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Small-group monopolistic competition in a global computable general equilibrium model: Meeting the Markusen challenge

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Since the 1990s, there have been rapid increases in concentration ratios in many industries in the U.S., Australia and, we suspect, in other countries. Despite this, applications of GTAP continue to be based on pure competition or Melitz-style Large-Group Monopolistic Competition (LGMC). In either case, all firms are small, there is free entry, and industries make zero pure profits. Markusen challenges modellers to move to Small-Group Monopolistic Competition (SGMC) in which industries have high levels of concentration and firms are aware of the likely behaviour of their rivals. By making two generalizations of Melitz-LGMC specifications, we create a version of GTAP in which some industries are modelled as SGMC. First, we treat the demand elasticities perceived by firms for their products as variables. In our SGMC specification, markups over marginal costs, which depend on perceived elasticities, rise when these elasticities are reduced (in absolute terms) by anti-competitive practices. Second, we allow for sticky adjustment of the number of firms in an industry and simulate situations in which entry is blocked or partially blocked, allowing incumbent firms to make positive pure profits. As illustrated in our simulations, the emergence of pure profits has the potential to suppress real wage rates.

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1. Introduction

Industries dominated by a few large firms are now a common feature of many economies. Statistica lists 20 industries in which the top 4 firms in the U.S. account

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for more than 88% of U.S. production. These include industries supplying medical equipment, financial intermediation, air traffic control, aircraft manufacturing, courier services and computer storage devices. Grullon et al. (2019) document a rapid increase in the concentration of U.S. industries since the 1990s. They show that industries with the largest increases in product-market concentration show higher profit margins than other industries. They find no evidence that increased concentration has been accompanied by productivity-enhancing scale economies.

Despite these developments, all applications of computable general equilibrium (CGE) models of which we are aware assume that industries are composed of large numbers of small firms. In most cases, it is assumed that industries are perfectly competitive. In some cases, large-group monopolistic competition (LGMC) is assumed. Harris (1984) pioneered LGMC specifications in CGE modeling, working with a single-country Canadian model. In the Australian context, Abayasiri-Silva and Horridge (1998) improved and extended the Harris specification. More recently, Melitz-style LGMC has been adopted in versions of the global multi-country GTAP model, see for example Akgul et al. (2016), Balistreri and Rutherford (2013), Bekkers and Francois (2018), and Dixon et al. (2018 and 2019). [1,2] LGMC allows for economies of scale, but with either perfect competition or LGMC, there are zero pure profits and free entry. In setting their prices and quantities, firms take no account of likely reactions by their rivals.

In his recent Journal of Global Economic Analysis (JGEA) article, Markusen (2023, p.61) attacks the LGMC setup. He says:

"It is bafflingly inconsistent to assume that firms produce with increasing returns to scale, yet have no mass. This has remained true in almost all papers modeling heterogeneous firms, where the most productive firms are very large relative to their industry average."

Markusen advocates for the adoption of small group monopolistic competition (SGMC) in which industries have high levels of concentration and firms make decisions taking account of the likely reactions of their rivals. Markusen uses a theoretical model with stylized numbers to illustrate the potential importance of switching from LGMC to SGMC for trade and welfare results in CGE models. Nevertheless, Markusen continues to assume free entry.

In this paper, we describe a version of the Melitz model that incorporates SGMC. We refer to this theoretical model as MM (Melitz-Markusen). Unlike Melitz

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[1] Melitz (2003) is the foundation theory paper.

[2] GTAP models are global computable general equilibrium models developed initially by the Global Trade Analysis Project at Purdue University. The original documentation is Hertel (1997). See also Corong et al. (2017) and Aguiar et al. (2019). GTAP models are supported by a database covering trade, production, taxes and environmental variables for 65 industries in about 160 countries. Over the last 30 years, there have been literally thousands of GTAP applications. Currently there are 30,000 people in the world-wide network of contributors to and users of GTAP resources.

and Markusen, we allow for barriers to entry and pure profits. We think these are potentially important explanators in some countries of reductions in the labor share of GDP.

We embed our MM specification in a version of the GTAP model. The resulting GTAP-MM model generalizes earlier GTAP-Melitz models in two directions.

First, GTAP-MM treats the perceived elasticity of demand by firms in SGMC industries as a variable. In Melitz, the perceived elasticities are parameters. In the SGMC specification, markups over marginal costs, which depend on perceived elasticities, rise when these elasticities are reduced (in absolute terms) by anti-competitive practices.

Second, GTAP-MM allows for sticky adjustment of the number of firms in an industry. In GTAP-Melitz models, with free entry, the number of firms in an industry adjusts continuously to ensure zero pure profits. In GTAP-MM, we simulate situations in which entry is partially or fully blocked, allowing incumbent firms to make excess profits.

The paper is set out as follows. In the rest of this section, we provide a brief refresher on Melitz' theory and contrasts with our MM theory. Section 2 describes the equations for an MM industry. Section 3 contains an illustrative simulation with GTAP-MM. The results highlight the potential for growth in pure profits to suppress real wages. Concluding remarks are in Section 4. Supplementary material details the mathematics underlying our MM specification and its representation in GTAP-MM.

1.1. Refresher on Melitz and contrasts with MM

Melitz (2003) sets out a model of an industry, which we will refer to as the Widget industry. This industry has four key features.

(a) Firms and varieties

Under the Melitz LGMC specification, the Widget industry in each country contains many firms with different productivity levels. Melitz assumes that each firm produces a single Widget variety. For Widget users, these varieties are imperfect substitutes.

An SGMC specification requires a small group of firms. However, for our MM model we need lots of varieties because otherwise love-of-variety effects become too dominant. The Melitz idea of having one variety per firm doesn't fit well with SGMC. It either gives us too few varieties or too many firms. Our solution to this problem is to assume, realistically, that big firms can produce multiple varieties.

For MM, the picture to have in mind is that the Widget industry in country s consists of a small number of identical firms, each of which produces its own distinctive varieties. Productivity levels differ across varieties. The minimum productivity level for a variety to justify sales from s to d is the same for all firms in s.

