CHAPTER 24

Market Structure in Multisector General Equilibrium Models of Open Economies

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Abstract

We provide an overview of several approaches to modeling market structure in multisector general equilibrium (MSGE) models, including both oligopoly and monopolistic competition. We emphasize open economy models and applications to international economic policy. We map out practical strategies for implementing variations on market structure, including functional forms and calibration strategies. We also identify areas that, in our view, are promising for further research. This includes both exploring the implications of moving away from average cost pricing models (including monopolistic competition) for labor market outcomes and inequality, and better methods for econometric estimation of parameters and confronting alternative forms of market structure against measures of model performance (specification testing).

Keywords

Market structure in MSGE models, oligopoly, monopolistic competition

JEL classification codes

F10, F17, D43, D58

24.1 INTRODUCTION

Once we depart from the world of perfect competition, variations in market structure can greatly complicate general equilibrium analysis of the impact of policy. This relates to potential shifts in the cost of production, rising and falling profit margins, new product introduction, increased competitive pressure on domestic producers, cross-boder shifts in profits, and changes in the parameters underlying strategic decisions made by firms.[1]

[1] Market structure has proven to be an important factor in explaining differences in otherwise seemingly identical multisector computable general equilibrium-based policy assessment exercises. See, e.g. Francois (2006), Baldwin and Venables (1995), and Gilbert and Wahl (2002), as well as the survey by Francois and Roland-Holst (1997). While the interaction of market structure can be quite complex, the minimum conditions for welfare gains are often linked to realized changes in industry output (Markusen *et al.*, 1994).

Handbook of CGE Modeling - Vol. 1 SET
ISSN 2211-6885, http://dx.doi.org/10.1016/B978-0-444-59568-3.00024-9

The early generation of multisector general equilibrium (MSGE) models often avoided questions of market structure, emphasizing constant returns to scale technologies, competitive markets and constant factor productivity. The move away from the constant returns to scale and perfect competition MSGE models began in the 1980s, and was inspired by the "new" trade theory of the 1970s and 1980s.[2] This move to incorporate representations of imperfect competition in the subsequent MSGE literature has included firm- and industry-level efficiency linked to strategic interactions between firms, pressure on pricing structures linked to trade and foreign direct investment (FDI), variety effects linked to monopolistic competition, and productivity at the industry level linked to Schumpeterian mechanisms of firm selection. At one level, the question of market structure in applied general equilibrium models can be viewed as a theoretical one — how has market structure been specified mathematically? At the same time, there is a deeper question that is often left unanswered — what is the "best" specification of market structure for the question at hand? This matters for a number of reasons. One reason is that different market structures imply a different propensity for trade and industry location to adjust to (and in some cases to essentially offset) policy changes. The sensitivity of firm location to market structure has been important to the literature on economic geography and location of industry.[3] Another reason is that, under imperfect competition, firms may absorb reductions in trade costs and taxes, such that there is less impact on trade and prices than theory would suggest (Francois and Wooton, 2001, 2010). If market structure matters for the question at hand, getting it wrong may lead to substantial overestimation or underestimation of the efficacy of policies. Finally, alternative policies that appear equivalent under perfect competition can have quite different effects depending on market structure. For example, tariffs and quotas alter the competitive position of domestic firms relative to foreign firms in different ways (Bhagwati, 1965).

In this chapter, we provide an overview of several of the approaches found in the literature. We emphasize open economy models and applications to international economic policy.[4] Section 24.2 focuses on models of oligopoly. This is followed in Section 24.3 by discussion of monopolistic competition in MSGE models. We then

2 See Norman (1990), Brown *et al.* (1999), Brown (1994), and Harris (1984).

3 For example, the vast bulk of computational assessments of climate change mitigation policies have drawn on relatively pedestrian, Armington-based demand structures (Burniaux and Truong, 2002). The sensitivity of industry location to market structure may point to a very real need to critically assess the sensitivity of carbon leakage estimates under regional emission schemes to underlying market structures (Boehringer *et al.*, 2004).

4 We do not provide a comprehensive set of MSGE model code for modeling imperfect competition. We refer the reader to Francois and Roland-Holst (1997), Francois (1998), and Balisteri and Rutherford (2012) for maquette applications of oligopoly, scale economies with average cost pricing, and small- and large-group monopolistic competition. For detailed sample code of monopolistic competition with firm heterogeneity, see Balistieri and Rutherford (2012).

focus on directions for future research in Section 24.4. A short summary is provided in Section 24.5.

24.2 OLIGOPOLY

Between perfect competition and monopoly lies a wide range of possible industry structures. Indeed, when the number of firms is small enough for them to influence one another, complex strategies can arise. Compared to the literature on industrial organization, the MSGE literature does not cover a particularly wide spectrum with respect to such strategies. Rather, it largely follows a limited, parsimonious set of oligopoly specifications.[5] This reflects very real limits on data availability, as well as the level of aggregation typically available for MSGE modeling. Given the level of aggregation often found in multisector models, they are not always clear, therefore we gain insight when increasingly complex, firm-level interactions are explicitly modeled for a heterogeneous sector such as "other machinery" or "chemicals, pharmaceuticals and cosmetics," that is at best a mixed bag of products, firms and industries. Even where we clearly do have only a few firms (like automobiles or mid-sized aircraft), the best approach may still be a stylized one due to data limitations.

While MSGE models of oligopoly are likely to be relatively simple compared to what is found in the antitrust literature, the general equilibrium approach to market structure also yields substantially different (and in some ways arguably richer) perspectives on antitrust and distributional effects of strategic competition and trade policy than does the standard partial equilibrium industrial organization framework. For example, the typical industrial organization analysis suggests that significant markups within a single industry are a clear indication of socially wasteful misallocation of resources. Yet once analysis is extended to a general equilibrium framework, the perspective changes fundamentally. In particular, once the interplay between markups (from exercise of market power) in different sectors is taken into account, it is the difference in competition between sectors that is actually critical (Francois and Horn, 2004). In other words, it is not so much levels of markups, but their variation across sectors that matters for resource allocation. In addition, the scope for strategic trade policy through the application of strategic competition policy (e.g. by promoting collusion by exporting firms) is also likely to be limited in general equilibrium by its impact on marginal costs. Finally, because by definition profits are the gap between price and cost, in general equilibrium they represent a reallocation of income from primary factor owners to the recipients of rents. As such, oligopoly models can also yield much stronger real income effects from policy

[5] See Sutton (2007) and Berry and Reiss (2007) for reviews of the recent literature in this area. For discussion of theoretical issues raised in general equilibrium, multisector models, see Francois and Horn (2008) and Leahy and Neary (2011).

experiments through changes in labor incomes than either Armington or monopolistic competition models. This is because falling average markups across an economy in general equilibrium signal a reallocation of income toward primary factors.[6]

In this section we examine a number of these issues. We start with a basic algebraic discussion of oligopoly and reduced-form collusion. This is followed by a discussion of entry and exit, as well as applications in the literature.

24.2.1 Fixed incumbents and reduced-form collusion

A key starting point with oligopoly is representation of markups. We have econometric evidence that in a world of imperfect competition, industries that are more exposed to trade have profit (price—cost) margins, suggesting less monopolistic power and greater benefits to intermediate and final consumers.[7]

In formal terms, introduction of markup rates μ involves both introducing a markup or wedge between price and cost, and introducing a formal rule, based on a model of market structure, for the determination of this rate of markup within the model. Under constant returns to scale such that average cost is equal to marginal cost $ac_i = mc_i$. In more general terms, the markup rate μ_i relative to unit cost follows from profit maximization and is defined as:

$$(1 + \mu_i)mc_i = P_i$$

$$\Rightarrow \mu_i = \frac{P_i - mc_i}{mc_i} \tag{24.1}$$

$$\mu_i\left(\frac{mc_i}{P_i}\right) = \frac{P_i - mc_i}{P_i}. \tag{24.2}$$

[6] Francois and Horn (2004) examine the concept of Lerner proportionality, where markups are identical across sectors. In this case, and in the absence of non-homothetic preferences, the impact of imperfect competition is not to distort output, but to redistribute income from factor owners to recipients of profits. Hence, aggregate welfare is unaffected, while trade/strategic competition policy is focused on owners of firms in the imperfectly competitive sector in the country imposing a markup. The only primary factors that do not lose unambiguously from such a policy are those that are relatively specific to the competitive sector.

