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The application of spatial models in the analysis of bilateral trade flows: An alternative to the Armington approach for the world sugar market

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Abstract

This paper suggests spatial models as an alternative to the Armington approach to model bilateral trade. While the use of spatial models has been accepted for decades, they are rarely chosen for such analyses. However, problems inherent in the application of the Armington approach can be overcome through the use of spatial models. To demonstrate, a simple spatial model of the world sugar market is built and used to simulate a multilateral liberalization scenario. Additionally, an identical model is constructed, applying the Armington approach. The results of the spatial model of the sugar market are found to be more plausible than those generated by the Armington-based model.

JEL classification: F11; F15; C69.

Keywords: bilateral trade, trade preferences, partial equilibrium models, Armington approach, sugar.

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1 Introduction

The Armington approach (ARMINGTON 1969) is used widely in models of international trade. It is currently the standard method to represent bilateral trade flows in such models. However, the assumption that the same types of goods from different countries or regions are imperfect substitutes, and the way this is incorporated into models, may lead to numerous severe difficulties. The objective of this paper is to specify the problems arising from the application of the Armington approach, to provide an overview of past efforts to cope with these problems, and to offer a possibility for their solution.

In Section 2, the drawbacks of the Armington approach are discussed, the most prominent of which is the "4S" (small shares stay small) property. Some recent attempts to overcome these drawbacks are surveyed, yet all of these approaches retained the assumption of imperfect substitutes. The application of spatial models, developed by TAKAYAMA AND JUDGE (1971), could be an alternative to address these problems. Unlike other approaches, the use of spatial models would release the imperfect substitutability assumption, which seems appropriate for many agricultural commodities, such as sugar. To test the applicability of this approach, a multi-country, single commodity model of the world sugar market is constructed, and a multilateral liberalization scenario is run. Sugar is chosen as a product for several reasons. Besides its prominent role in the current debate about agricultural trade liberalization, sugar is especially interesting for the purpose of this modeling effort. The results of the spatial model are presented in Section 3 and compared to results of a similar scenario run with an Armington-based model using the same base data and behavioral parameters. Section 4 resumes the discussion of Section 2 and relates the identified strengths and weaknesses of both approaches to the results presented in Section 3. Conclusions are drawn and scope for further research and application of the approach is identified. The primary aim of the study is to contribute to the technical discussion - the results obtained in the modeling efforts should not be interpreted as realistic.

2 Problems with the Armington approach in modeling bilateral trade flows and approaches to their solution

The Armington approach is used by most large models that represent bilateral trade. The most well-known of those is the GTAP model (HERTEL (ED.) 1997), used by many researchers throughout the world to simulate the effects of trade policy changes and other scenarios. However, this approach has three major drawbacks, which can lead to implausible results under certain conditions. The first of these problems has been referred to as the 4S property (HANSLOW 2001): Countries that have a small share of another country's import market for a certain commodity due to high bilateral trade barriers will not be able to increase their share significantly once the barriers are removed. This is because only increases relative to the initial share can take place in an Armington-based model. To allow a country that has a small share in another country's imports in the base situation to gain a significant share under a counterfactual scenario, the elasticity of substitution would need be so high that results would become extremely volatile once this share is achieved. To solve this problem, HANSLOW suggests the adaptive CRESH-Function (Constant Ratio Elasticity of Substitution Homothetic Function). The basic idea of the CRESH-Function is an elasticity of substitution, which adapts its value as relative prices are changing. As well the 4S property as the problem of volatile results is circumvented that way.

Another attempt to solve the problem has been proposed by WITZKE ET AL. (2005). Unlike HANSLOW they tackle not only the 4S property, but also the second major problem of the Armington Approach: If in the base scenario a country's share is zero in a certain market, it can never obtain a share different from zero in that market no matter how high the elasticities of substitution or the changes in relative prices. A full explanation of the WITZKE ET AL. approach is complicated, but in summary, the utility function from which demand functions are derived is generalized by an additional parameter that allows zero trade flows to become positive (and significant) and existing trade flows to disappear.