(b) Setting up new firms

In Melitz, entrepreneurs look at current profits in the Widget industry in deciding whether to produce a new variety, which is the same as setting up a new firm. To set up a new firm, a Melitz entrepreneur must incur a fixed setup cost before knowing whether the new firm will be profitable. Melitz encapsulates this prior uncertainty by assuming that an intending Widget entrepreneur pays for a draw from a distribution of productivity levels. Equivalently, he could have assumed that the producer draws a demand-side variable or attractiveness variable from a probability distribution. Whether it is a supply-side variable or a demand-side variable doesn't matter. The point is that a favourable draw means that the new variety (firm) will be profitable. An unfavourable draw means that the new variety may never reach production stage.

In the MM model, we retain the idea that current profits determine entry to the Widget industry, that is, creation of new firms. However, unlike Melitz and Markusen we assume that entry may only partially eliminate profits. Although appealing, we don't think the Melitz idea of prior uncertainty in setting up a firm is necessary in the MM model. We assume that an intending Widget entrepreneur incurs a fixed cost to buy the ability to produce an array of Widget varieties with a known distribution of productivity levels.

(c) Link-specific fixed costs

A Widget firm in Melitz incurs a fixed cost to set up sales of its variety to the domestic market and to each foreign market. We refer to these as link-specific fixed costs. For any given firm, incurring these fixed costs may be worthwhile for only a selection of potential markets. For low-productivity firms, there may be no market for which it is profitable to incur the link-specific setup cost. In this case, the firm will not produce any output.

In MM we retain this story for determining what varieties will be sent on each link. Firms in country s send only their high productivity varieties to d if there are high setup costs in d. But relative to Melitz, there is an extra complication. In MM, firms must take account of the effect of the sales of each of their varieties on the sales of their other varieties, and on the sales of varieties produced by other firms. These inter-variety effects are absent in Melitz: each firm in Melitz produces just one variety and each firm is too small to have to worry about the effects of its decisions on other firms.

(d) Reducing the model to relationships between variables for typical varieties

Although a Widget industry in Melitz contains many varieties, Melitz was able to reduce his model to a system of equations that connect variables only for typical varieties. Melitz does this by assuming that the distribution from which Widget entrepreneurs make their productivity draws belongs to one of several common families of distributions [Melitz (2003), footnote 15]. Following Zhai (2008), CGE modellers have invariably adopted the Pareto distribution. The reduction of the variety dimension to just typical varieties makes Melitz theory practical for CGE modelling. It also means that the Melitz model can be well understood at an intuitive level by working through a manageably small number of equations such as those in Table 1.

In MM, we use the Pareto distribution to describe the distribution of productivity levels across the varieties producible by a firm in country s. Then, as set out in the supplementary material, we apply Melitz' method to reduce the MM model to typical varieties.

2. A Melitz-Markusen model: theory

Table 1 lists equations describing a generic industry, the Widget industry under MM assumptions. To a large extent, Table 1 is Melitz plus additional equations to allow the transition from LGMC to SGMC. This section explains Table 1.

Preliminary comments

The table is not the whole of a general equilibrium model. It is the specification for just one industry. The industry variables determined in this part of the general equilibrium model are indicated next to the equations. The notation list, which follows the equations, includes not only these variables, but also endogenous variables determined elsewhere in the general equilibrium system and variables that are naturally exogenous. Parameters are also listed.

The equations in Table 1 are simplified versions of those used in GTAP-MM. We leave out intermediate inputs, multiple primary factors and numerous taxes, all of which are present in GTAP-MM. Our aim is to make the relevant theory readily accessible. Complications in translating from theory to practical modelling are addressed in the supplementary material (section A.5 and the references given there).

Here we provide explanations of the equations in Table 1.

The price of Widgets sent from s to d, equations (T1a) and (T1b)

Equation (T1.1a) specifies the price in region d of the typical variety of Widget sent from s as marginal cost *times* a markup factor ($M_{d,}$ same for all s). In common with Melitz, the marginal cost of supplying the typical variety on the sd-link is specified in MM as:

the cost of the input bundle (W_s) used in Widget production in region s;

deflated by marginal productivity ($\Phi_{\bullet sd}$, which is the increase in the number of units of the typical sd variety that are produced in s from an extra input bundle);

grossed up by the tariff and transport factor (T_{sd}) applying to all Widget flows from s to d.

Table 1. The Widget industry in the Melitz-Markusen model.

Identifier	Equation	What the equation determines
(T1.1a)	$P_{\bullet sd} = \left(\frac{W_s T_{sd}}{\Phi_{\bullet sd}}\right) * M_d$	$P_{\bullet sd}$: price in d of a typical variety of Widget sent from s to d
(T1.1b)	$\Phi_{\bullet sd} = \beta * \Phi_{\min(s,d)}$	$\Phi_{\bullet sd}$: marginal productivity of an input bundle in production of a typical Widget variety sent from s to d
(T1.2a)	$P_d = \left(\sum_s N_{sd}\delta_{sd}^{\sigma} P_{\bullet sd}^{1-\sigma}\right)^{\frac{1}{(1-\sigma)}}$	P_d: cost to Widget users in d of satisfying a unit of demand
(T1.2b)	$N_{sd} = N_s * B_s * \left(\Phi_{\min(s,d)}\right)^{-\alpha}$	N_{sd}: number of varieties sent from s to d
(T1.3a)	$Q_{\bullet sd} = Q_d \delta_{sd}^{\sigma} \left(\frac{P_d}{P_{\bullet sd}}\right)^{\sigma}$	$Q_{\bullet sd}$: quantity sent from s to d of a typical variety
(T1.3b)	$V_{sd} = P_{\bullet sd} N_{sd} Q_{\bullet sd}$	V_{sd}: value in d of Widgets purchased from s
(T1.3c)	$Q_{sd} = N_{sd} Q_{\bullet sd}$	Q_{sd}: quantity of Widgets from s purchased in d
(T1.4a)	$(M_d - 1)\left(\frac{Q_{min(s,d)}}{\Phi_{m\,in(s,d)}}\right) - F_{sd} * Z_{sd} = 0$	$\Phi_{m\,in(s,d)}$: minimum marginal productivity for an input bundle over all varieties sent from s to d
(T1.4b)	$Q_{\min(s,d)} = Q_{\bullet sd}/\beta^{\sigma}$	$Q_{\min(s,d)}$: quantity sent from s to d of a variety with minimum productivity
(T1.5)	$\Pi tot_s = \sum_d N_{sd}\left[\frac{W_s}{\Phi_{\bullet sd}} * Q_{\bullet sd} * (M_d - 1) - W_s * F_{sd}\right] \quad - N_s H_s W_s$	Πtot_s: profits in the Widget industry in s
(T1.6)	$L_s = \sum_d \frac{N_{sd} Q_{\bullet sd}}{\Phi_{\bullet sd}} + \sum_d N_{sd} F_{sd} \quad + N_s H_s$	L_s: number of input bundles used in the Widget industry in s
	Add-ons for small group monopolistic competition	
(T1.7a)	$M_d = \frac{\Gamma_d}{\Gamma_d - 1}$	M_d: markup factor (price/marginal cost) applied by all Widget suppliers to d
(T1.7b)	$\Gamma_d = \frac{1}{\frac{1}{Ntot_d} + \left(1 - \frac{1}{Ntot_d}\right) * \frac{1}{\sigma}}$	Γ_d: elasticity of demand perceived by suppliers of Widgets to d