[7] Tybout (2000) surveys econometric evidence on trade and industry performance in developing countries. These show that even small firms are relatively efficient and it is not scale of inefficiency, but exercise of market power that is affected by openness of markets. Levinsohn (1993) provides estimates of the effect on firms' markups or price—cost margins of the large-scale removal of import protection in the Turkish manufacturing sector in 1984, finding support for the "import-as-market-discipline" hypothesis. Harrison (1994) finds similar results for Côte d'Ivoire. Roberts and Tybout (1996), summarizing the results of five case studies of semi-industrialized countries, report that in every country studied a relatively high industrywide exposure to foreign competition is associated with lower cost—price margins and that this effect is concentrated in large plants. Berry *et al*. (1997) provide a detailed econometric study of the US voluntary export restraints (VERs) on automobiles from Japan under oligopoly, estimating net welfare losses to the US de Melo and Tarr (1992) reach a similar conclusion based on a numerical general equilibrium assessment.

In the presence of scale economies for firm i, we can define the cost disadvantage ratio $\phi_i = ac_i - mc_i/ac_i$. This is a term in the industrial economics literature and follows from engineering studies on the impact of operating manufacturing facilities below the planned scale of production. It measures the extent to which average cost per unit includes a share of fixed or overhead costs that decline on a per unit basis with increased output. At lower scales of production, this per unit overheads burden will be higher in the face of fixed costs (Francois and Roland-Holst, 1997). With some manipulation, this can be shown to be equivalent to the condition $mc_i = ac_i(1 - \phi_i)$. The markup over average cost is then:

$$P_i = (1 + \mu_i)(1 - \phi_i)ac_i. \tag{24.3}$$

Equation (24.3) links the gap between prices and average cost to a mix of market power and scale effects. Combined with homothetic cost functions, it provides us an immediate bridge to simple models of market power and scale (e.g. with symmetric Cournot–Nash firms producing subject to scale economies). In what follows in this section, we focus on the determinants of such price–cost markups. For representing them in a MSGE context, this can be done through a "profit tax" on output set on average costs at rate μ under constant returns or at rate $\mu(1 - \phi_i)$ when we have scale economies (and so a spread between average and marginal costs). Essentially the rate of this "tax" will depend on the endogenously determined markup.[8] In single-household models, it is then sufficient to map the income from such markups back to the aggregate household. Where they are collected by different agents (either domestic for foreign), a more detailed mapping is called for.

One early introduction of markups determined by firm behavior into an open economy MSGE model involved the Eastman–Stykolt specification of collusive behavior. Under this approach, firms are assumed to set their prices based on a limit determined by the landed price of imports. This assumption results in relatively large potential effects because it brings about greater rationalization of firm output than under either perfect competition or monopolistic competition, by which we mean greater equilibrium firm output response to changes in policy variables. Indeed, Harris (1984) demonstrated that specifying oligopolistic competition in sectors where this appears to be appropriate can substantially affect the estimated static welfare implications of trade reform and related measures such as the productivity implications of trade reform. In Cox and Harris (1985), this assumption contributed to far greater estimated welfare gains from trade reform than monopolistic competition because the Eastman–Stykolt speficiation resulted in greater rationalization of firm output than under other specifications. However, the assumptions of the Eastman–Stykolt has not been supported in subsequent analysis (Baggs *et al.*, 2002).

[8] In contrast, in large-group monopolistic competition models, as discussed later, these markups are fixed.

An alternative is the so-called Cournot conjectural variations model. This has been available as extensions to multiregion models like GTAP (Global Trade Analysis Project) since the mid- 1990s (see, e.g. Francois, 1998; Francois and Roland-Holst, 1997). To illustrate this approach, assume that each firm produces a homogeneous product, faces downward-sloping demand and adjusts output to maximize profits, with a common market price as the equilibrating factor. Further assume, following Frisch (1933), that firms anticipate or conjecture the output responses of their competitors. These firms are in an industry populated by n identical firms producing collective output $Q = nQ_i$. When the ith firm changes its output, its conjecture with respect to the change in industry output is represented by Ω_i, which equals a common value Ω under the assumption of identical firms. Formally, we therefore define the coefficient Ω as the (common) value of this conjectural variation in output:

$$\Omega_i = \frac{\mathrm{d}Q}{\mathrm{d}Q_i}. \tag{24.4}$$

The representative profit function is as:

$$\pi_i = PQ_i - TC_i, \tag{24.5}$$

where TC_i is the total cost for firm i with marginal cost $mc_i = MC$, P is the common equilibrium price and π_i is profit. Combining Equations (24.4) and (24.5) we can derive the following first-order condition for profit maximization:

$$\begin{aligned}\frac{\mathrm{d}\pi_i}{\mathrm{d}Q_i} &= P + Q_i\frac{\partial P}{\partial Q}\,\frac{\partial Q}{\partial Q_i} - \frac{\partial TC_i}{\partial Q_i}\\ &= P + Q\frac{Q_i}{Q}\,\frac{P}{P}\,\frac{\partial P}{\partial Q}\,\frac{\partial Q}{\partial Q_i} - \frac{\partial TC_i}{\partial Q_i}\\ &= P - \frac{P}{n\varepsilon}\Omega - MC = 0.\end{aligned} \tag{24.6}$$

In Equation (24.6), the term ε is the elasticity of demand $\frac{\partial Q}{\partial Q}\,\frac{P}{Q}$, and we have substituted $n = Q_i/Q$ and our definition of Ω. Manipulation of Equation (24.6) leads to the following oligopoly pricing rule:

$$\frac{P - MC}{P} = \frac{\Omega}{n\varepsilon}. \tag{24.7}$$

We can combine Equation (24.7) with (24.2) and/or (24.3) to determine and apply markups against costs. Equation (24.7) covers a range of relevant cases. The classic Cournot specification corresponds to $\Omega/n = n^{-1}$, where each firm acts as if the others will not change their output in response. In this case, perceived industry output changes coincide with its own. Price–cost margins vary inversely with the number of firms (n)

and the market elasticity of demand (ε), as logic would dictate. In the extreme cases, a value of $\Omega = 0$ corresponds to perfectly competitive average cost pricing, while $\Omega = n$ is consistent with a perfectly collusive or monopolistic market. The range of outcomes between these extremes, as measured by $0 \leq \Omega/n \leq 1$, provides a reduced form mechanism for representing varying degrees of market power within an industry. As such it can be used to gain insight into the significance of varying degrees of market power.

24.2.2 Entry and exit

The ultimate scope for entry, exit or realization of scale economies in particular industries is an empirical question. In the present context, entry and exit are basically model closure problems, taking the form of limiting rules for incumbent profits, prices or some other indicator of the return on existing operations. In general, these rules should provide an explicit link between profits and entry.[9] Another is to take the population of potential firms as given, but characterized by heterogenous cost structures. Equilibrium price then reflects the number of firms that can remain in the market, given negativity constraints on profits.

While the framework above can be appropriate when the degree of industry cooperation or collusion is regulated, we can also extend this framework to allow for the possibility of market entry and exit in response to changed market conditions. The number of firms n then becomes endogenous and the competitive climate in the industry varies accordingly.[10] To do this, first note that the price–cost margin in Equation (24.7) varies with the number of firms. In particular, margins shrink with an increase in the number of firms. This is the first effect of entry. To model this effect we can combine a variation of a limit (non-zero) profit condition $\pi_i \geq 0$, with Equation (24.7). We then have entry limiting profits and the number of firms endogenous to the commercial climate (e.g. import competition). Another effect of entry and exit relates to firm-level-scale economies. Entry and exit can alter the average scale of firm operations, other things being equal, and in the increasing and decreasing returns cases this can have aggregate efficiency effects. Yet another effect, when firms vary in cost structures, is the impact of changes in equilibrium price on the profitability of individual firms.

We can also extend the basic oligopoly structure to include geographic price discrimination under product differentiation. For example, if we assume Armington

9 Recent literature (theoretical and econometric) on trade and firm heterogeneity with trade and FDI has largely avoided the question of oligopoly. This situation is reflected in the MSGE literature as well, which includes some nascent steps to incorporate heterogeneity with monopolistic competition (discussed later in this chapter), but no real systematic effort to look at oligopoly with heterogeneous firms in a MSGE framework. Given that most industries are dominated by a small number of large firms, it seems to us that this would be a step closer to how individual markets actually work (both for the theoretical and applied literature) than the current emphasis on "atomistic heterogeneity" under monopolistic competition.