Neither HANSLOW nor WITZKE ET AL. addresses the third problem of the Armington approach: Products from different origins are necessarily regarded as imperfect substitutes. While this is likely true for a large range of products, this assumption may be inappropriate for some agricultural commodities, including sugar. Unlike Armington-based models, there are a number of models that can allow for homogeneous products (i.e., perfect substitutes). However, most of these models are net-trade models, which means it is impossible for them to simulate bilateral trade flows. A country is either an exporter or an importer, but not both[1]. The only method known to the author to depict homogeneous products in a model framework allowing for bilateral trade flows is the approach of spatial models by TAKAYAMA AND JUDGE (1971). In these models, determinants of consumer and producer prices are transportation costs and bilateral trade policies, in addition to marginal production cost. In the past, spatial models have rarely been used in the analysis of bilateral trade (ABLER 2005).

[1] A possibility to depict, though inflexibly, bilateral trade flows in a net-trade model has been suggested and implemented in the European Simulation Model (ESIM) by BANSE ET AL. (2005).

3 Model description and results

3.1 Model description and base data

In this section, two simple one product, five regions models of the world sugar market are constructed, and a multilateral liberalization scenario is run with both. The first is a spatial model assuming homogeneous goods. The second is an Armington-based model assuming heterogeneity with regard to origin. Supply and demand functions are iso-elastic and depend solely on own prices. Elasticities are extracted from STOUT AND ABLER (2003)[2]. The spatial model is formulated as a mixed complementarity problem (MCP). The Armington model is a fully determined system of equations where the share of a supplying country in a demanding country's market is determined by the ratio of the price for sugar from the supplying country and the average price for sugar in the demanding country. Sugar is a particularly interesting product for the purpose of this paper. The protection of sugar markets is, at least in the European Union (EU), significantly higher than the protection of other crop products. Also, to a large extent, the value of agricultural trade preferences for developing countries is dependent on sugar preferences (GRETHE 2005). Therefore, the role of sugar in the current discussion on agricultural trade liberalization is eminent. But it is also interesting from a technical point of view. The large number of TRQs providing many countries with small market shares in the EU lets the 4S property influence the results crucially.

Table 1 shows the regional aggregation of the two models, determined to a large extent by the EU's preferential agreements. The EU is modeled as a single country, as is Brazil, the world's largest sugar producer and exporter. The countries that enjoy preferential access to the EU sugar market are grouped into low cost producers (PLC) and high cost producers (PHC). All other countries are aggregated to the rest of the world (ROW). The preferential agreements taken into account for this study comprise the sugar protocol with African Caribbean and Pacific (ACP) countries, the special preferential sugar (SPS) quotas, the quota for the Balkan countries, and the "Everything but Arms" (EBA) quotas in the 2003-2004 marketing year.

2 No elasticities for preferential suppliers to the European Union (EU) market could be obtained from STOUT AND ABLER (2003). Demand elasticities are therefore set at the level of the rest of the world (ROW). Supply elasticities are set at the level of Brazil for low cost preferential suppliers (PLC). It is frequently claimed that preferential exports of some high cost suppliers to the EU market are very sensitive to prices. The supply elasticity for high cost preferential producers (PHC) is therefore set at twice the value of Brazil's supply elasticity. The Armington elasticity of substitution of household demand for sugar has been set at 4.4, which is, according to KERKELÄ AND HUAN-NIEMI (2005), the standard assumption. Substitution between sugar from different origins, including domestic production, is a one stage process here.

Table 1: Regions in the model.

Regional Aggregates	Countries in Region
EU-25 (EUR)	European Union
Brazil (BRA)	
Low Cost Preferential Producers (PLC)	Zambia, Zimbabwe, Ethiopia, Mozambique, Sudan
High Cost Preferential Producers (PHC)	India, Balkans, Barbados, Belize, Congo, Rep., Côte d'Ivoire, Fiji, Guyana, Jamaica, Kenya, Madagascar, Malawi, Mauritius, St. Kitts and Nevis, Swaziland, Tanzania, Trinidad and Tobago, Other LDC
Rest of the World (ROW)	

Source: Own compilation. Grouping into high cost and low cost producers based on ISERMEYER ET AL. (2005).

Table 2 presents the regional sugar policies in the base scenario. The EU applies a quota regime, a prohibitive most favored nation (MFN) tariff, and export subsidies. Besides the above-mentioned preferential quotas, two quotas for Brazil and the ROW exist at reduced duty rates. No information about trade policies of PHC countries to the EU market was available. It is, therefore, assumed that they, like the EU, apply a prohibitive tariff to protect their markets.