(Continued…)

Table 1. The Widget industry in the Melitz-Markusen model. (…Continued)

Identifier	Equation	What the equation determines
(T1.7c)	$Ntot_d = \left(\frac{\bar{N}tot_d}{\prod_s \bar{N}_s^{K(s,d)}}\right) * \prod_s N_s^{K(s,d)}$	$Ntot_d$: number of domestic and foreign Widget producers competing for sales in d
(T1.7d)	$S_{sd} = \frac{V_{sd}}{P_d Q_d}$	S_{sd}: share of firms from s in Widget sales in d
(T1.7e)	$Z_{sd} = 1/\left(1 - S_{sd} * \left(\frac{\sigma - \Gamma_d}{\sigma - 1}\right)\right)$	Z_{sd}: modification of markups to account for effects of one variety on profitability of other varieties
(T1.7f)	$N_s = \bar{N}_s * exp\left(\Psi_{1s}\left(\frac{\Pi tot_s}{W_s L_s} - \Psi_{0s}\right)\right)$	N_s: Number of Widget firms located in s

Notation for Table 1

Endogenous variables determined in the specification of the Widget industry

$P_{\bullet sd}$ is the price paid by Widget users in d for Widgets sent from s.

$\Phi_{\bullet sd}$ is the marginal productivity of an input bundle in the production of a typical Widget variety sent on the sd link.

P_d is the cost to Widget users in d of satisfying a unit demand for Widgets.

N_{sd} is the number of Widget varieties supplied by s for use in d.

$Q_{\bullet sd}$ is the quantity used in d of the typical Widget variety sent on the sd link.

V_{sd} is expenditure in d on Widgets sent from s to d.

Q_{sd} is the total quantity of Widgets sent from s to d.

$\Phi_{min(s,d)}$ is the minimum marginal productivity of an input bundle over all varieties sent from s to d.

$Q_{min(s,d)}$ is the quantity of the lowest-productivity variety of Widgets sent on the sd link.

Πtot_s is excess profits in the Widget industry in country s. These are earnings beyond what is required to cover costs, including normal rates-of-return on capital.

L_s is the number of input bundles used by Widget firms in s. This covers production, set up on links, and set up of firms.

M_d is the markup factor (price/marginal cost) which all Widget producers apply in pricing to customers in country d.

Γ_d, which we assume is greater than 1, is the elasticity of demand for their products perceived by all suppliers of Widgets to country d.

$Ntot_d$ is literally the number of domestic and foreign Widget producers competing for sales in d. However, in implementing the MM model, we interpret $Ntot_d$ merely as an indicator of competition in supplying d's Widget requirements.

S_{sd} is the share of firms from s in total Widget sales in d.

(Continued…)

Table 1. The Widget industry in the Melitz-Markusen model.(…Continued)

Z_{sd} is a variable whose value is greater than 1 and which acts as a markup on the sd set-up requirement (F_{sd}) in the determination of the minimum productivity level required for a variety to be viable on the sd link, see section A.3 of the supplementary material.
N_s is the numbers of Widget firms located in s.
Endogenous variables determined in the rest of the model
W_s is the cost of an input bundle used in Widget production in s. To simplify the exposition, we assume that labor is the only input so that W_s is the wage rate. In our implementation of MM in GTAP, we allow for other primary factors and intermediate inputs.
Q_d is the quantity of composite Widgets used in d.
Exogenous variables
T_{sd} is the power (1 +rate) of the tariff and transport costs applying to flows of Widgets from s and d.
F_{sd} is the number of input bundles required up-front to make it possible to sell Widgets from s to d.
H_s is the number of inputs bundles required to set up a Widget firm in country s.
Ψ_{1s} and Ψ_{0s} are exogenous variables that control the sensitivity of movements in the number of Widget firms in s to profits in s.
Parameters
β in a parameter with value greater than 1, see (A.2.10) in section A.2 of the supplementary material.
σ is the elasticity of substitution by Widget users between Widget varieties. This is assumed to be greater than 1 (e.g. 5). For convenience, we assume it is the same for Widget users in all countries.
δ_{sd} is a preference parameter in the Constant Elasticity of Substitution (CES) function that specifies the creation of composite Widgets for use in d.
B_s in a parameter interpreted as the number of potentially producible varieties per Widget firm in s.
α is a parameter in the Pareto distribution used to describe the distribution of productivities over Widget varieties in region s, see section A.2 in the supplementary material.
$\kappa(s, d)$ is the weight given to N_s in determining competition in supplying Widgets to d.
$\bar{N}\text{tot}_d$ and $\overline{N}_s$are initial values of $Ntot_d$ and N_s .

Different from Melitz, M_d in the MM model is a destination-specific endogenous variable. In Melitz it is a parameter with the same value for all destinations. As described below, in the MM model, M_d is determined by the elasticity of demand for their products perceived by all Widget suppliers to region d. The perceived elasticity for region d (and hence M_d) depends on the amount of competition in d's market. This is determined endogenously in an MM industry by the number of firms.