10 See, e.g. Bekkers and Francois (2008) and Leahy and Neahy (2011).

demand structures, then the elasticity of demand for the population of firms that make up a national industry will be a function not only of the population of firms at home, but also of market access conditions at home and abroad. Recall that in Armington models, goods are differentiated by country of origin and the similarity of goods from different regions is measured by the elasticity of substitution. Formally, within a particular region, we assume that demand for goods in sector j from different regions s is represented as an aggregate composite good according to the following constant elasticity of substitution (CES) function:

$$q_{j,r} = \left[\sum_{s=1}^{R} \alpha_{j,s,r} X_{j,s,r}^{\rho_j}\right]^{1/\rho_j} \qquad 0 < \rho_j < 1. \tag{24.8}$$

In Equation (24.8), $X_{j,s,r}$ is the quantity of j from region s consumed in region r. The elasticity of substitution between varieties from different regions is then equal to σ_j, where $\sigma_j = 1/(1-\rho_j)$. For tractability, we focus here on the non-nested case, where σ_j is identical across regions, and is equal to the degree of substitution between imports, as a class of goods, and domestic goods. As Equation (24.8) is a CES function, the price index for the composite good is the corresponding CES price index:

$$P_{j,r} = \left[\sum_{s=1}^{R} \alpha_{j,s,r}^{\sigma_j} P_{j,s,r}^{1-\sigma_j}\right]^{1-1/\rho_j}. \tag{24.9}$$

At the same time, from the first-order conditions for constrained optimization of (24.8), the demand for good $X_{j,s,r}$ can be shown to equal:

$$X_{j,s,r} = [\alpha_{j,s,r}/P_{j,s,r}]^{\sigma_j} P_{j,r}^{\sigma_j-1} E_{j,r}. \tag{24.10}$$

In Equation (24.10), the term $E_{j,r}$ is total expenditure in region r on goods indexed by j. Assuming Cobb–Douglas demand at the upper nest, the elasticity of demand can then be derived from Equations (24.9) and (24.10) for each variety s sold in market r:[11]

$$\epsilon_{j,s,r} = \sigma_j + (1-\sigma_j) S_{j,s,r}. \tag{24.11}$$

The last term in Equation (24.11) measures the effect of market share S in market r on the elasticity of demand. We have a number of options at this point and in large multiregion models, full regional price discrimination for each product in each region can add a great deal of numerical complexity to the model.[12] We could

[11] If we drop the Cobb–Douglas assumption, we need to add an additional term for changes in sector-level expenditure, linked to the CES price index.

[12] The recent literature on firm heterogeneity (although generally under monopolistic competition) focuses, theoretically, on pricing rules that are destination specific. This has proven an obstacle to extension to applied (MSGE) models. In large part, this is because calibration then requires information on fixed versus marginal cost on a bilateral basis sufficient to calibrate bilateral markup rates by product.

proceed here with a monopolist or a representative oligopolist in each region that can price discriminate between regional markets. In this case, the regional elasticity of demand (and hence the relevant markup of price over marginal cost) is determined in each market by Equation (24.11). However, this poses a potentially large computational (and data) problem in multiregion, multisector MSGE models. In particular, it implies at a minimum nR^2 sets of elasticity and price markup equations for an R-region, n-sector model. In models where different sources of demand can potentially source imported inputs in different proportions, we then have a potential for $(\upsilon + k)\upsilon R^2$ elasticity and markup equations, where k is the number of demand sources in each region and υ the number of sectors. Additionally, depending on the context of the modeling exercise, one must be careful not to hang too much significance on the benefits of highly complex representation of strategic pricing decisions.

Given all the caveats in the previous paragraph, a greatly simplifying assumption involves assuming that firms charge a single ex-factory price. With trade, this could mean that traded goods are first sold domestically to exporters. It is also consistent with antidumping rules, which technically make price discrimination by destination actionable by punitive antidumping duties. Following this approach, our representative firm charges a single markup. The aggregate elasticity of demand will then be determined by a combination of σ_j and a weighting of $(1-\sigma_j)$ determined by regional market shares. This involves the weighting parameter we represent by ζ. We can formalize this in:

$$\varepsilon_{j,s} = \sigma_j + (1-\sigma_j)\zeta_{j,s} \tag{24.12}$$

$$\zeta_{j,s} = \sum_{r=1}^{R} \frac{X_{j,s,r}}{X_{j,s}} S_{j,s,r} \tag{24.13}$$

$$\frac{P_{j,s} - MC_{j,s}}{P_{j,s}} = \frac{\Omega_{j,s}}{n_{j,s}\varepsilon_{j,s}} = \frac{\Omega_{j,s}}{n_{j,s}}[\sigma_j + (1-\sigma_j)\zeta_{j,s}]^{-1}. \tag{24.14}$$

Here, demand for the regional product is downward-sloping, as defined by Equations (24.12) and (24.13). We have further assumed that firms anticipate or conjecture the output responses of their local competitors, which leads to Equation (24.14) as a determinant of price—cost margins as a function of $n_{j,s}$, the number of local firms. Further competition from producers of other national varieties is felt through the impact of market shares on perceived elasticities.

We can also introduce a heterogenous cost structure across firms, in terms of variations in mc_i. For example, returning to Equation (24.6), assume a population of firms i with different marginal costs mc_i:

$$\begin{aligned}\frac{d\pi_i}{dQ_i} &= P + Q_i\frac{\partial P}{\partial Q}\,\frac{\partial Q}{\partial Q_i} - \frac{\partial TC_i}{\partial Q_i}\\ &= P + Q\frac{Q_i}{Q}\frac{P}{P}\,\frac{\partial P}{\partial Q}\,\frac{\partial Q}{\partial Q_i} - \frac{\partial TC_i}{\partial Q_i}\\ &= P - \frac{\theta_i P}{\varepsilon}\Omega - MC = 0.\end{aligned} \tag{24.15}$$

In Equation (24.15) the term θ_i refers to market share for an individual firm i. In the classic Cournot case where $\Omega = 1$, at price P, θ_i is then:

$$\theta_i = \max\left[0, \left(\frac{P - mc_i}{P}\right)\varepsilon\right]. \tag{24.16}$$

The zero share holds for firms with costs above prices. Firms with lower marginal costs will have greater market share, while firms with high marginal costs may be squeezed out if the price falls below the marginal cost (e.g. due to tariff reductions).

Table 24.1 summarizes the steps for implementation of the Cournot–Armington model developed above. Given the equivalence, in a single-household model,

Table 24.1 Cournot–Nash–Armington oligopoly—specification and calibration

Markup taxes	
Price discrimination indexed by destination d.	Export and home sales tax $tm_{\mathrm{d}} = \Omega n^{-1}(\sigma + (1-\sigma)S_{\mathrm{d}})^{-1}$
Ex-factory pricing.	Output tax $tm = \Omega n^{-1}(\sigma + (1-\sigma)\zeta)^{-1}$
Differential enforcement by competition authorities.	Export and home sales tax $tm_{\mathrm{d}} = \Omega_{\mathrm{d}} n^{-1}(\sigma + (1-\sigma)S_{\mathrm{d}})^{-1}$
Implementation and calibration	
Benchmark markups need to be inserted in the data as sales or export taxes.	
A standard CES (Armington)-type demand system can be used.	
With average markup data, Ωn^{-1} can be calibrated from the ex-factory markup equation.	
Properties	
Markups are increasing in market power Ωn^{-1}.	
Markups are decreasing in entry n.	
Without price discrimination, loss of market power in one market lead to falling markups in other markets.	
With price discrimination, if the output response from improved market access in one market leads to higher marginal costs and falling market share in third markets, markups will fall in third markets; in short, trade diversion may also mean diversion of markups.	
If we model Ωn^{-1} as a regulatory outcome, regulatory differences imply markup differences.	

between markups and production or sales taxes, markups in Table 24.1 are specified as output or trade taxes. In particular, implementation of variations in oligopoly in a MSGE framework involves adding equations to the basic model for the determination and application of the markups as taxes, per the equations in Table 24.1. This requires calibration. One option, given demand parameters, is to calibrate markups consistent with given degrees of market power or concentration. Unfortunately, the available estimates of markups are crude at best, plagued by estimation problems (DeSouza, 2009) and indeed markups are typically estimated under assumptions of constant returns to scale. It is just recently that estimators of markups and scale have emerged that are consistent with scale economies (Feenstra and Weinstein, 2010; Katayama *et al.*, 2009).

