increased by 25% in GTAP-HET model (Melitz).
E3. the production costs of China's tech-intensive industry exporting to the U.S. increased by 25% in GTAP-HET model (Melitz).

4. Major Simulation Results

4.1 The Overall Impact

4.1.1 The Role of "Firm Heterogeneity" in Tariff Policies

Scenario A: In standard GTAP model, the U.S. imposed a 25% tariff on China's light industry, reducing the real GDP of China and the U.S. by 0.04% and 0.08% respectively; China's total output increased by 0.09%, while that of the U.S. decreased by 0.01%; Merchandise exports of China and the U.S. decreased by 0.14% and 1.39% respectively, and merchandise imports decreased by 0.92% and 0.84%. In GTAP-HET model, the U.S. imposed a 25% tariff on China's light industry, increasing China's real GDP by 0.15% while decreasing that of the U.S. by 0.11%; China's total output increased by 0.09%, while that of the U.S. remained unchanged; merchandise exports of China and the U.S. decreased by 1.32% and 0.82% respectively, and merchandise imports decreased by 0.85% and 0.94%.

Scenario B: In standard GTAP model, the U.S. imposed a 25% tariff on China's tech-intensive industry, reducing the real GDP of China and the U.S. by 0.13% and 0.10% respectively; China's total output decreased by 0.01%, and that of the U.S. increased by 0.07%; merchandise exports of China and the U.S. decreased by 0.52% and 1.10% respectively, while merchandise imports decreased by 2.71% and 1.96%. In GTAP-HET model, the U.S. imposed a 25% tariff on China's tech-intensive industry, decreasing China's real GDP by 0.47% while increasing that of the U.S. by 0.08%; China's total output decreased by 0.15%, while that of the U.S. increased by 0.13%; merchandise exports of China and the U.S. decreased by 0.27% and 5.89% respectively, and merchandise imports decreased by 4.41% and 1.79%.

4.1.2 The Role of "Firm Heterogeneity" in Non-tariff Policies

Scenario C: In standard GTAP model, the production costs of China's light industry exporting to the U.S. increased by 25%, reducing the real GDP of China and the U.S. by 0.04% and 0.16% respectively; China's total output increased by 0.09%, and that of the U.S. increased by 0.01%; merchandise exports of China and the U.S. decreased by 0.16% and 1.11% respectively, and merchandise imports decreased by 0.96% and 0.79%. In GTAP-HET model, the production costs of China's light industry exporting to the U.S. increased by 25%, increasing China's real GDP by 0.16% while decreasing that of the U.S. by 0.18%; total output of China and the U.S. increased by 0.09% and 0.02% respectively; merchandise exports of China and the U.S. decreased by 1.38% and 0.71% respectively, and merchandise imports decreased by 0.89% and 0.87%.

Scenario D: In standard GTAP model, the production costs of China's tech-intensive industry exporting to the U.S. increased by 25%, reducing the real GDP of China and the U.S. by 0.13% and 0.19% respectively; China's total output decreased by 0.01%, while that of the U.S. increased by 0.10%; merchandise exports of China and the U.S. decreased by 0.58% and 0.55% respectively, and merchandise imports decreased by 2.83% and 1.95%. In GTAP-HET model, the production costs of China's tech-intensive industry exporting to the U.S. increased by 25%, decreasing China's real GDP by 0.47% while increasing that of the U.S. by 0.06%; China's total output decreased by 0.15%, while that of the U.S. increased by 0.14%; merchandise exports of China and the U.S. decreased by 0.25% and 5.97% respectively, and merchandise imports decreased by

4.48% and 1.75%.

Table 3: Comparison of Overall Results (1) %

Policies	Model	Economy	Shock in Perfectly Competitive Sector				Shock in Imperfectly Competitive Sector			
			Real GDP	Output	Exports	Imports	Real GDP	Output	Exports	Imports
Tariff Policies	Standard GTAP	China	-0.04	0.09	-0.14	-0.92	-0.13	-0.01	-0.52	-2.71
		U.S.	-0.08	-0.01	-1.39	-0.84	-0.10	0.07	-1.10	-1.96
	GTAP-HET	China	0.15	0.09	-1.32	-0.85	-0.47	-0.15	-0.27	-4.41
		U.S.	-0.11	0.00	-0.82	-0.94	0.08	0.13	-5.89	-1.79
Non-tariff Policies (production costs of export)	Standard GTAP	China	-0.04	0.09	-0.16	-0.96	-0.13	-0.01	-0.58	-2.83
		U.S.	-0.16	0.01	-1.11	-0.79	-0.19	0.10	-0.55	-1.95
	GTAP-HET	China	0.16	0.09	-1.38	-0.89	-0.47	-0.15	-0.25	-4.48
		U.S.	-0.18	0.02	-0.71	-0.87	0.06	0.14	-5.97	-1.75

Source: Authors' estimates.