Equation (T1.1b) specifies the marginal productivity ($\Phi_{\bullet sd}$) of the typical sd variety in terms of the minimum marginal productivity $\Phi_{min(s,d)}$ over all varieties sent on the sd-link. In (T1.1b), β is a parameter with value greater than 1. The determination of

$\Phi_{min(s,d)}$ is explained later in Table 1. The maths underlying (T1.1b) and the evaluation of β are set out in the supplementary material [see equation (A.2.10)].

The cost of satisfying a unit of demand and love of variety: equations (T1.2a) and (T1.2b)

Versions of these equations are in Melitz.

Equation (T1.2a) specifies the cost (P_d) in region d of satisfying a unit demand for Widgets. This is a Constant Elasticity of Substitution (CES) combination of the prices ($P_{\bullet sd}$) of the supplies of typical varieties to d. The parameters of the CES function are the elasticity of substitution between Widget varieties (σ, assumed to be greater than 1 and the same in all markets) and the preference parameters (δ_{sd}).

Love of variety is introduced in (T1.2a) through the variable N_{sd}, which is the number of varieties sent from s to d. If N_{sd} increases, then at given prices, P_d falls: an increase in varieties allows Widget users in d to choose varieties that more closely match their requirements thereby reducing the cost of meeting any given level of demand.

Equation (T1.2b) determines N_{sd}. In this equation, B_s is the number of potentially producible varieties per firm in country s, assumed to be a parameter. It appears in MM, but not in Melitz, because we don't use the Melitz assumption of one variety per firm. N_s is the number of Widget firms in country s and $\Phi_{min(s,d)}$ is, as defined earlier, the minimum productivity over all varieties sent on the sd-link. α is the parameter in the Pareto distribution used to describe the distribution of productivities over the varieties producible by a firm in region s. If a higher level of productivity is required to justify the set-up costs of sending a variety from s to d [an increase in $\Phi_{min(sd)}$], then via (T1.2b) there is a decline in the number of varieties per firm sent from s to d (a decline in N_{sd}/N_s). Equivalently, for each firm there is a decline in the proportion of its potential varieties sent from s to d [a decline in $(N_{sd}/N_s)/B_s$].

This still leaves $\Phi_{min(s,d)}$ and N_s to be explained by later equations.

Demands: equations (T1.3a) to (T1.3c)

Again, these equations are versions of those in Melitz.

Equation (T1.3a) is region d's demand function for typical-variety Widgets from s. Consistent with a CES optimizing problem (set out in the supplementary material), region d's source-specific demands ($Q_{\bullet sd}$) depend on d's overall requirement for Widgets (Q_d, determined predominantly by income and other CGE variables outside the Widget industry), and the price of a typical Widget variety from s ($P_{\bullet sd}$) relative to Widget costs averaged over all sources [P_d, see (T1.2a)].

Equation (T1.3b) calculates the value in d of Widgets sent from s to d (V_{sd}) as the quantity for the typical variety times the number of varieties times the price. Equation (T1.3c) calculates the quantity of the s-to-d flow (Q_{sd}) by dividing the value by the price of a typical variety ($P_{\bullet sd}$).

A confusing aspect of the demand equations is the role of love of variety and the concept of effective quantities. We think it is easiest to interpret $Q_{\bullet sd}$ and Q_{sd} as normal quantities such as number of Widgets or tonnes of Widgets. However, Q_d cannot be interpreted in this way. It is a CES combination of Widgets sent to d from all sources and is not simply the sum over s of Q_{sd}. As discussed in the supplementary material,

$$Q_d = \left(\sum_s \delta_{sd} N_{sd} Q_{\bullet sd}^{(\sigma-1)/\sigma}\right)^{\sigma/(\sigma-1)} \quad (1)$$

This means that the effective quantity of Widgets supplied to d increases if $Q_{\bullet sd}$ halves and N_{sd} doubles even though there is no change in the s-to-d quantity (Q_{sd}). This is the "quantity-side" of love of variety corresponding to the reduction in P_d associated with increased variety discussed in the previous sub-section.

Unlike quantities, there is no interpretive difficulty with values. (T1.2a) together with (T1.3a) – (T1.3c) imply that the value of Widget expenditure in d (P_dQ_d) equals the value of supplies to d, ($\sum_s V_{sd}$):

$$\sum_s V_{sd} = \sum_s P_{\bullet sd}\, N_{sd} Q_{\bullet sd} = P_d Q_d \qquad (2)$$

Minimum productivity to justify sending a variety on the s-to-d link: equations (T1.4a) and (T1.4b)

These equations tie down one of the loose ends from the discussion of (T1.2a) and (T1.2b), namely the determination of the marginal productivity [$\Phi_{min(sd)}$] for the lowest productivity variety on the sd-link.

For understanding (T1.4a) we start by assuming temporarily that the variable Z_{sd} is fixed on 1 and can be ignored. Then (T1.4a) can be derived by assuming, as Melitz does, that the contribution to the profits of Widget producers in s from the lowest productivity (highest cost) variety sent on the sd-link is zero. As shown in the supplementary material, under our MM assumption that the markup factor (M_d) is the same for all varieties sent to d, varieties with lower productivity are not sent because they would not earn sufficient revenue to cover their costs of production, transport and tariffs, and the fixed costs of establishing the variety on the link. With zero profits assumed for the lowest productivity variety, we obtain:

$$0 = \frac{P_{min(sd)}}{T_{sd}} * Q_{min(sd)} - \frac{W_s}{\Phi_{min(sd)}} * Q_{min(sd)} - W_s * F_{sd} \qquad (3)$$

where

$\Phi_{min(s,d)}$ is the lowest productivity over all varieties sent on the sd-link;

$P_{min(sd)}$ and $Q_{min(sd)}$ are the price and sales volume on the sd-link of the minimum productivity variety sent on the link; and

F_{sd} is the number of input bundles required to setup sales of a variety on the sd-link.

With the M_d factor for the typical variety also applying to the minimum productivity variety,

$$P_{min(sd)} = \frac{W_s T_{sd}}{\Phi_{min(sd)}} * M_d \qquad (4)$$

Substituting from (4) into (3) gives (T1.4a) with Z_{sd} equal to 1. This is a Melitz equation.