24.2.3 Further aspects of market power

Despite data constraints, specifying oligopoly in sectors (where appropriate) does matter. It can lead to substantially different estimated welfare effects from trade policy adjustment. This is because reductions in trade barriers can reduce pricecost margins, and result in gains to national income resulting from output expansion and greater exploitation of scale economies as well as those from increased imports. For example, Devarajan and Rodrik (1998) found that expansion of firm output in the presence of scale economies in Cameroon was an important source of gain from trade liberalization, with the benefits increasing from around 1% of GDP to 2% when this component of adjustment was included. Recent work on services has also emphasized the importance of markups for the welfare consequences of policy reform in services. Indeed, where policies generate real costs, their removal may give both falling markups on costs and falling costs. Recent examples along these lines include Konan and Maskus (2006), who examine market structure in services in Tunisia; Rutherford *et al.* (2005), who examine market structure in financial services in Russia; and Tarr in Chapter 6 of this Handbook who looks at services and FDI in models with endogenous productivity effects. In recent models of this type, FDI can play a central role, alongside trade itself, in placing competitive pressure on firms. In addition, the recent services literature has also extended modeling of price–cost margins to reflect market power in the distribution sector. For example, Bradford (2003) examines distribution markups across the Organization for Economic Cooperation and Development (OECD) with a four-region MSGE model, finding that inefficiencies in distribution reduce imports and have effects comparable to tariffs and non-tariff barriers. This is similar to the finding by Francois and Wooton (2010) that in the EU, variations in distribution sector competition may, in effect, greatly limit scope for increased trade under the EU single-market program. Francois and Wooton (2001) focus on a related issue, with a numerical model where trade requires transport costs supplied by a shipping sector operating as an oligopoly. A basic message is that when service sectors are oligopolies (including trade and transport/logistic firms), with distribution firms exercising market power on two margins, both towards producers and consumers, gains from trade in goods also hinges on the degree of competition in services.

Labor market effects are another area where oligopoly can greatly change the estimated impact of policy shifts. In contrast to competitive and monopolistic competition models, models of oligopoly typically include markups of price over average cost. This is potentially quite important when we focus on labor market impacts. To understand this point, it helps to think about what exercise of market power means. When firms constrain output to raise price, this will invariably depress demand for labor. In general equilibrium, labor markets then clear by cutting wages (with flexible wages) or cutting employment levels (when labor markets are inflexible). This adjustment along the wage or employment margin then establishes equilibrium, given that firms are exercising market power to open a gap between price and cost. In other words, when individual oligopolists then try to raise prices by reducing output, this leads to falling factor prices. With falling marginal cost, oligopolists boost output, restoring full employment at lower factor prices. In this sense, an economy-wide equivalence in the degree of competition is like an economy-wide value-added tax (VAT) or output tax, although the revenue goes to profit recipients. Where policy squeezes margins, we will then see rising real wages as income shares shift from profits to factors. For example, Francois (1998) reports real wage increases for Japan from a global free trade experiment of 2.4 to 3.4% with average cost pricing (Armington and monopolistic competition specifications), but 13.3 to 14.8% under oligopoly. The difference stems from the treatment of markups. Under monopolistic competition (as discussed below) markups are applied in a context of average cost pricing (and so apply to marginal, but not average cost) while under oligopoly they yield a gap between price and average cost.[13] The wedge between average price and average cost under oligopoly is what then drives the greater wage effects. As a simple example, with 20% markups for the full economy and a wage share of 60% of value added, a policy shock that reduced the prevailing markups from 20 to 10% and left GDP unchanged would also increase the share of national income accruing to primary factors. For labor, with a constant 60% of value added and an increased payment to value added at the expense of economic profits, this means a real wage increase of 12.5%. This points to income distribution effects under MSGE models with oligopoly absent under monopolistic competition models. Indeed, to the extent we do not actually have average cost pricing, assuming so may mean ignoring substantial redistribution impacts and attributing real wage changes to factors like productivity rather than changes in competition.

[13] Also see Francois (2001) for a comparison of labor market effects under both oligopoly and monopolistic competition.

24.3 MONOPOLISTIC COMPETITION

Monopolistic competition has been an important feature in multiregion MSGE models of the Doha and Uruguay Rounds, and can be traced to earlier MSGE work on US—Canada trade in the 1980s, including Reinert and Shiells (1993) and Francois and Shiells (1994), and the literature on deeper integration in the European Community (Smith and Venables, 1988). These models integrate firm-level differentiation of intermediate and final goods with intermediate-good linkages and input-output linkages. Arguments for following such an approach to market structure in MSGE models can be traced to Norman (1990) and Brown (1987), while the properties of this type of model, including agglomeration and stability properties, have been explored computationally by a number of authors (including Brown, 1994; Francois, 1998).

The use of Dixit—Stiglitz preferences for intermediate and final goods can result in larger estimates of the overall welfare benefits of trade reform by expanding the range of varieties available to consumers who prefer variety. Broadly speaking, in this class of models, effects are much larger with firm-based variety effects than with models based on the Armington specification. The love-of-variety specification is now widely used for non-agricultural sectors, but rarely used for agriculture, and this difference in specification can bring about large differences in the measured welfare implications of reform from different sectors, with the Michigan Model, for example, generating much larger gains from reform of the manufacturing sector relative to the agricultural sector (Brown *et al.*, 1999).

24.3.1 Variety, efficiency, markups and scale

We focus here on an approach involving homogenous firms with Spence—Dixit—Stiglitz (SDS) preferences. This is followed by discussion of recent heterogenous firm models. Within a representative firm, one can assume individual varieties are symmetrical in terms of selling at the same price and quantity, but that increases in the number of varieties yielding benefits because they are perceived to be different by intermediate and final demand agents. This approach can be nested within a basic CES demand system that includes both Armington- and SDS-type demand systems for individual sectors. This is because one can reduce Ethier and Krugman (differentiated intermediate and differentiated consumer goods)-type monopolistic competition models algebraically to Armington-type demand systems with external scale economies linked to a variety of effects (Francois and Roland-Holst, 1997; Francois and Nelson, 2002). In this case, we need to introduce the concept of variety-scaled goods. These are physical quantities indexed by country of origin s and scaled to include available varieties from each source s.

Our starting point is the standard conditions of monopolistic competition—free entry forces average cost pricing, while firms are each monopolists in their own product niche:

$$P_i\left(1-\frac{1}{|\varepsilon_i|}\right) = MC_i \tag{24.17}$$

$$P_i = AC_i. \tag{24.18}$$

Here, the term ε_i represents the demand elasticity for each unique variety i supplied to the market. Making substitutions, we then have:

$$\left(1-\frac{1}{|\varepsilon_i|}\right) = MC_i/AC_i$$

$$|\varepsilon_i|^{-1} = \frac{AC_i - MC_i}{AC_i} = \phi_i. \tag{24.19}$$

In Equation (24.19) the term ϕ_i is known as the cost-disadvantage ratio (CDR) (discussed above in the oligopoly section) and is a measure of economies of scale. In early literature, calibration was often based on engineering studies of the scope for scale economies in different industries (Francois and Shiells, 1994). Equation (24.19) tells us there is a functional relationship, in models of monopolistic competition, between demand conditions and the scale of production. Following Dixit and Stiglitz, we will combine this condition with aggregate demand based on CES preferences. In particular, assuming sufficient separability across sectors we can introduce a CES aggregation function at the industry level over varieties as:

$$Q = \left(\sum_{i=1}^{n} x_i^{\rho}\right)^{1/\rho} \quad \text{where } 1 > \rho > 0. \tag{24.20}$$

Given Equation (24.20), the demand elasticity for any variety is a function, in reduced form, of market share ξ_i of individual firms and of the substitution elasticity $\sigma = 1/(1-\rho)$:[14]

$$|\varepsilon_i| = \sigma + (1-\sigma)\xi_i. \tag{24.21}$$

Making a substitution of Equation (24.21) into Equation (24.19) yields a basic equilibrium condition, under SDS preferences, linking the scale of production and the demand conditions faced by individual firms. This condition balances optimal exercise or market power against the benefits of economies of scale:

$$\phi_i^{-1} = \sigma + (1-\sigma)\xi_i \tag{24.22}$$

[14] See Helpman and Krugman (1985) for explicit derivation.

$$\phi_i^{-1} = |\varepsilon_i|. \tag{24.23}$$

Equation (24.23) highlights a point we will return to when we discuss calibration. There is a close relationship between the elasticity of demand and the strength of scale economies. Depending on functional forms, this will place restrictions on what we can use to calibrate cost functions and demand functions. What we will do now is introduce specific functional forms and assumptions about firms, so that we can derive a set of equations that can be used to implement these equilibrium conditions within a MSGE model. This involves two alternative specifications of scale—fixed costs and fixed CDRs. This will also illustrate the closeness of cost- and demand-side parameters, as in Equation (24.23).

