General equilibrium models of monopolistic competition:
A new approach

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Outline

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Motivation

1. Complete the analytical framework
2. Improve analytical tractability of CARA functions
3. Micro basis for trade
Chamberlinian monopolistic competition model:

- Single-consumption good, provided as a continuum of horizontally differentiated varieties.
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Chamberlinian monopolistic competition model:

- Single-consumption good, provided as a continuum of horizontally differentiated varieties.
- $\Omega$: set of varieties, with measure $\mathbb{N}$
- Firms can COSTESSLY differentiate their products $\Rightarrow$ each variety produced by only one firm
- Each firm has some monopoly power, but entry/exit drives monopoly profits to zero.
Our functions

\[ u(x) = k + \kappa x^\rho \]  \hspace{1cm} \text{(CRRA)}

\[ u(x) = k - \kappa e^{-\alpha x} \]  \hspace{1cm} \text{(CARA)}

\[ \varphi(xy) = \varphi(x) \cdot f(y) \quad \forall x, y > 0 \]  \hspace{1cm} \text{(MQS)}

\[ \varphi(xy) = \varphi(x) + f(y) \quad \forall x, y > 0 \]  \hspace{1cm} \text{(AQS)}

\( f \) is assumed to be continuously differentiable and strictly monotone.
Some remarks (I)

Risk aversion: related to the curvature of $u(x)$

Definition

$ARA_x = - \frac{u''(x)}{u'(x)}$

Example

Exponential utility is CARA

$u(x) = -e^{-\alpha x}$
Some remarks (II)

**Definition**

\[ RRA_x = -\frac{x u''(x)}{u'(x)} = xARA_x \]

**Example**

CES utility is CRRA

\[ u(x) = \frac{x^{1-\rho}}{1-\rho} \]
Consumer’s problem

Assumptions on $u$:

1. $u' > 0 \equiv Mg\ utility > 0 \Rightarrow$ Monotone preferences
2. $u'' < 0 \equiv Mg\ utility$ is decreasing
Consumer’s problem

Assumptions on $u$:

1. $u' > 0 \equiv \text{Mg utility} > 0 \Rightarrow \text{Monotone preferences}$
2. $u'' < 0 \equiv \text{Mg utility is decreasing}$

Maximization problem of a representative consumer

$$\max_{q_i, i \in \Omega} U \equiv \int_{\Omega} u[q_i] \, di$$

$$\text{st } \int_{\Omega} p_i q_i \, di = E$$

$E > 0$

$p_i > 0$

$q_i \geq 0$
General solution

By pointwise maximization, we get the FOCs for an interior solution (no corner because we love variety)

\[ u'[q_i] = \lambda p_i \quad \forall i \in \Omega \]

Taking the ratio between any two varieties \( i, j \)

\[ u'[q_i] = u'[q_j] \frac{p_i}{p_j} \quad \forall i, j \in \Omega \]
Consumer’s problem

Let’s denote \( \varphi = (u')^{-1} \):

\[
\varphi^{-1}[q_i] = \varphi^{-1}[q_j] \frac{p_i}{p_j} \quad \forall i, j \in \Omega
\]

Notice that by assumptions on \( u \), \( \varphi \) is continuously differentiable.

We can apply \( \varphi \) to both sides to get

\[
q_i = \varphi\left[\varphi^{-1}[q_j] \frac{p_i}{p_j}\right] \quad \forall i, j \in \Omega
\]
Theorem 1

A continuously differentiable function \( \varphi \equiv (u')^{-1} : \mathbb{R}^+ \rightarrow \mathbb{R}^+ \) is MQS if and only if the function \( u \) is of the CRRA type, i.e., \( u(x) = k + \kappa x^\rho \).
Theorem 1

Proof

⇒) \( \varphi \) is MQS ⇒ \( u \) is of the CRRA type

Let \( a, b > 0 \) arbitrarily given. We take them as strictly positive by assumptions on \( u \) and prices.