Z_{sd} comes to life when we move to SGMC. We assume that suppliers on the sd-link understand that supplying extra varieties affects the sales of all varieties sold into d. This leads to the conclusion that the range of varieties supplied on the sd-link will not be pushed to the point where the lowest-productivity variety on the sd-link makes zero contribution to the profits of Widget producers in s. In our modelling of SGMC, Z_{sd} is a variable whose value is greater than or equal to 1 and which responds to changes in the perceptions of Widget producers in s regarding the level of competition that they face in market d. Our specification of Z_{sd} is given in (T1.7e) and discussed later in this section. Mathematical details are in the supplementary material.

The value of Z_{sd} affects the values of $Q_{min(sd)}$ and $Q_{\bullet sd}$. However, irrespective of Z_{sd}, $Q_{min(sd)}$ and $Q_{\bullet sd}$ are related by the parameter β^{σ} in equation (T1.4b). This parameter is more than 1, implying that sales of minimum-productivity varieties are less than those of typical varieties. The derivation of (T1.4b) is in the supplementary material.

Total profits in the Widget industry of country s: equation (T1.5)

The contribution ($\Pi_{\bullet sd}$) to profits in s's Widget industry from selling a typical variety on the sd-link is:

$$\Pi_{\bullet sd} = \frac{P_{\bullet sd}}{T_{sd}} * Q_{\bullet sd} - \frac{W_s}{\Phi_{\bullet sd}} * Q_{\bullet sd} - F_{sd} * W_s \tag{5}$$

This is revenue net of transport costs and tariffs *less* production costs *less* the fixed costs of setting up sales of a variety on the sd-link. These fixed costs are calculated as the number of input bundles (F_{sd}) required to commence sales of a variety on the sd-link *times* the cost of a bundle (W_s). Using (T1.1a), we can write (5) as

$$\Pi_{\bullet sd} = \frac{W_s}{\Phi_{\bullet sd}} * Q_{\bullet sd} * (M_d - 1) - F_{sd} * W_s \tag{6}$$

(T1.5) calculates total profits (Πtot_s) for the Widget industry in s as the sum over all destinations d of the profit contribution of a typical variety on the sd-link [$\Pi_{\bullet sd}$ given by (6)] *times* the number of varieties on the sd-link (N_{sd}) *less* the fixed cost over all firms of setting up to start production. The start-up cost for a firm is the number of input bundles required per firm (H_s) *times* the cost of a bundle. This gives the total production start-up cost for the Widget industry in s as $N_sH_sW_s$ where N_s is the number of firms.

Total input to the Widget industry in country s: equation (T1.6)

Total input to the Widget industry in s (L_s) has three parts. The first is input to production. This is the sum over all destinations d of the input required for production of a typical variety on the sd-link ($Q_{\bullet sd}/\Phi_{\bullet sd}$) *times* the number of varieties on the sd-link (N_{sd}). The second part is the input required to set up sales on the links. This is the sum over all d of the link setup cost per variety on the sd-link (F_{sd}) *times* the number of varieties on the sd-link. The third part is the input required for setting up firms. This is the input requirement for start-up per firm (H_s) *times* the number of firms in s (N_s).

Add-ons for SGMC: equations (T1.7a) to (T1.7f)

Equation (T1.7a) is an application of Lerner's rule. In stripped-down notation, omitting subscripts, it can be derived from the following profit-maximizing problem:

$$\begin{gathered} \textit{choose } P \\ \textit{to maximize } P*Q - MC*Q \\ \textit{subject to } Q = P^{-\Gamma} \end{gathered} \tag{7}$$

where

P and Q are the price and quantity set by a supplier to market d;

MC, assumed constant, is the marginal cost of supplying market d; and

Γ, assumed greater than 1, is the elasticity of demand perceived by all suppliers of Widgets to market d.

Optimization problem (7) implies that P/MC, that is the markup factor, is $\Gamma/(\Gamma-1)$.

Equation (T1.7b) is adapted from Markusen (2023). It relates the perceived elasticity of demand (Γ_d) in market d to the users' substitution elasticity (σ) between Widget varieties and to the number of firms ($Ntot_d$), domestic and foreign, supplying market d. If the number of firms is large, then Γ_d in (T1.7b) is close to σ, and M_d is close to $\sigma/(\sigma\text{-}1)$, which is the markup value used by Melitz in his LGMC model. When we move to SGMC and assume that there are a small number of competing firms, each of which anticipates reactions by its competitors, then Γ_d can be considerably less than σ, and M_d can be considerably greater than $\sigma/(\sigma\text{-}1)$. Assume for example that $\sigma = 5$ and $Ntot_d = 4$. Then the SGMC values for Γ_d and M_d are 2.5 and 1.667 whereas under LGMC, with a large value for $Ntot_d$, their values are 5 and 1.25. Markusen derives (T1.7b) under the Cournot conjecture: each firm anticipates that a change in the prices of its own varieties in market d will generate responses from its competitors aimed at maintaining the quantities of their sales.

Equation (T1.7c) determines the number of firms, $Ntot_d$, that compete in d's Widget market. In simulations, the model moves $Ntot_d$ away from its initial value in response to changes in the number of producing firms in all countries, N_s for all s. The parameters, $\kappa(s,d)$ are set so that $\sum_s \kappa(s,d) = 1$. Consequently, if N_s doubles for all s, then in (T1.7c) $Ntot_d$ doubles. The weight, $\kappa(s,d)$, given to movements in N_s is set to reflect the initial number of Widget firms in s ($\bar{N}_s$) and the importance of these firms in supplying market d. Details of the weighting scheme are in section A.3 of the supplementary material. The term in round brackets on the RHS of (T1.7c) ensures that the equation is consistent with the initial conditions.

While we refer to $Ntot_d$ as the number of firms competing in d and N_s as the number of firms set up in s, these definitions cannot be interpreted literally. We have to accept the idea of fractional firms and interpret $Ntot_d$ as an indicator of competition in supplying d's Widget requirements, and N_s as one of the determinants of $Ntot_d$. The initial value of $Ntot_d$ can be backed out from (T1.7a) and (T1.7b) after imposing data or judgements concerning values of markup factors (M_d) and substitution elasticities (σ). As explained in section A.3 of the supplementary material, we can refer to output data in setting initial values for N_s.