24.3.1.1 Fixed costs

Consider first the simple (and commonly used) assumption that scale economies follow from fixed costs. The cost function for an individual firm can be represented as:

$$c(x_i) = (a_i + b_i x_i)P_z \tag{24.24}$$

$$\phi_i = 1 - \frac{bx_i}{a_i + b_i x_i}. \tag{24.25}$$

Here, P_z is the price index for a bundle of inputs used in production. We next combine Equation (24.24) with Equation (24.22). This yields:

$$\bar{x}_i = \left(\frac{a_i}{b_i}\right)(\sigma - 1)(1 - \xi_i). \tag{24.26}$$

Equation (24.26) is a basic equation linking the equilibrium scale of production of individual firms $\bar{x}_i$ to equilibrium market shares and to firm cost structures. If we assume "large-group" monopolistic competition, wherein we have a sufficient number of firms so that $\xi_i \rightarrow 0$, Equation (24.26) tells us that equilibrium output per firm with positive production is fixed by its cost structure, and is indeed insensitive to entry and exit of additional firms. At this stage, we can also introduce a measure of markup. As we have monopolistic competition, with average cost pricing, we will define this relative to marginal costs. From Equation (24.17), we can rearrange and make a substitution from Equation (24.21). This yields the following expression for equilibrium markups:

$$m_i = (1 + \mu_i) = 1 + ((\sigma - 1) + (1 - \sigma)\xi_i)^{-1} \tag{24.27}$$

$$= \underset{\xi_i \rightarrow 0}{\sigma / (\sigma - 1)}, \tag{24.28}$$

where $P_i = m_i b_i P_z = (1 + \mu_i) b_i P_z$. To close the system, we need to solve the term ξ, and link it to inputs and global market shares. To do this, we adopt an additional assumption. Firms within a national industry are assumed to be symmetric and are assumed to engage in ex-factory pricing. As such, their individual market shares are a combination of the number of firms in the national industry n and the weighted market share of the national industry across markets ζ as defined in Equation (24.12) above. We therefore introduce two additional conditions — full utilization of the input bundles Z allocated to the sector and the definition of firm market share:

$$\xi_i = n^{-1}\zeta \tag{24.29}$$

$$Z = n(a + b\bar{x}). \tag{24.30}$$

Combining Equations (24.29) and (24.30) with Equations (24.26) and (24.27), we can derive the following equilibrium conditions:

$$\bar{x} = (a/b)(\sigma - 1)\left((Z - \zeta a)(Z + \zeta a(\sigma - 1))^{-1}\right) \tag{24.31}$$

$$m = (\sigma - 1)^{-1}(Z + \zeta a(\sigma - 1))(Z - \zeta a)^{-1} \tag{24.32}$$

$$n = (\sigma a)^{-1}(Z + \zeta a(\sigma - 1)). \tag{24.33}$$

Going further, we can also define what is known as "variety-scaled output," in a form that can be substituted directly into an Armington-type demand system (Francois, 2002). This term refers to physical quantities, with a "scaling" or quality coefficient that reflects the varieties embodied on total physical output. To do this, we first will impose our national symmetry conditions on Equation (24.20) and rearrange. Indexing across varieties indexed by source country s we have:

$$Q = \left(\sum_{s=1}^{R}\sum_{j=1}^{n_s} x_{s,j}^{\rho}\right)^{1/\rho} \quad \text{where } 1 > \rho > 0$$

$$Q = \left(\sum_{s=1}^{R} n_s \bar{x}_s^{\rho}\right)^{1/\rho} \quad \text{where } 1 > \rho > 0. \tag{24.34}$$

We define variety-scaled output as:

$$\tilde{X}_s = n_s^{1/\rho}\bar{x}_s. \tag{24.35}$$

If we substitute Equation (24.35) into Equation (24.34), we arrive at a version of Armington-type preferences defined in terms of $\tilde{X}$:

$$Q = \left(\sum_{s=1}^{R} \tilde{X}_s^{\rho}\right)^{1/\rho} \text{where } 1 > \rho > 0. \tag{24.36}$$

We can substitute Equations (24.33) and (24.31) into Equation (24.36) to arrive at a workable equation for variety-scaled gross output by industry:

$$\tilde{X}_{k,s} = G_k(Z_{k,s} - \zeta_{k,s}a_k)(Z_{k,s} + \zeta_{k,s}a_k(\sigma_k - 1))^{1/(\sigma-1)} \tag{24.37}$$

$$\text{where } G_k = (a/b_k)(\sigma_k - 1)(\sigma_k a_k)^{-1/\rho_k}.$$

It should be stressed that in calibrating Equation (24.36), just as in the standard Armington model, there is scope to include additional CES weights by country, as variety scaling basically makes these weights endogenous. They implicitly include variety, along with whatever else might fit theoretically under the umbrella of the CES weights. We have left them out here, in Equation (24.36), again for notational simplicity. Under the assumption of large group monopolistic competition, the term ζ vanishes to insignificance and the full system becomes much simpler. Starting from Equations (24.31), (24.32), (24.33) and (24.37), we take the limit as $\varsigma \rightarrow 0$:

$$\bar{x} = \left(\frac{a}{b}\right)(\sigma - 1) \tag{24.38}$$

$$m = 1 + \mu = \sigma(\sigma - 1)^{-1} \tag{24.39}$$

$$n = Z(a\sigma)^{-1} \tag{24.40}$$

$$\tilde{X} = \left((\sigma - 1)(a\sigma)^{-1/\rho}(a/b)\right)Z^{\sigma/(\sigma-1)}. \tag{24.41}$$

Note also that scale economies and the demand/substitution elasticity σ are now closely linked. In particular, Equations (24.38), (24.24) and (24.25) mean that:

$$\phi^{-1} = \sigma. \tag{24.42}$$

As such, we can calibrate from estimates of either σ or ϕ in large group cases, but not both. The equilibrium conditions for small and large group monopolistic competition are summarized in Table 24.2. We will discuss both the small- and large-group cases further below, after we have covered an alternative specification of scale economies.

24.3.1.2 Fixed CDRs

As an alternative to the small-group model with fixed costs, we will now develop the properties of a small-group model where scale economies follow not so much from fixed costs, but rather are linked to the organization of production. From the engineering literature, we know that scale economies follow, in a large part, from the reorganization of production, with subdivision of tasks and resulting scale economies from specialization at the level of tasks (Gold, 1981). Indeed, while the more recent