Differentiating the CRRA expression w.r.t. \( a \) and w.r.t. \( b \), we get

\[
\varphi'(ab)b = \varphi'(a)f(b) \quad \forall a, b > 0 \\
\varphi'(ab)a = \varphi(a)f'(b) \quad \forall a, b > 0
\]
Theorem 1

Since $\varphi' < 0$, $f' \neq 0$, $a, b > 0 \implies \varphi$ and $f$ are non-zero. Then, we can divide the previous equations and get this ratio:

$$\frac{b}{a} = \frac{\varphi'(a)f(b)}{\varphi(a)f'(b)} \implies \frac{\varphi'(a)}{\varphi(a)}a = \frac{f'(b)}{f(b)}b \quad \forall a, b > 0$$

Keeping $a$ fixed, the elasticity of $f$ must be constant: $c$
Theorem 1

Since \( \varphi' < 0, f' \neq 0, a, b > 0 \Rightarrow \varphi \) and \( f \) are non-zero. Then, we can divide the previous equations and get this ratio:

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\frac{b}{a} = \frac{\varphi'(a)f(b)}{\varphi(a)f'(b)} \quad \Rightarrow \quad \frac{\varphi'(a)}{\varphi(a)}a = \frac{f'(b)}{f(b)}b \quad \forall a, b > 0
\]

Keeping \( a \) fixed, the elasticity of \( f \) must be constant: \( c \)

Therefore, integrating this expression

\[
\int \frac{\varphi'(a)}{\varphi(a)} da = \int \frac{c}{a} da \Rightarrow \ln(\varphi(a)) = c \ln(a) + d \Rightarrow \\
\Rightarrow \varphi(a) = e^{c \ln(a)} e^d = a^c e^d
\]

Thus, calculating the inverse and getting \( u' \) is verifiable that \( u \) is of the CRRA type.
Theorem 1

\(\iff u\) is of the CRRA type \(\Rightarrow \varphi\) is MQS

\[u(a) = k + \kappa a^\rho\]

where

\[k \in \mathbb{R}, \kappa > 0 \text{ and } 0 < \rho < 1\]

Therefore, we can say that

\[u'(a) = \kappa \rho a^{\rho - 1} > 0\]
\[u''(a) = \kappa \rho (\rho - 1) a^{\rho - 2} < 0\]
Theorem 1

We are looking for the inverse of the marginal utility:

\[ u'(a) = \kappa \rho a^{\rho - 1} \Rightarrow a = \kappa \rho [u'(a)]^{\rho - 1} \Rightarrow [u'(a)]^{-1} = \varphi(a) = \left( \frac{a}{\kappa \rho} \right)^{1/(\rho - 1)} \]

This shows that \( \varphi \) is MQS because

\[ \varphi(ab) = \left( \frac{ab}{\kappa \rho} \right)^{1/(\rho - 1)} = \varphi(a) \cdot f(b), \text{ for } f(b) = b^{1/(\rho - 1)} \]
Theorem 2

A continuously differentiable function $\varphi \equiv (u')^{-1} : \mathbb{R}^+ \to \mathbb{R}^+$ is AQS if and only if the function $u$ is of the CARA type, i.e., $u(x) = k - \kappa e^{-\alpha x}$.
Theorem 2

Proof

$\implies \) $\, \varphi$ is AQS $\implies \) $\, u$ is CARA

Let $a, b > 0$ be arbitrarily given.

Differentiating the CARA expression w.r.t. $a$ and w.r.t. $b$, we get

$$\varphi'(ab)b = \varphi'(a) \quad \forall a, b > 0$$
$$\varphi'(ab)a = f'(b) \quad \forall a, b > 0$$
Theorem 2

Since \( \varphi' < 0, f' \neq 0, a, b > 0 \Rightarrow \varphi \) and \( f \) are non-zero. Then, we can divide the previous equations and get this ratio:

\[
\frac{b}{a} = \frac{\varphi'(a)}{f'(b)} \Rightarrow \varphi'(a)a = f'(b)b
\]

Keeping \( a \) fixed, \( f'(b)b \) must be constant: \( c \)
Theorem 2

Since $\varphi' < 0$, $f' \neq 0$, $a, b > 0 \implies \varphi$ and $f$ are non-zero. Then, we can divide the previous equations and get this ratio:

$$\frac{b}{a} = \frac{\varphi'(a)}{f'(b)} \Rightarrow \varphi'(a)a = f'(b)b$$

Keeping $a$ fixed, $f'(b)b$ must be constant: $c$

Therefore, integrating this expression

$$\int \varphi'(a)da = \int \frac{c}{a}da \Rightarrow \varphi(a) = c \ln a + d$$

Calculating the inverse we get $u'(a) = e^{a/c}e^{-d/c}$, which proves that $u$ must be of the CARA type.
\textbf{Theorem 2}