Equation (T1.7d) defines the share of Widgets from s in d's Widget expenditure.

Equation (T1.7e) determines Z_{sd}. The role of this variable was explained in the discussion of (T1.4a). In the supplementary material, we derive (T1.7e) by assuming that in choosing the lowest productivity (lowest profitability) variety for the sd-link, producers in country s maximize total profits generated on the link, taking account of the effect of their choice on sales of all varieties. In this optimization problem, the elasticity of demand perceived by suppliers to d's market (Γ_d) reappears. This is because suppliers perceive that changes in the array of varieties in d's market affect the cost in d of satisfying a unit of demand (P_d).

Looking more closely at (T1.7e), we see that Z_{sd} is always greater than 1 provided that $1<\Gamma_d< \sigma$. Z_{sd} equals 1 if $\Gamma_d = \sigma$, which is the implicit LGMC assumption in Melitz. Z_{sd} will be close to 1 if country s is a minor supplier to d (S_{sd} is close to zero).

With $\Psi_{1s} > 0$, equation (T1.7f) specifies a positive relationship between the number of Widget-producing firms in country s (N_s) and industry profits per unit of resource input cost ($\Pi tot_s/W_s L_s$). If profits increase in response to a favourable shock, then under (T1.7f), the number of firms increases but not by enough to return profits to their initial level. We have in mind an intermediate time frame, somewhere between the short run, in which it would be reasonable to assume no movement in the number of firms, and the long run, in which it would be reasonable to assume complete adjustment in the number of firms to eliminate profits. Papers such as those by Barkai (2020) and Grullon et al. (2019) indicate that the intermediate time frame could be many years, perhaps decades, in which pure profits are maintained in some industries with only weak entry responses. Ideally, the process of entry and profit elimination should be handled in a dynamic framework. That remains a challenge for future research.

To ensure that (T1.7f) is consistent with the initial situation in which $N_s = \bar{N}_s$, the initial value of Ψ_{0s} is the initial value of the profit ratio (that is $\Psi_{0s} = \bar{\Pi}tot_s/\bar{W}_s\bar{L}_s$).

If profits are initially zero, so that Ψ_{0s} is zero, and if Ψ_{1s} is given a very large value, then (T1.7f) will closely mimic Melitz and Markusen's assumption of free entry and zero profits. With a large value for Ψ_{1s}, movements in $\Pi tot_s/W_sL_s$ away from zero cause large movements in the number of firms in s, driving profits back towards zero. At the other extreme, we could set Ψ_{1s} at zero. This would be appropriate for investigating the implications of blocked entry to s's Widget industry: with $\Psi_{1s} = 0$, N_s is unresponsive to profitability. For the intermediate time frame, cases between free and blocked entry can be simulated with intermediate values for Ψ_{1s}.

In the MM specification in GTAP-MM, we treat Ψ_{0s} and Ψ_{1s} as exogenous variables rather than parameters. This extends the range of the model's applications. For example, we can apply a positive shock to Ψ_{0s} to simulate an anti-competitive policy for s's Widget industry.

3. An illustrative simulation under Melitz-Markusen assumptions

Section A.5 of the supplementary material describes how we convert GTAP into GTAP-MM. This requires the addition of a few equations to standard GTAP. Then, to incorporate MM features with minimal alterations to the core GTAP model we use: technical change variables to capture economies of scale implied by fixed costs; tax variables to represent profits and to capture differences across s-to-d trade links in prices charged by the Widget industry in country s; and preference variables to capture love-of-variety.

In this section, we describe a GTAP-MM simulation. We use a version of GTAP-MM in which there are 10 regions and 65 industries, of which 13 are MM industries accounting for 36 per cent of world GDP.[3] For each of the MM industries, the initial value of $Ntot_d$ is 4. In combination with GTAP elasticities of import/domestic substitution, this led to initial markup factors in the MM industries of between 1.6 and 2.2.

We simulate a movement in the equilibrium pure profit rate for the 13 MM industries from 1 per cent to 10 per cent in all countries/regions. We chose this simulation to illustrate the possible deadening effects on wage growth of reduced competition and the emergence of pure profits.

The simulation is purely illustrative. It was conducted with an old database (2008). We also use a simple but crude closure, the main features of which are as follows:

- Real investment, real public consumption and the ratio of the balance-of-trade to GDP in each region are exogenous, unaffected by the shocks.[4] Real GDP and

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[3] The 13 selected MM industries are: Oil extraction; Gas extraction; Other mining; Wearing apparel; Motor vehicles; Other transport equipment; Electronic equipment; Other machinery; Construction; Communications; Other financial intermediation; Insurance; and Other business services.

[4] We allow an endogenous uniform shift in the trade-balance/GDP ratios to avoid over determinacy.

private consumption are endogenous, with private consumption being determined as a residual in the identity

$GDP = C + I + G + X - M.$

With this set up, C can be used as a measure of welfare.

- The employment of each of the 5 primary factors in the GTAP database (land, unskilled labor, skilled labor, capital and natural resources) is exogenous, unaffected by the shocks.
- The government in each region achieves revenue neutrality by varying in a uniform manner the power of the income taxes applying to all primary factors and production taxes applying to all industries.

3.1. The effects of worldwide deterioration in competition

In the simulation, we apply shocks to ψ_{0s} in equation (T1.7f) in Table 1. Specifically, we raise ψ_{0s} from an initial value of 0.01, in all regions and the 13 MM industries, to a final value of 0.10. Figure 1 helps to explain what this means.

The figure is a stylized representation of relationships between the number of firms (N_s) in an MM industry in region s and the profitability of the industry. Profitability is represented by the ratio of pure profits (Π) to the total costs of inputs (WL).

The downward-sloping M_0 line marked "Market" traces out what would happen to industry profitability if we made exogenous movements in the number of firms. We would expect that when the number of firms increases, industry output would increase and reduce profitability by reducing prices. The upward-sloping E_0 line marked "Entry incentive" is a diagrammatic representation of (T1.7f) with the ψ variables set at their initial values. The E_0 line shows that the emergence of higher profits induces entry of new firms. The initial equilibrium occurs at point A where the M_0 and E_0 lines intersect. As shown in the figure, we assume that this occurs with the profit ratio equal to the initial setting for ψ_{0s}, which is 0.01, and with the number of firms equal to $N_s^{initial}$ [denoted as $\bar{N}_s$ in (T1.7f)]. We set ψ_{1s} at 2.2314. With this value, a 10 percentage point movement rightward along the E_0 line increases N_s by 25 per cent [1.25 = exp(2.2314*(0.11-0.01))].