4.1.3 The Role of Trade Cost Variables in GTAP-HET Model

Scenario E: In GTAP-HET model: (i) The set-up costs in tech-intensive industry exporting to the U.S. increased by 25%, increasing China's real GDP by 0.11%, while decreasing that of the U.S. by 1.22%; total output of China and the U.S. decreased by 0.12% and 0.33% respectively; China's merchandise exports decreased by 2.88%, while that of the U.S. increased by 17.78%; China's merchandise imports increased by 1.21%, while that of the U.S. decreased by 6.07%. (ii) The fixed trading costs of China's tech-intensive industry exporting to the U.S. increased by 25%, decreasing China's real GDP by 0.12%, while increasing that of the U.S. by 0.01%; China's total output decreased by 0.04%, while that of the U.S. increased by 0.03%; merchandise exports of China and the U.S. decreased by 0.09% and 1.47% respectively, and merchandise imports decreased by 1.10% and 0.44%. (iii) The production costs of China's tech-intensive industry exporting to the U.S. increased by 25%, decreasing China's real GDP by 0.47%, while increasing that of the U.S. by 0.06%; China's total output decreased by 0.15%, while that of the U.S. increased by 0.14%; merchandise exports of China and the U.S. decreased by 0.25% and 5.97% respectively, and merchandise imports decreased by 4.48% and 1.75%.

Table 4: Comparison of Overall Results (2) %

Variable	Set-up Costs		Fixed Trading Costs		Production Costs	
Economy	China	U.S.	China	U.S.	China	U.S.

Variable	Set-up Costs		Fixed Trading Costs		Production Costs	
Real GDP	0.11	-1.22	-0.12	0.01	-0.47	0.06
Total Output	-0.12	-0.33	-0.04	0.03	-0.15	0.14
Exports	-2.88	17.78	-0.09	-1.47	-0.25	-5.97
Imports	1.21	-6.07	-1.10	-0.44	-4.48	-1.75

Source: Authors' estimates.

4.2 Impacts on Sectors

4.2.1 Different Impact of "Firm Heterogeneity" on Sectors in Tariff Policies

Scenario A: In standard GTAP model, the U.S. imposed a 25% tariff on China's light industry, reducing its exports by 10.26%, imports by 2.48%, and output by 1.51%; accordingly, imports and exports of the U.S. light industry decreased by 7.55% and 1.90% respectively, while its output increased by 1.43%. In GTAP-HET model, the U.S. imposed a 25% tariff on China's light industry, reducing its exports by 13.05%, imports by 0.83%, and output by 1.99%; accordingly, imports and exports of the U.S. light industry decreased by 7.79% and 0.92% respectively, while its output increased by 1.54%.

Scenario B: In standard GTAP model, the U.S. imposed a 25% tariff on China's tech-intensive industry, reducing its exports by 9.40%, imports by 4.72%, and output by 2.60%; accordingly, imports and exports of the U.S. tech-intensive industry decreased by 6.02% and 2.60% respectively, while its output increased by 1.82%. In GTAP-HET model, the U.S. imposed a 25% tariff on China's tech-intensive industry, reducing its exports by 14.17%, imports by 6.84%, and output by 4.30%; accordingly, imports and exports of the U.S. tech-intensive industry decreased by 10.22% and 5.79% respectively, while its output increased by 4.44%.

4.2.2 Different Impact of "Firm Heterogeneity" on Sectors in Non-tariff Policies

Scenario C: In standard GTAP model, the production costs of China's light industry exporting to the U.S. increased by 25%, reducing its exports by 10.60%, imports by 2.60%, and output by 1.56%; accordingly, imports and exports of the U.S. light industry

decreased by 6.34% and 1.59% respectively, while its output increased by 1.72%. In GTAP-HET model, the production costs of China's light industry exporting to the U.S. increased by 25%, reducing its exports by 13.51%, imports by 0.86%, and output by 2.06%; accordingly, imports and exports of the U.S. light industry decreased by 6.39% and 0.99% respectively, while its output increased by 1.77%.