Table 2: Policies in the base situation (all quantities in white sugar equivalents (WSE)).

Region	Sugar Policies
EUR	Prohibitive MFN tariff; Export subsidies to keep price at € 725/ton; Production Quota: 17.441 million tons; Duty free TRQ for PLC and PHC (ACP, SPS, EBA, Balkans), PLC 0.162 million tons, PHC 1.626 million tons; Reduced duty TRQ for BRA and ROW (CXL), BRA 0.022 million tons, ROW 0.054 million tons.
BRA	None
PLC	None
PHC	Prohibitive MFN tariff
ROW	None

Source: BERKUM ET AL. (2005), EUROPEAN COMMISSION (2004a, 2004b), UNCTAD (2005), own calculations.

In Table 3 the base data of supply and demand in the regional aggregates are shown. Some adjustments are made to simplify the analysis. First, the production of C-Sugar in the EU is ignored. Reasons for the production of C-Sugar—a commodity that has revenue for producers far below marginal production costs—have been debated intensively (see, for instance, GOHIN AND BUREAU (2005) and ADENÄUER AND WITZKE (2004)); however, the primary purpose of this study is not to depict the outcomes of policies, but rather to show the effects of the different modeling approaches. Therefore, C-Sugar is ignored. Second, despite high costs, some PHC countries export significant quantities of sugar to countries other than the EU, likely the result of bilateral trade arrangements between these countries. To keep the model simple, these exports are ignored and the production quantity is determined to be the domestic demand plus preferential exports to the EU. Both quantities are added to ROW production.

Table 3: Base data (million tons WSE), 2000-2002.

Region	Supply	Demand
EUR	17.441	16.098
BRA	18.802	8.817
PLC	1.682	1.548
PHC	22.828	21.202
ROW	62.731	75.819
Total	123.484	123.484

Source: FAOSTAT (2004), own calculations.

Table 4 shows the prices in the base situation. Producer prices and consumer prices are equal in all countries and regions. For the EU, a shadow price for producers also is listed, as the price level in the EU does not equal marginal production costs due to the quota system. Having no knowledge about the shadow price, it is set at 80% of the market price as suggested by BANSE ET AL. (2005). In an Armington-based model there is usually no unique price for the same product from different origins in one market. The same holds in most Armington models for the producer price. In the model presented here, however, there is no CET specification of the production technology for different destinations as is usually the case. Hence, there is only one producer price in each region. The prices in Table 4 are, therefore, producer prices[3].

[3] In the base situation, consumer prices in a certain country for sugar from all regions are equal in Armington models.

Table 4: Prices in the base situation.

Region	Prices
EUR	725 €/ton
EUR, Shadow Price for Producers	580 €/ton
BRA	246 €/ton
PLC	256 €/ton
PHC	650 €/ton
ROW	256 €/ton

Source: EUROPEAN COMMISSION (2004b), ISERMEYER ET AL. (2005), own calculations.

Table 5 shows bilateral trade flows in the base situation. These are grouped not only by sources (rows) and destinations (columns), but also by the channels (domestic supply, subsidized exports, preferential exports, and exports on a MFN basis) through which they are traded. The EU, exporting roughly 3 million tons, is the second largest exporter after Brazil (based on export subsidies only). All regions represented in the model export to the EU, however, those exports all take place on a preferential or TRQ basis.

Table 5: Bilateral trade in the base situation (million tons WSE).

		EUR	BRA	PLC	PHC	ROW	Total Supply
EUR	Domestic	14.234					17.441
	Export Subsidies					3.207	
BRA	Domestic		8.817				18.802
	CXL	0.022					
	MFN			0.028		9.935	
PLC	Domestic			1.521			1.682
	Preferential	0.162					
PHC	Domestic				21.202		22.828
	Preferential	1.626					
ROW	Domestic					62.677	62.731
	CXL	0.054					
Total Demand		16.098	8.817	1.548	21.202	75.819	123.484

Source: BERKUM ET AL. (2005), EUROPEAN COMMISSION (2004a, 2004b), FAOSTAT (2004), UNCTAD (2005), own calculations.