In the simulation, we shift the entry-incentive line upward from E_0 to E_1 in the 13 MM industries in all regions. For any given number of firms, the profit ratio compatible with zero entry or exit is increased by 0.09. We have in mind a situation in which competition is reduced via mergers and anti-competitive practices, facilitated by, for example, government regulations, loyalty schemes and computer systems that make shifting between service providers difficult. With the upward shift in the Entry-incentive line, the equilibrium moves from A to B.

Simulation results for a selection of variables are shown in Table 2. For each variable the results are similar across regions. For explaining the results, it will be sufficient to focus on just one region, North America. To keep the results to a manageably small number, we report totals or averages over the 13 commodities/industries ($c \in MM$).

Consistent with Figure 1, the movement from the initial equilibrium to the final equilibrium (A to B in Figure 1) increases total pure profits (by 3.71 per cent of GDP in North America) and reduces the number of firms in MM industries (ave $N_s(c)$ for s = North America falls by 7.03 per cent).

With similar reductions in the number of MM firms in other regions, there is a decrease in the number of effective competitors in North America's domestic markets for MM commodities (ave $Ntot_d(c)$ for d = North America falls by 6.97 per cent).

Table 2. Effects of a reduction in competition: a 9 percentage-point upward shift in the entry-incentive line in all regions and all MM industries*.

		Oceania	East Asia	SE Asia	South Asia	N America	Latin America	EU_25	MENA	SSA	Rest of World
1	Pure profits as a per cent of GDP: change in 100*Π/GDP	3.72	4.74	4.54	2.38	3.71	3.37	4.44	3.90	3.51	3.91
2	Number of firms in MM industries in s: ave over c in % Δ in $N_s(c)$, c∈MM	-6.33	-7.03	-6.57	-6.43	-7.03	-6.51	-6.89	-6.07	-6.36	-6.49
3	Number of effective competitors in markets for MM coms: ave over c in % Δ in $Ntot_d(c)$	-6.88	-6.91	-6.85	-6.90	-6.97	-6.84	-6.90	-6.90	-6.79	-6.82
4	Perceived elasticities by suppliers to MM markets in d: ave over c in % Δ in $\Gamma_d(c)$	-2.59	-2.60	-2.59	-2.60	-2.62	-2.58	-2.59	-2.60	-2.55	-2.56
5	Markup applied by suppliers to MM markets in d: ave over c in % Δ in $M_d(c)$	2.52	2.53	2.51	2.53	2.56	2.51	2.53	2.53	2.49	2.50
6	Modification of min. productivity of varieties supplied to d: ave over c and s in % Δ in $Z_{sd}(c)$	3.26	3.71	1.95	2.82	3.64	3.20	3.64	2.93	2.54	3.09
7	Varieties delivered to MM markets in d: ave over c and s in % Δ in $N_{sd}(c)$	3.38	3.01	4.49	4.28	2.79	3.79	2.96	4.24	4.18	3.75
8	Price to users in d of MM coms: ave over c in % Δ in $P_d(c)$ relative to general price level in d	4.19	4.48	3.97	3.85	4.27	3.95	4.56	4.11	4.26	4.19
9	Real GDP: percentage change	0.45	0.45	0.23	0.36	0.40	0.48	0.52	0.62	0.41	0.50
10	Real private consumption (welfare): percentage change	-0.09	1.43	0.94	0.37	0.39	0.52	0.87	0.55	0.03	0.43
11	Real post-tax wage rate: percentage change	-3.69	-3.32	-3.35	-1.26	-3.74	-2.62	-4.39	-2.44	-3.11	-3.17

Notes: *These are the 13 industries listed in footnote 3.

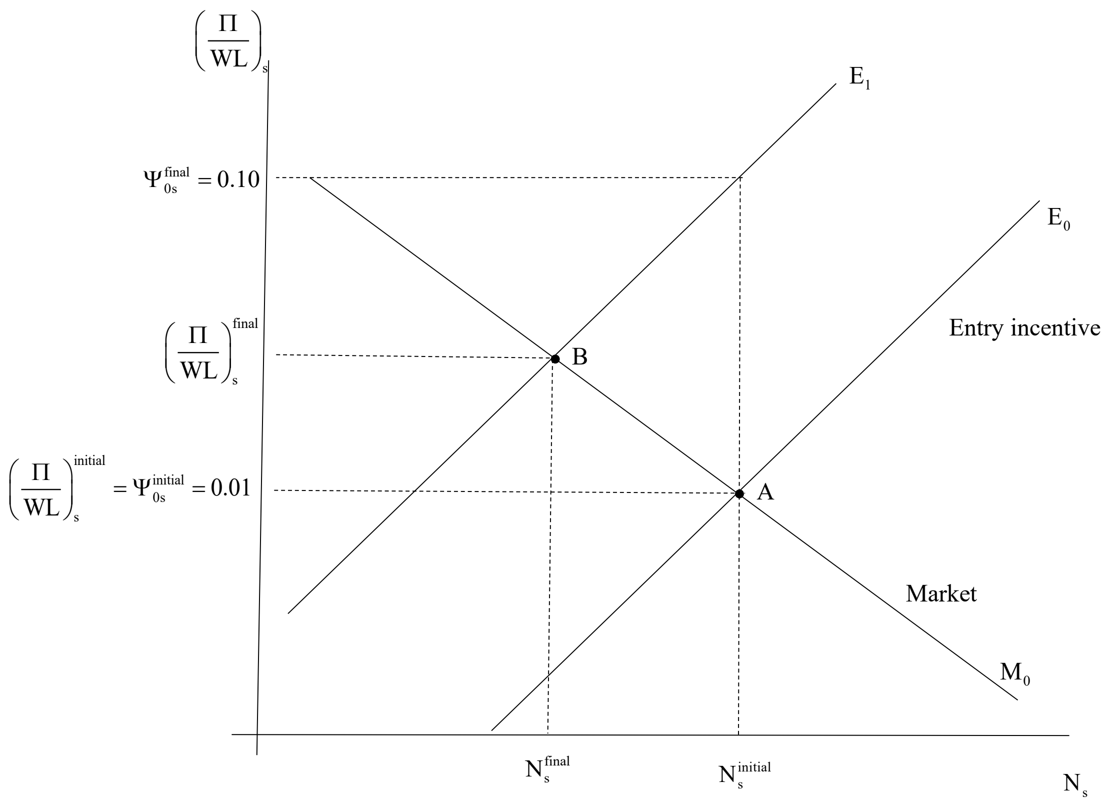

Figure 1. Simulating a reduction in competition by an upward shift in the entry-incentive curve.