Table 24.2 Monopolistic competition—specification and calibration

Large-group model with fixed costs	
Equilibrium firm size	(38) $\bar{x} = \left(\frac{a}{b}\right)(\sigma - 1)$.
Equilibrium markups over marginal cost	(39) $m = 1 + \mu = \sigma(\sigma - 1)^{-1}$.
Equilibrium number of firms	(40) $n = Z(a\sigma)^{-1}$.
Equilibrium variety-scaled output	(41) $\tilde{X} = ((\sigma - 1)(a\sigma)^{-1/\rho}(a/b))Z^{\sigma/(\sigma-1)}$.
Implementation	Standard CES (Armington)-type calibration Output is replaced by $\tilde{X}$. Scale elasticities are fixed: $\varepsilon_{\tilde{X},Z} = \frac{\mathrm{d}\tilde{X}}{\tilde{X}} \Big/ \frac{\mathrm{d}Z}{Z} = \sigma/(\sigma - 1)$.
Properties	Output per firm is fixed. Variety is proportional to inputs. Markups are fixed, as is the CDR. Industry output is proportional to inputs.
Calibration issues	Requires estimate of one of ϕ, m or σ, not all three because $\phi = \sigma^{-1}$, $m = (\sigma - 1)^{-1}$.
Small-group model with fixed costs	
Equilibrium firm size	(31) $\bar{x} = (a/b)(\sigma - 1)((Z - \zeta a)(Z + \zeta a(\sigma - 1))^{-1})$.
Equilibrium markups over marginal cost	(32) $m = (\sigma - 1)^{-1}(Z + \zeta a(\sigma - 1))(Z - \zeta a)^{-1}$.
Equilibrium number of firms	(33) $n = (\sigma a)^{-1}(Z + \zeta a(\sigma - 1))$.
Equilibrium variety-scaled output	(37) $\tilde{X} = G\,(Z - \zeta a)(Z + \zeta a(\sigma - 1))^{1/(\sigma-1)}$, where$(a/b)(\sigma - 1)(\sigma a)^{-1/\rho}$.
Implementation	Standard CES (Armington) type calibration. Output is replaced by $\tilde{X}$.
Properties	Firm output and variety rise with Z. Varieties rises and firm output falls with ζ. Markups fall with Z and rise with ζ. Industry output changes more than proportionally to changes in Z. For given Z, increased competition (loss of aggregate market power ζ) leads to increased efficiency.
Calibration issues	Note that with estimates of m, σ and data on shares, the term a can be calibrated. This specification then requires estimates of a, m, share terms and σ to calibrate initial scale elasticities.

(*Continued*)

Table 24.2 Monopolistic competition—specification and calibration—cont'd

Small-group model with fixed CDR	
Equilibrium firm size	(45) $\bar{x} = \left(\frac{\sigma - \phi^{-1}}{(\sigma - 1)}\right)^{1/(1-\phi)} Z^{1/(1-\phi)}\zeta^{-1/(1-\phi)}$.
Equilibrium markups over marginal cost	(46) $m_i = 1 + \mu_i = (1-\phi)^{-1}$.
Equilibrium number of firms	(47) $n = \zeta \frac{(\sigma - 1)}{\sigma - \phi^{-1}}$.
Equilibrium variety-scaled output	(48) $\tilde{X} = n^{1/\rho}\bar{x} = \left(\frac{\sigma - \phi^{-1}}{(\sigma - 1)}\right)^{-g} Z^{1/(1-\phi)}\zeta^{g}$, where $g = \sigma((\sigma-1)^{-1} - (\sigma - \phi\sigma)^{-1}) < 0$.
Implementation	Standard CES (Armington) type calibration. Output is replaced by $\tilde{X}$. Scale elasticities are constant.
Properties	Firm outputs rise with Z. Varieties rise and output falls with ζ. Markups are fixed by technology. Industry output changes more than proportionally to changes in Z. For given Z, increased competition (loss of aggregate market power ζ) leads to increased efficiency at firm level (larger firms), though variety is lost.
Calibration issues	Note that with estimates of m and σ, the full system can be calibrated. As an alternative, estimates of σ and ϕ can be used. To calibrate ϕ from σ and n, one can use (49) $\phi = n\ (n\sigma + S(\sigma-1))^{-1}$. or drop S and use the global firms in the sector. If using external estimates of both ϕ and σ remember that you need $\sigma > \phi^{-1}$, and that you should also cross-check the implied number of firms.

literature on tasks is grounded in constant returns to scale (Baldwin and Robert-Nicoud, 2010), engineering studies on scale have long emphasized that splitting up tasks opens scope for the benefits of scale. A high-volume production plan does not look the same as a low-volume one, as Adam Smith noted in his famous example of the pin factory. Here, we will follow the model of production developed in Francois (1990), wherein there are scale economies from an increased division of labor in production, combined with coordination costs linked to the subdivision of tasks. As long as we maintain homotheticity over inputs needed for the tasks and coordination, we can derive a reduced-form cost function as:

$$C(x_i) = x_i^{1-\phi} P_z \quad \text{where } 1 > \phi > 0. \tag{24.43}$$

While in the previous section we have scale economies following from fixed costs, here they follow from an internal division of labor and the resulting reduced-form cost function has a constant cost disadvantage ratio. Equation (24.30) needs to be modified, given Equation (24.43):

$$Z = n\bar{x}^{1-\phi}. \tag{24.44}$$

Starting again from Equations (24.29) and (24.22), combined now with equation (24.44), we can derive the following equilibrium values:

$$\bar{x} = \left(\frac{\sigma - \phi^{-1}}{(\sigma - 1)}\right)^{1/(1-\phi)} Z^{1/(1-\phi)} \zeta^{-1/(1-\phi)} \tag{24.45}$$

$$m_i = 1 + \mu_i = (1 - \phi)^{-1} \tag{24.46}$$

$$n = \frac{\zeta(\sigma - 1)}{\sigma - \phi^{-1}} \tag{24.47}$$

$$\tilde{X} = n^{1/\rho}\bar{x} = \left(\frac{\sigma - \phi^{-1}}{(\sigma - 1)}\right)^{-g} Z^{1/(1-\phi)} \zeta^{g} \quad \text{where } g = \sigma\left((\sigma - 1)^{-1} - (\sigma - \phi\sigma)^{-1}\right). \tag{24.48}$$

Calibration requirements for this form of small-group monopolistic competition are somewhat easier than under the fixed cost small-group model, as we do not need to explicitly find firm-level fixed costs. Indeed, as noted in Table 24.2, a combination of estimates for n, σ and ϕ is sufficient, or alternatively of σ and m. Section 24.3.2 focuses on the properties of both sets of specifications. If we have an estimate of the total number of firms n, for example, along with a substitution elasticity estimate (e.g. from the tariff coefficient in a gravity equation) then we can calibrate ϕ:

$$\phi = n(n\sigma + \zeta(\sigma - 1))^{-1}. \tag{24.49}$$

In general, an important restriction in this flavor of monopolistic competition is that $\sigma > \phi^{-1}$. The closer these two values are, the greater the number of firms in equilibrium.

24.3.2 Groups large and small, and the choice of framework

Table 24.2 summarizes the properties of the fixed cost and fixed CDR models. The least demanding in terms of parameters and implementation is large-group monopolistic competition with fixed costs. This is because in this case the reduced form is a model with external scale economies in $\tilde{X}$, while demand can be modeled as Armington defined over intermediate and consumption of $\tilde{X}$. No additional parameters are needed relative to a standard model. Calibration can be based on the trade substitution elasticity, mapped to the reduced-form scale elasticity. The specification with fixed CDRs is also relatively straightforward, but does require an estimate of what the CDRs actually are. Like the Cournot model, this specification also requires tracking industry-level global market shares ζ. Again, the model with fixed CDRs can be implemented as one with reduced-form scale economies at industry level for $\tilde{X}$, with a constant set of scale elasticities. As a warning, all three versions of the model may prove numerically challenging. From experience, a stepwise estimation with an updating of the scale elasticities as shown in Table 24.2 may actually be easier to solve than a system with explicit equations for $\tilde{X}$ in levels. What we mean here is the following. Consider, for example, where the set of variables $\mathbf{Y}$ with elements y can be expressed as non-linear implicit functions of the set of variables $\mathbf{B}$ with elements b:

$$\mathbf{Y} = g(\mathbf{B}). \tag{24.50}$$

With some derivations we can then link proportional changes in elements of $\mathbf{Y}$ to proportional changes in elements of $\mathbf{B}$, where $\frac{\mathrm{d}b_j}{\mathrm{b}_j} = \hat{b}_j$:

$$\begin{aligned} \mathrm{d}y_i &= \sum \partial g/\partial b_j \mathrm{d}b_j \\ \frac{\mathrm{d}y_i}{y_i} &= \sum \partial g/\partial b_i \frac{x_j}{y_i}\frac{\mathrm{d}b_j}{b_j} \\ \hat{y}_i &= \sum \varepsilon_{i,j}\frac{\mathrm{d}b_j}{b_j} = \sum \varepsilon_{i,j}\hat{b}_j. \end{aligned} \tag{24.51}$$

In the final equation, what we now have is a locally linear model, in terms of proportional changes. For non-local changes in $\mathbf{B}$, such an approximation requires the updating of the elasticity term $\varepsilon_{i,j}$, where it is a function of other values in the system. In Table 24.2, under both the large-group monopolistic competition case, and the case with small group and a fixed CDR, the elasticity of variety-scaled output $\tilde{X}$ with respect to the input bundle Z is constant. However, in the small-group version of the Dixit–Stiglitz model, this elasticity is endogenous. In this case, we can break up the exogenous changes in $\mathbf{B}$ into pieces or "steps," and use a version of the system of Equations (24.51) to then update endogenous elasticities and core data after each step in the estimation. Such a stepwise procedure is illustrated in Figure 24.1 below. At each step, we update before proceeding with another log-linear approximation. The more steps, the more accurate the solution.[15] Even if you are programming a multisector model without using linearized representations (common with GAMS-based models) you might consider programming a loop to break exogenous

15 GEMPACK (Harrison and Pearson, 1996; Harrison *et al.*, 2000) uses an explicit Newton type of this form, while related algorithms lurk behind many algorithms in software like GAMS, where systems are locally linearized or log-linearized to solve updating problems in response to changes to a calibrated set of equations.