3.2 Model results

The results of the model runs are shown in Tables 6 to 10 and in Figure 1. The variables that are discussed are prices, supply, demand, and bilateral trade. The price changes predicted by the two models are shown in Table 6. With no barriers to trade in place, prices are converging. In the spatial model where homogeneous goods are assumed, the law of one price holds and prices differ from each other by transportation costs only[4]. In the Armington model where imperfect substitutability is assumed, this is not the case and price differences are stronger. The spatial model assumes the world market price (London, c.i.f.) increases to 385 € per ton of white sugar. This means an increase of roughly 50% for those producers who already face the world market price in the base scenario. For the former high cost producers, it means a price decrease of 41% to 47%. The price changes in the Armington model move in the same direction but are less pronounced throughout. The prices shown are producer prices (as in Table 4); however, in this situation they differ from (average) consumer prices in one country[5].

Table 6: Model results for prices (€/ton WSE).

Region	Base	Armington		Spatial	
EUR	725	479	-34%	385	-47%
EUR, Shadow Price for Producers	580	479	-17%	385	-34%
BRA	246	268	+9%	375	+52%
PLC	256	350	+37%	375	+46%
PHC	650	626	-4%	385	-41%
ROW	256	282	+10%	385	+50%

Source: Own calculations.

Table 7 shows the model results for supply quantities. Following the price changes, the quantities of former PLC countries increase and those of former PHC countries decrease. Because supply functions are equal in both models, the prices fully explain the different forecasts for supply changes. As with the price changes, the supply changes are more pronounced in the spatial model than in the Armington model. The difference is largest for PHC countries, where supply is predicted to decrease by only 5% in the Armington model but by almost 50% in the spatial model. In the base scenario, this region was a self-sufficient sugar producer with no imports and exports, comprising only a small share

4 Having no information about bilateral transport costs for sugar, they are assumed to be 10 € per ton of internationally traded sugar and zero for sugar sold on domestic markets.

5 Consumer prices in one country for sugar from different sources now differ. Prices for sugar from one country in another can be obtained by adding the producer price of the supplying country and the transportation costs.

of production; an Armington model allows for hardly any changes in prices or quantities as a response to changing circumstances in international markets.

Table 7: Model results for supply quantities (million tons WSE).

Region	Base	Armington		Spatial	
EUR	17.441	15.633	-10%	13.791	-21%
BRA	18.802	19.887	6%	24.634	+31%
PLC	1.682	2.056	22%	2.148	+28%
PHC	22.828	21.767	-5%	11.637	-49%
ROW	62.731	64.663	+3%	71.154	+13%
Total	123.484	124.007	0%	123.364	0%

Source: Own calculations.

The results for demand quantities listed in Table 8 show the same behavior as those for supply. Model results move in the same direction in most cases, but the changes are more pronounced in the spatial model. Compared to the changes in supply quantities, the changes in demand are smaller due to a smaller own price elasticity of demand.

Table 8: Model results for demand quantities (million tons WSE).

Region	Base	Armington		Spatial	
EUR	16.098	17.227	7%	17.782	+10%
BRA	8.817	8.747	-1%	8.485	-4%
PLC	1.548	1.513	-2%	1.505	-3%
PHC	21.202	21.267	0%	22.053	+4%
ROW	75.819	75.253	-1%	73.539	-3%
Total	123.484	124.007	0%	123.364	0%

Source: Own calculations.

Table 9 shows the results for bilateral trade flows obtained with the Armington model. After abolishing export subsidies, exports of the EU decrease by more than 90%. The quantity of domestically consumed EU sugar increases as the relative price decreases. The EU’s imports from PLC countries increase by huge percentages, yet the absolute values remain small, providing a good example of the 4S property. As mentioned previously, PHC countries stay self-sufficient in the Armington model; however, the formerly preferential exports to the EU decrease by almost 70%.

Table 9: Model results for bilateral trade (Armington model, million tons WSE).