Scenario D: In standard GTAP model, the production costs of China's tech-intensive industry exporting to the U.S. increased by 25%, reducing its exports by 9.88%, imports by 4.93%, and output by 2.69%; accordingly, imports and exports of the U.S. tech-intensive industry decreased by 5.58% and 1.98% respectively, while its output increased by 2.37%. In GTAP-HET model, the production costs of China's tech-intensive industry exporting to the U.S. increased by 25%, reducing its exports by 14.38%, imports by 6.93%, and output by 4.39%; accordingly, imports and exports of the U.S. tech-intensive industry decreased by 10.28% and 5.70% respectively, while its output increased by 4.79%.

Table 5: Comparison of Sectoral Results (1) %

Policies	Model	Economy	Variable	Perfectly Competitive Sector			Imperfectly Competitive Sector		
				Light Industry	Tech-inten. Industry	Other Manu	Light Industry	Tech-inten. Industry	Other Manu
Tariff Policies	Standard GTAP	China	Output	-1.51	1.40	0.77	1.00	-2.60	1.00
			Export	-10.26	3.20	2.60	6.05	-9.40	5.88
			Import	-2.48	-0.80	-0.90	-3.03	-4.72	-2.68
		U.S.	Output	1.43	-0.86	-0.38	-0.14	1.82	-0.04
			Export	-1.90	-2.05	-1.11	-0.58	-2.60	-0.63
			Import	-7.55	0.52	0.33	0.55	-6.02	0.27
	GTAP-HET	China	Output	-1.99	2.30	0.24	1.60	-4.30	1.70
			Export	-13.05	4.25	-0.27	9.93	-14.17	10.03
			Import	-0.83	-2.46	0.38	-4.92	-6.84	-4.26
		U.S.	Output	1.54	-0.90	-0.17	-1.17	4.44	-1.72
			Export	-0.92	-1.79	-0.33	-7.57	-5.79	-6.68
			Import	-7.79	0.63	-0.02	4.35	-10.22	3.24
Non-tariff Policies	Standard GTAP	China	Output	-1.56	1.43	0.80	1.09	-2.69	1.08
			Export	-10.60	3.27	2.68	6.28	-9.88	6.13

Policies	Model	Economy	Variable	Perfectly Competitive Sector			Imperfectly Competitive Sector		
				Light Industry	Tech-inten. Industry	Other Manu	Light Industry	Tech-inten. Industry	Other Manu
			Import	-2.60	-0.83	-0.94	-3.15	-4.93	-2.81
		U.S.	Output	1.72	-0.74	-0.28	-0.05	2.37	0.17
			Export	-1.59	-1.71	-0.85	0.12	-1.98	-0.10
			Import	-6.34	0.31	0.19	0.17	-5.58	0.04
	GTAP-HET	China	Output	-2.06	2.38	0.24	1.66	-4.39	1.70
			Export	-13.51	4.38	-0.30	10.11	-14.38	10.22
			Import	-0.86	-2.58	0.40	-5.00	-6.93	-4.33
		U.S.	Output	1.77	-0.67	-0.14	-1.20	4.79	-1.75
			Export	-0.99	-1.46	-0.33	-7.77	-5.70	-6.85
			Import	-6.39	0.25	-0.01	4.46	-10.28	3.35

Source: Authors' estimates.

4.2.3 Different Impact of Trade Cost Variables on Sector in GTAP-HET Model

Scenario E: In GTAP-HET model: (i) The set-up costs 'in tech-intensive industry exporting to the U.S. increased by 25%, increasing its exports, imports and output by 1.27%, 0.92% and 1.00% respectively; accordingly, imports of the U.S. tech-intensive industry increased by 4.08% while its exports and output decreased by 13.22% and 13.40% respectively. (ii) The fixed trading costs of China's tech-intensive industry exporting to the U.S. increased by 25%, decreasing its exports, imports and output by 3.44%, 1.68% and 1.05% respectively; accordingly imports and exports of the U.S. tech-intensive industry decreased by 2.50% and 1.38% respectively while its output increased by 1.17%. (iii) The production costs of China's tech-intensive industry exporting to the U.S. increased by 25%, decreasing its exports, imports and output by 14.38%, 6.93%, and 4.39% respectively; accordingly, imports and exports of the U.S. tech-intensive industry decreased by 10.28% and 5.70% respectively while its output increased by 4.79%.