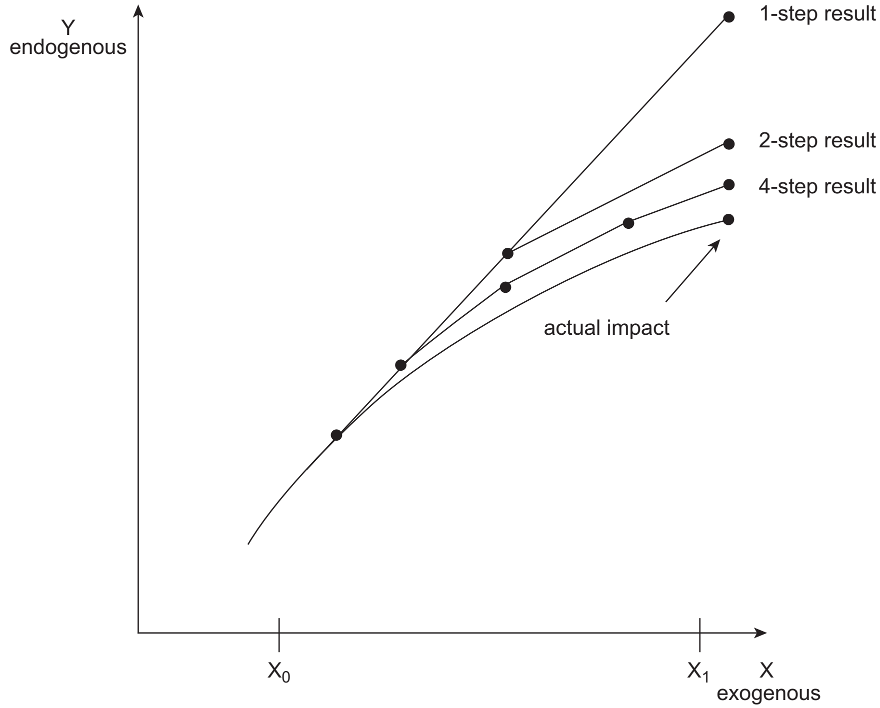

Figure 24.1 Stepwise solution with local linearization.

shocks up in steps if you run into solution/convergence problems in solving your model, when it includes scale economies. Scale effects, modeled as productivity shocks based for example on Equation (24.40), can then be updated between steps, so that you can isolate the source of non-convexities. This means, for example, that you could use a GAMS-based constant returns model with an Armington structure, but nested in a loop where you update an estimated productivity shock based on Equation (24.40) and updating until convergence. The reason is that scale economies also imply local non-convexities and, as a brute-force workaround, an extra stepwise procedure (even if you just break up the exogenous shocks but keep the model non-linear otherwise) may help with such solution issues. Other approaches to limiting non-convexities include making factors sector-specific (either totally or with imperfect mobility across sectors) or imposing an Armington nest on top of local monopolistically competitive sectors.

While all specifications in Table 24.2, in reduced form, reflect industry-level scale economies linked to a mix of variety and volume, the underlying stories are different. In the small-group models, we have a mix of changes in output per firm and changes in number of firms linked to market conditions. For example, holding domestic industry size fixed, in terms of inputs as indexed by Z, if there is increased foreign production and competition across markets, as measured by a drop in the term ζ, we will have increasing firm size under the small-group fixed cost and small-group fixed CDR models. This follows from weaker market power and so leads to an expansion of output to reflect new optimal production levels which can be seen by inspecting Equations (24.31) and (24.45). In both equations, loss of market power by individual firms in the face of foreign competition, manifested in falling ζ values, will lead to this effect. This also implies consolidation of firms — fewer varieties and larger volume per variety — following from changes in market conditions in third markets. Similarly, improved access to markets (e.g. from a trade agreement), if it involves a major market, implies conflicting mechanisms — rising production as indexed by Z implies increasing firm size and more varieties, while potentially greater market shares will moderate this effect away from output per firm and toward variety. As long as the volume effects, indexed by Z, dominate, we will have increased trade linked to higher firm productivity and falling ex-factory prices. In the fixed cost model, this will also be accompanied by falling markups over marginal cost. In addition, liberalization in the home market, assuming this is the primary market, will lead to incentives to increase size through the impact on ζ, but with a scaling back from effects on Z. The net effect is analytically ambiguous. These offsetting effects are not ambiguous in the large group model, because all action involves entry and exit.

The small group models offer the advantage of adjustment in scale and variety, and with market access conditions in third markets leading to potential changes in efficiency, scale and variety at home. The small-group fixed cost model also offers endogenous markups, shifting with industry size, export potential and overall market shares. Yet, this richness of result also comes at a cost. Since, in reduced form, both the large-group and small-group specifications reduce to a model with external scale economies by industry, the net effect can actually be quite similar (Francois, 1998). As such, where interest is in aggregate effects for macroeconomic indicators, the large-group approach, which requires only use of the estimate of σ to calibrate a scale elasticity, is the least demanding. The small-group models require a mix of markup, firm population data and scale economy estimates for calibration: n, m and ϕ.

Apart from differences relative to Armington models, an important question about the large-group Dixit—Stiglitz class of models has been raised by Hummels and Klenow (2005), who note that the pure Dixit—Stiglitz model attributes all export expansion to increases in varieties exported. However, they find that only around 60% of the increase in exports in growing economies comes from increases in product variety, with the remainder coming from increases in both the quantity and quality of goods exported. Ardelean (2006) estimates a model of export expansion that nests the conventional, Armington model and the Dixit—Stiglitz model, and finds that consumers' love of variety is roughly 40% less than would be suggested by a pure Dixit—Stiglitz model. Francois (2006) found in a simulation context that full love of variety resulted in an apparently excessive preference for variety, and obtained more plausible results in a model that was intermediated between the Armington- and Dixit—Stiglitz-type models. As noted above, one can accommodate a mix of scale and variety with small-group monopolistic competition, where we then have a mix of variety (quality) and quantity effects.[16]

There is some empirical support for incorporating more information on the population of firms with heterogeneous cost structures based on Melitz (2003). Baldwin (2005) shows that the Melitz model generates many important testable hypotheses, including that greater openness raises productivity, and that policy reforms that lower marginal costs of trade may have different implications from those that lower fixed beachhead costs. These offer potential to greatly enrich insights from MSGE-based assessments. However, a basic challenge in this regard will be to find relatively parsimonious reduced forms like Equation (24.37) that avoid geometric expansion in the computational complexity of the models. The issue of dimensionality in this context is discussed explicitly by Balisteri and Rutherford in Chapter 23 of this Handbook. However, Melitz models, with monopolistic competition, may be unsatisfactory if our motivation is the empirical evidence, discussed above in our overview of oligopoly, of the impact of trade on firm pricing strategies. With Melitz-style versions of Ethier and Krugman models, markups remain fixed and large firms are in reality small *vis-à-vis* the mass population of firms in an industry. Melitz and Ottaviano (2005) have extended the Melitz model to allow for endogenous markups that respond to the strength of competition – something observed in firm-level analyses and closer to the MSGE oligopoly models of markups discussed above. This endogeneity is also found in the oligopoly and small-group monopolistic frameworks developed here.