		EUR	BRA	PLC	PHC	ROW	Total Supply
EUR	Domestic	15.341 +7.8%					15.633
	MFN					0.292 -90.9%	
BRA	Domestic		8.747 -0.8%				19.887
	MFN	0.258 +1072.7%		0.072 +157.1%		10.810 +8.8%	
PLC	Domestic			1.441 -5.3%			2.056
	MFN	0.615 +279.6%					
PHC	Domestic				21.267 +0.3%		21.767
	MFN	0.500 -69.2%					
ROW	Domestic					64.150 +2.4%	
	MFN	0.513 +850.0%					64.663
Total Demand		17.227	8.747	1.513	21.267	75.253	124.007

Source: Own calculations.

The changes in bilateral trade flows predicted by the spatial model are shown in Table 10. As goods are homogeneous and no trade policies are in place, each country is now either an exporter or an importer, but not both (as the EU and PLC countries were in the base scenario). The only region now exporting to the EU is Brazil. The only other exporting region, the PLC aggregate, exports its surplus to the PHC countries[6]. The number that differs most from its counterpart in Table 9 is the domestic supply of sugar in PHC countries, which is almost 45% lower than the amount forecasted by the Armington model. In addition to absolute numbers, relative changes of trade flows are indicated in Tables 9 and 10. One feature of the results of the spatial model in Table 10 is 100% (or infinite percentage) changes in trade flows, which means existing trade flows disappear and others are newly established. In any Armington model, it is impossible to simulate such events.

6 This is arbitrary and completely dependent on transportation costs. Making different assumptions about the latter can lead PLC countries to ship their exports to the EU or ROW instead.

Table 10: Model results for bilateral trade (Spatial model, million tons WSE)

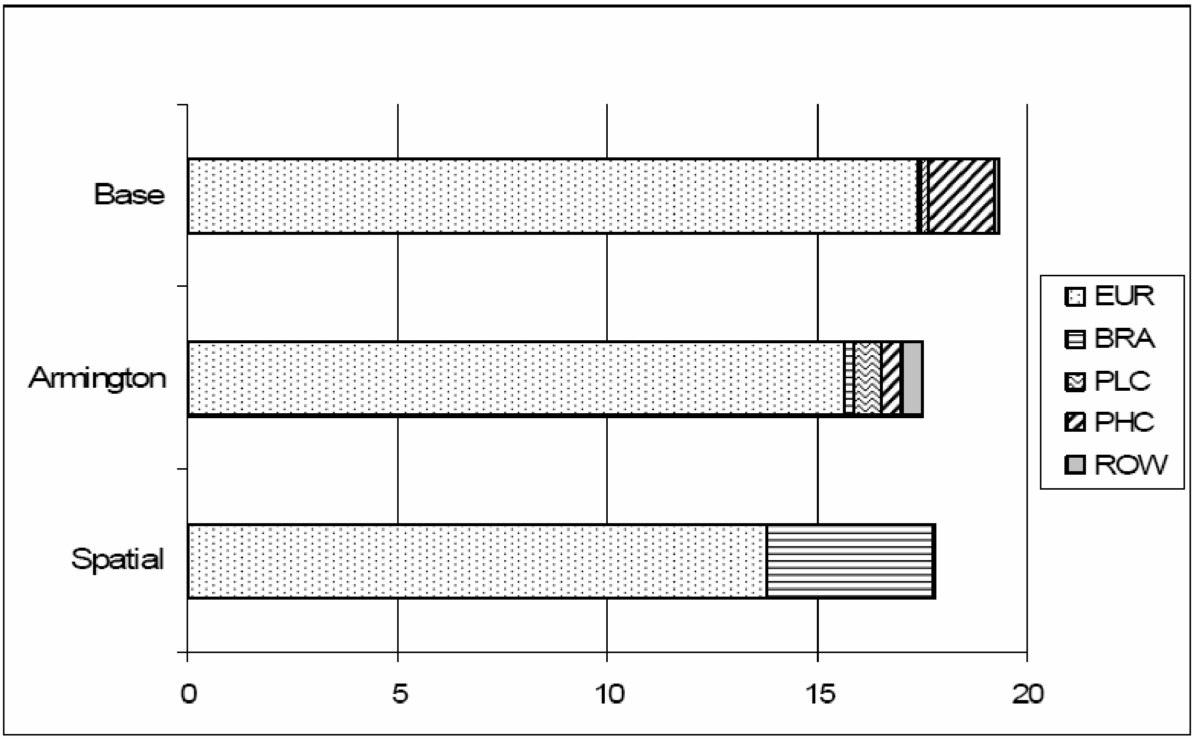
		EUR	BRA	PLC	PHC	ROW	Total Supply
EUR	Domestic	13.791 -3.1%					13.791
BRA	Domestic		8.485 -3.8%				24.634
	MFN	3.992 + 18,045.5%		-100.0%	9.773 + ∞ %	2.385 -76.0%	
PLC	Domestic			1.505 +1.1%			2.148
	MFN	-100.0%			0.644 + ∞ %		
PHC	Domestic				11.637 -45.1%		11.637
	MFN	-100.0%					
ROW	Domestic					71.154 +13.5%	71.154
	MFN	-100.0%					
Total Demand		17.782	8.485	1.505	22.053	73.539	123.364