Consequently, domestic and foreign suppliers of MM products to North America perceive a decrease in the elasticity of demand for their products in North America (ave $\Gamma_d(c)$ for d = North America falls by 2.62 per cent).

The reduction in the perceived elasticities leads suppliers of MM products to adopt higher markup factors on marginal costs in setting their prices (ave $M_d(c)$ for d = North America rises by 2.56 per cent).

With less competitors in North America (lower $Ntot_d$), suppliers of MM products make their variety decisions with more awareness of the likely reactions of rivals. This is encapsulated in the increase in the average Z-factor on sales of MM commodities (ave $Z_{sd}(c)$ for d = North America rises by 3.64 per cent).

Table 2 shows an increase in the number of MM varieties delivered to each destination d, 2.79 per cent for North America. This is the net outcome of three forces: two negative and one positive. The first negative is the higher value for Z_{sd}. This has a negative influence on the number of varieties per firm supplied from s to d. The second negative is the reduction in the number of firms in s. The positive influence is the higher markup in d (higher value for M_d). This encourages suppliers to d's market to send more varieties because with a higher markup factor, some varieties that could not previously meet the threshold net revenue requirement to cover setup costs on the sd-link can now do so. It turns out that in the determination of the number of varieties in the d market, the M_d effect dominates the combined effects of higher Z_{sd}'s and lower numbers of firms in s. In section A.6 of the supplementary material we show that that a sufficient condition for an increase in varieties to d is that $Z_{sd}/(M_d\text{-}1)$ falls for all s. This condition holds in our simulation.

Through the love-of-variety effect, the increase in varieties in market d has a negative effect on the cost to consumers of satisfying a unit of demand of an MM product. However, this effect is outweighed by the increase in the markup factor in market d. In Table 2, P_d increases in each market (ave $P_d(c)$ for d = North America rises by 4.27 per cent). Again, as demonstrated in section A.6 of the supplementary material, a sufficient condition for an increase in P_d is that $Z_{sd}/(M_d\text{-}1)$ falls for all s.

Macro results

The reduction in competition in MM industries causes GDP to increase in all regions (0.40 per cent in North America). With increases in GDP, there are increases in private consumption in all regions except Oceania. The small decrease in private consumption in Oceania was caused an unfavorable terms-of-trade movement.

The positive movements in GDP reflect economies of scale for firms in MM industries. As shown in row 2 of Table 2, there are sharp declines in the numbers of these firms. This saves on set up costs, increasing output per unit of input in the MM industries in all regions. The saving on input costs is equivalent to a GDP-increasing technological improvement.

With increases in GDP and consumption, what is not to like about a deterioration in competition?

The answer is negative effects on real wage rates (-3.74 per cent for North America). This is the most important result from our simulation. Deterioration in competition can lead to inequitable changes in the distribution of income.

4. Concluding remarks

Melitz introduced an attractive theoretical model of trade that recognizes:

- industries with multiple varieties which are treated by users as imperfect substitutes;
- economies of scale flowing from two types of fixed costs, setup costs for firms and setup cost on trade links;
- an endogenous cut-off point for each s-d link that determines the minimum productivity variety that is sent on the link;
- industry productivity effects that arise from changes in the variety composition of an industry's output.

Melitz adopts the LGMC assumptions that all firms in an industry are small and that free entry ensures that industry pure profits are zero. Inspired by Markusen (2023), we reformulated the Melitz model as SGMC. Like Markusen we allow for large firms whose decision making anticipates reactions by competitors. Both Melitz and Markusen assume that each firm produces just one variety. To reconcile having industries with a small number of firms but a large number of varieties, we assume that each firm can produce multiple varieties. A major point of difference in our model from those of Melitz and Markusen is that pure profits can persist at the industry level.

Melitz and Markusen focus primarily on trade. With Melitz-Markusen (MM) features embedded, we obtained GTAP-MM results in an illustrative tariff simulation [reported in Dixon and Rimmer, 2024] that are distinctly different from those generated by a standard Armington model. It would be of interest in future research to calculate optimal tariffs in GTAP-MM. Consistent with the arguments in Balistreri and Markusen (2009) and Dixon and Rimmer (2010), we would expect the inclusion in GTAP-MM of market power and pure profits to lower optimal tariffs. Nevertheless, we don't think that trade policy is the most important application area for GTAP-MM.

We think that the MM formulation may give new perspectives on competition policy. In the illustrative MM simulation in section 3, we showed that deterioration in competitiveness in industries can increase pure profits as a share of GDP and reduce real post-tax wage rates. Deterioration in competitiveness has been documented by Grullon et al. (2019) for the U.S. and by Fels (2024) for Australia. With pure profits accruing mainly to top managers in large corporations and to well-off, old people holding large retirements funds, could a deterioration in competitiveness be part of the explanation of public discontent with the performance of economies despite high rates of employment and satisfactory growth in macro variables such as GDP and private consumption? Could lack of competition be part of the explanation of intergenerational inequity in which young people relying on declining or sluggishly growing wage income struggle to achieve an acceptable standard of living, while older people enjoy a prosperous lifestyle?

Relative to Armington and LGMC versions of Melitz, the MM model is a step in the right direction towards answering these questions. It contains necessary ingredients: pure-profits and non-competitive oligopolistic behaviour. However, much more research is necessary. We will need to analyse data on industry concentration ratios (e.g. shares of industry outputs accounted for by the top 4 firms) and on profit shares in GDP. We will need to move from the relatively crude comparative-static modelling in this paper to dynamic modelling.

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