Table 6: Comparison of Sectoral Results (2) %

Model	Economy	Variable	Light Industry	Tech-intensive Industry	Other Manu
Set-up Costs	China	Output	-1.02	1.00	-1.11
		Export	-5.88	1.27	-6.34
		Import	2.37	0.92	1.47
	U.S.	Output	5.56	-13.40	9.09
		Export	42.90	-13.22	34.36
		Import	-17.56	4.08	-14.17
Fixed Trading Costs	China	Output	0.39	-1.05	0.40
		Export	2.36	-3.44	2.38
		Import	-1.23	-1.68	-1.06
	U.S.	Output	-0.29	1.17	-0.43
		Export	-1.94	-1.38	-1.70
		Import	1.05	-2.50	0.79
Production Costs	China	Output	1.66	-4.39	1.70
		Export	10.11	-14.38	10.22
		Import	-5.00	-6.93	-4.33
	U.S.	Output	-1.20	4.79	-1.75
		Export	-7.77	-5.70	-6.85
		Import	4.46	-10.28	3.35

Source: Authors' estimates.

5. Conclusions and Analysis of the Mechanism of "Firm Heterogeneity"

5.1 Under Same Policy: "Firm Heterogeneity" Plays A More Significant Role When Policy Shock is Imposed on Imperfectly Competitive Sectors

By comparing the simulation results, it is found that under same policy (either tariff or non-tariff policies), "firm heterogeneity" plays a more significant role in imperfectly competitive sectors than in perfectly competitive ones under policy shock – greater difference was observed in the simulation results between standard GTAP and GTAP-HET model. This conclusion holds true for both the overall impact and impacts on

different sectors. As far as current findings are concerned, this conclusion only applies to limited nominal variables, such as output, import and export volume, etc. As for the change of actual variables – for example, the impact on real GDP, a consistent conclusion has not yet been reached.

The mechanism underpinning the conclusion is that all sectors are perfectly competitive in standard GTAP model; however, in GTAP-HET model, the light industry in this paper is assumed as a perfectly competitive sector while the tech-intensive industry as an imperfectly competitive one. Hence, neither model is directly affected by "firm heterogeneity" when the light industry suffers policy shock, while GTAP-HET model is indirectly affected by "firm heterogeneity" within an incompletely competitive sector as a result of inter-sector input-output effect. When policy shock is imposed on the tech-intensive industry, GTAP-HET model is directly affected by "firm heterogeneity", while standard GTAP model does not have such mechanism, making the difference in simulation results between the two models greater than that in the policy-affected sector of perfect competition – namely, a more significant role for "firm heterogeneity".

5.2 Under Different Policies: No Significant Role of "Firm Heterogeneity" is Observed

By comparing the simulation results, it is found that the difference between simulation results under tariff policies and those under non-tariff policies (production cost of export) remains insignificant when "firm heterogeneity" is taken into account. That is to say, the difference between simulation results from two different models under tariff policies is not significantly larger (or smaller) than that under non-tariff policies. Similarly, this conclusion holds for both the overall impact and impacts on sectors, so does it for both perfectly and imperfectly competitive sector. In addition, this conclusion applies not only to nominal variables, also to the change of actual variables such as real GDP.

6. Suggestions on Model Application and Further Research

Based on the above analysis, no result has suggested the simulation under tariff (or non-tariff) policies is more suitable for standard GTAP model than GTAP-HET model; that is, the role of "firm heterogeneity" under different policies is not significantly different.

However, in policy-affected economic sectors of different market structure, it is found that the role of "firm heterogeneity" has a significant impact on the simulation results.

It is suggested to apply GTAP-HET model to observe the role of "firm heterogeneity" when policy shock – be it tariff policy or non-tariff policy – is imposed on sectors of imperfect-competition type. For example, the first product list from U.S. Section 301 mainly targets Chinese electronic products and mechanical equipment, of which are mainly from imperfectly competitive markets.

It is suggested to adopt standard GTAP model when policy shock is imposed on sectors of perfect-competition type because "firm heterogeneity" would not lead to significant difference in simulation results. Therefore, opting for a model with fewer parameters is helpful to observe the major changes, without wasting too much time on complicated model setting and calibration. For example, the third product list from U.S. Section 301 concentrates on Chinese clothing and other manufactured goods, of which are mainly from perfectly competitive markets.

The aforementioned conclusions are preliminary and based on simple simulation analysis only. The research itself is not thorough, thus requiring further study. It is authors' intention that more time and efforts should be spent in selecting applicable methodologies to study the research question, as more realistic factors would complicate research model. Meanwhile, different perspectives are required to further explore the research question in this paper in order to seek a more comprehensive solution. Besides, theoretical foundation and simulation approach also need to be further refined to advance the depth of research.

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