Another issue sterilized in both the representative and heterogenous firm models found in recent MSGE applications is the scope for individual firms to learn or otherwise increase productivity in response to accessing broader markets. Rather, while firms may self-select in MSGE models, cost structures of individual firms typically do not change in large-group models, be they homogenous or heterogeneous firms. Early work on firm-level efficiency effects of trade assumed that the process of exporting created productivity differences through learning-by-doing. Exporting firms might, for instance, learn about new techniques and products from their foreign buyers in the manner suggested by Arrow (1962). However, a number of influential firm-level studies, including Clerides *et al*. (1998) and Bernard and Jensen (1999), concluded that the changes in productivity following entry into export markets arose primarily because higher-productivity firms self-selected into exports. This is consistent with Melitz-type strategies or the heterogenous Cournot approach discussed above. This conclusion remains controversial. A number of more recent studies contradict the result of not learning-by-doing with findings of empirically important increases in productivity after firms enter export markets. Blalock and Gertler (2004)

[16] For numeric examples in a MSGE context, see the maquete GTAP-based code of Francois (1998).

find evidence of an increase in firm productivity of between 2 and 5% after Indonesian firms enter export markets. Fernandes and Isgut (2006) find evidence of an increase in productivity from learning-by-exporting when Colombian firms entered export markets. van Biesebrock (2005) finds that while African exporting firms had higher productivity before entering export markets, their productivity levels, and their subsequent rates of productivity growth, increased even further after entering export markets. Girma *et al.* (2004) found both higher initial levels of productivity and higher productivity growth rates after entry into exporting. Moreover, these sources of productivity gain from improvements in production processes are additional to any resulting from improvements in product variety or product quality. This suggests that, in addition to exploring mechanisms that drive changes in the pricing (markup) strategies of individual firms, incorporating changes in the cost structures of individual firms because of trade may also be an important part of the story currently sterilized under standard and emerging modeling strategies. As such, if this is of interest, the small-group models developed here, with scope for individual firms to realize changes in cost structure as a function of changes in demand conditions, may be relevant.

24.4 MODEL SELECTION AND VALIDATION

When one examines the literature that compares otherwise identical experiments with alternative model structures, the variation in results is striking.[17] This is not a new insight, but one the MSGE modeling community has known for some time. As illustration, Table 24.3 presents estimated macroeconomic and output effects for Japan from a free trade experiment, taken from Francois (1998).[18] The first set of simulation results involves constant returns to scale and perfect competition under the Armington assumption, and serves as a reference experiment. The next column in Table 24.3 corresponds to scale economies with average cost pricing. Table 24.3 then moves to monopolistic competition and on to Cournot competition. Welfare effects for Japan increase monotonically as we move across the columns. Evidence of potential pro-competitive effects can be seen if we compare the last two columns with the others. As trade liberalization erodes the market power derived from protection, markups are reduced and output increased significantly in the Cournot sector. The result is output effects roughly twice as great as those estimated under perfect competition. Particularly striking is the range of real wage effects. As discussed above, in general equilibrium broad-based pressure on price–cost markups has important implications for labor

17 Early comparisons include NAFTA (Francois and Shiells, 1994) and the Uruguay Round (Francois *et al.*, 1996).

18 Also see Francois and Roland-Holst (1997) and Francois (2001) for similar comparisons. In the applications reported in Table 24.3, scale economies are modeled per Equation (24.43), with pricing alternatively at average cost for the industry, so that $P = x^{-\phi}P_z$ (so that we have a contestable market with scale for a homogeneous Armington good) or with markups above average cost as in Equation (24.3).

Table 24.3 Market structure and the impact of free trade on Japan

	CRTS: AC pricing	IRTS: AC pricing	IRTS: Monopolistic competition	CRTS: Cournot	IRTS: Cournot
Welfare (%)	0.84	1.16	1.99	2.28	2.86
Manufacturing (%)	2.30	2.14	1.38	5.71	5.64
Real wages (%)	2.37	2.66	3.41	13.34	14.75

Source: Francois (1998). IRTS = increasing returns to scale. CRTS = constant returns to scale. AC = average cost pricing. Under monopolistic competition, calibration is from trade substitution elasticities as in Equation (24.42), while functional forms are as in Table 24.2, Equations (24.38), (24.39), (24.40) and (24.41). For comparison the implied scale coefficient θ per Equation (24.42) is then also used under the Cournot and free entry specifications. Cournot is specified as in Table 24.1, with a fixed ratio $\Omega/n = 0.5$.

markets. Under the Cournot specification, where markups are squeezed with increased trade, factor incomes rise as profits are squeezed, and real wages rise by four to five times more than under the other specifications, including monopolistic competition.

What Table 24.3 highlights is that getting market structure right matters. Of course, the experiments are notional, in that they compare results when we start from consistent measures of scale and substitution elasticities, and apply alternative market structures. Since these comparisons were made, the subsequent literature has focused almost entirely on either constant returns to scale (the first column) or monopolistic competition (the third column). This means we have collectively assumed away markups over average cost. However, when we turn to individual industries, there is evidence that concentration and markup structure are important, and as discussed elsewhere in this chapter there is reason to believe markups over average cost can be sensitive to regulation and to global competition. With plausible value-added shares and plausible markup rates at an average cost, squeezing markups can lead to substantively different impacts for labor income and employment, and so for unemployment, inequality and poverty, than we collectively allow in models with average cost pricing. The comparisons above do not include unemployment, but one can expect differences in employment level changes across the columns similar to the differences shown for wage changes, if we are faced with wage rigidities. In retrospect, this means we have most likely missed an important driver of linkages between labor income and openness. Looking forward, this seems a promising area to explore (i.e. focusing instead on the last two columns) when trying to get the story right.

The general equilibrium literature thrives on computational complexity and parameters are drawn from outside sources, while data are massaged (a two-step process involving construction of social accounting matrices and also calibration) to eliminate inconvenient incompatibilities between data and theory. Keeping in mind the impact of model structure on results, a more robust matching of model structure to econometric foundations for parameters and for model validation is called for. In general, the use of econometrics in this context has been driven by a need for parameters with which to feed the MSGE models, rather than specification testing *per se*. *Ex post* assessments, a promising channel for the validation of structural approaches, have been almost an afterthought, in reaction to critical questions by the policy community (a major consumer of these models) about how well the models actually perform. However, given the role of these models in policy formation, this is clearly an area that merits more mainstream focus. Some of the research along these lines has focused on matching the projected impact of NAFTA implementation to what has actually happened, including Fox (1999). Where data are available (e.g. with single-country models) fitting to time series also provides opportunity for model fitting and calibration (see Dixon and Rimmer in Chapter 19 of this Handbook).

24.5 SUMMARY

We have provided an overview of several approaches to modeling market structure in MSGE models, including both oligopoly and monopolistic competition. We have emphasized open economy models and applications to international economic policy. From the beginning, MSGE models have often been characterized by constant returns to scale technologies, competitive markets and constant factor productivity. There have been important innovations, largely inspired by the "new" trade theory and the incorporation of industrial organization features into general equilibrium theory. Most recently, there is work underway in the MSGE literature to incorporate firm heterogeneity into MSGE models. The bulk of the applied work emphasizes monopolistic competition models with constant markups over marginal costs and average cost pricing. We argue here that reliance on models with average cost pricing may miss important income distributional impacts of policy through labor market outcomes. We also argue that better attention needs to be paid to model validation and performance tests.

Despite data constraints, specifying oligopoly in sectors (where appropriate) does matter and so the difficulties may be justified in terms of the policy insights to be gained. Oligopoly can lead to substantially different estimated welfare effects from trade policy adjustment. This is because reductions in trade barriers can reduce price–cost margins and result in gains to national income, resulting from output expansion and greater exploitation of scale economies as well as those from increased imports. A major difference between oligopoly approaches as outlined here and those under monopolistic competition is the assumption of average cost pricing under the latter. This precludes general equilibrium factor market effects (changes in real wages) linked to potential squeezing of price–cost margins with increased competition. The fact that different models yield different results is not in itself surprising. It does, however, highlight the need to choose specifications of market structure appropriate for the questions at hand.

NOTE

All views expressed in this paper are strictly those of the authors and do not reflect the official views or positions of any institution with which they may be affiliated or of anyone at those institutions.

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