Source: Own calculations.

Figure 1 depicts the EU market shares of different exporting countries and the EU-25 itself. (It corresponds roughly with the "EUR" columns in Tables 5, 9 and 10[7].) In the base scenario, the shares of all exporting countries, except for PHC countries, are negligible. In the Armington model, no significant gains of market shares can be observed for current low cost producers such as Brazil and PLC countries, underlining the interpretation of the results presented in Table 9. In the spatial model, production decrease in the EU is strongest in contrast to the base scenario and the Armington model; Brazil, as the only remaining exporter, gains a significant market share.

[7] The EU market comprises domestic consumption of the EU plus exports, whereas in the tables only domestic consumption is shown in the columns.

Figure 1: Model results for market shares in the EU-25 (million tons WSE).



Source: Own calculations.

4 Conclusions and outlook

In the current debate on agricultural trade liberalization, sugar occupies a very prominent role. The protection of the sugar market, at least where the EU and its preferential suppliers are concerned, is considerably stronger than in most other agricultural sub-sectors. Experts agree that liberalization of the EU sugar market would lead to decreased sugar production in the EU and PHC countries and to increased production in Brazil and other PLC countries, which would fill the production gap[8]. The analysis shows that the spatial modeling approach of TAKAYAMA AND JUDGE (1971) is able to meet these predictions, whereas the Armington model cannot. Increasing the values of Armington elasticities of substitution, which is the only possible alteration within the framework suggested by ARMINGTON (1969), could alleviate this failure, though not completely. Furthermore, this alteration tackles only the 4S problem; a country that is self-sufficient under a protectionist regime, as is the case for the PHC countries in the base scenario, will always be self-sufficient, no matter how much relative prices change.

Although the market shares of low cost producers in the EU increase only slightly in the Armington model, they are of an order of magnitude to be visible in Figure 1. This is dependent on the existence of the tiny, policy-induced shares PLC countries have in the EU market in the base scenario. In reality,

[8] See ISERMEYER ET AL. (2005) for one example; the number of studies dealing with this topic is immense.

these shares are almost meaningless; taking them away would not affect total export revenues of Brazil nor the ROW aggregate significantly. If, however, the base scenario had been calibrated with respect to a situation in which these shares did not exist, the result would have been that those two regions would not export at all to the EU, even under liberalized markets.

The model analysis performed in this study is not meant to provide realistic results, and it does not. It was performed to show the drawbacks of the dominant method for analyzing bilateral trade and to suggest an alternative. The analysis indicates that the spatial model was able to meet the forecasts of market experts where the Armington model failed. However, the results obtained, however, do barely provide any information that goes beyond the experts' predictions, which were produced without applying any tools of quantitative trade analysis.

To obtain results that have predictive value, the model would need to be enhanced. A stronger regional disaggregation would be necessary, bringing with it detailed data requirements on production cost, bilateral policies, bilateral transport cost, and the potential to expand production, to name the most important. The ROW aggregate is especially problematic in this context - it is a net importer in the model, but includes countries such as Australia and Thailand, which are competitive producers and important exporters to the world market. A second issue is the model's inability to account for cross price effects, which must be expected with other agricultural products and also with the energy markets.

The model presented here also failed to meet one particular prediction of experts in the world sugar market: In the case of complete liberalization, some countries would abandon sugar production. With the model in its current structure (with iso-elastic supply curves), this abandonment is impossible to simulate. The application of a functional form for supply curves that has the possibility of introducing a positive intercept on the ordinate would, therefore, also be a necessary step towards obtaining realistic results.

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