\( \iff \) \( u \) is of the CARA type \( \Rightarrow \) \( \varphi \) is AQS

\[ u(a) = k - \kappa e^{-\alpha a} \]

where

\[ k \in \mathbb{R}, \ \kappa > 0 \text{ and } \alpha > 0 \]

Therefore, we can say that

\[ u'(a) = \kappa \alpha e^{-\alpha a} > 0 \]

\[ u''(a) = -\kappa \alpha^2 e^{-\alpha a} < 0 \]
Theorem 2

We are looking for the inverse of the marginal utility:

\[ u'(a) = \kappa \alpha e^{-\alpha a} \implies a = \kappa \alpha e^{-\alpha[u'(a)]} \Rightarrow [u'(a)]^{-1} = \varphi(a) = \frac{1}{\alpha} \ln\left(\frac{\alpha \kappa}{a}\right) \]

This shows that \( \varphi \) is AQS because

\[ \varphi(ab) = \frac{1}{\alpha} \ln\left(\frac{\alpha \kappa}{ab}\right) = \varphi(a) + f(b), \text{ for } f(b) = \frac{1}{\alpha} \ln\left(\frac{1}{b}\right) \]
Some additional restrictions

Notice that Theorems 1 and 2 hold regardless of the value of $k$.

However, we have to impose some *additional restrictions* on its value to ensure $U = \int_{\Omega} u(q_i)\,di$ to display "love of variety"; that is, $\frac{\partial U}{\partial N} \geq 0$

Let $\bar{Q} = Nq$ stand for a fixed level of total consumption when the consumer equally consumes each variety $\Rightarrow U = Nu(q)$
Some additional restrictions

**MQS case**

\[
U = N[k + \kappa q^\rho] = N[k + \kappa \left(\frac{Q}{N}\right)^\rho]
\]

\[
\frac{\partial U}{\partial N} = k + \kappa (1 - \rho) \left(\frac{Q}{N}\right)^\rho > 0
\]

Let’s look at the extreme values of \( N \):

- \( N = 0 \Rightarrow \) no market (not relevant)
- \( N = \infty \Rightarrow \left(\frac{Q}{N}\right) = 0 \Rightarrow \) a sufficient condition for \( \frac{\partial U}{\partial N} \) to be non-negative is \( k \geq 0 \). We’ll assume \( k = 0 \).
Some additional restrictions

**AQS case**

\[ U = N[k - \kappa e^{-\alpha q}] = N[k - \kappa e^{-\alpha \frac{Q}{N}}] \]

\[ \frac{\partial U}{\partial N} = k - \kappa e^{-\alpha \frac{Q}{N}} \left( 1 + \alpha \frac{Q}{N} \right) \]

Let \( z = \alpha \frac{Q}{N} \) and \( g(z) = k - \kappa e^{-\alpha z} (1 + z) \equiv \frac{\partial U}{\partial N} \).

Notice that \( z > 0 \) when \( N < \infty \)
Some additional restrictions

**AQS case**

\[ U = N[k - \kappa e^{-\alpha q}] = N[k - \kappa e^{-\alpha \frac{Q}{N}}] \]

\[ \frac{\partial U}{\partial N} = k - \kappa e^{-\alpha \frac{Q}{N}} \left( 1 + \alpha \frac{Q}{N} \right) \]

Let \( z = \alpha \frac{Q}{N} \) and \( g(z) = k - \kappa e^{-\alpha z} (1 + z) \equiv \frac{\partial U}{\partial N} \).

Notice that \( z > 0 \) when \( N < \infty \)

\[ g'(z) = e^{-z}(1 + \kappa z + \kappa) > 0 \quad \forall z > 0 \]

\[ g(0) = 0 \iff k \geq \kappa \]

A sufficient condition for \( \frac{\partial U}{\partial N} \geq 0 \) is \( k \geq \kappa \). We’ll assume \( k = \kappa \).
Demand: MQS case

\begin{align*}
q_i &= \varphi [ \varphi^{-1}(q_j) \frac{p_i}{p_j} ] \\
\text{MQS} &\equiv \varphi \varphi^{-1}(q_j) \cdot f \left( \frac{p_i}{p_j} \right) \\
&= q_j \left[ \frac{p_i}{p_j} \right]^{1/(\rho-1)} \quad \forall i, j \in \Omega
\end{align*}
Dividing both sides by \([p_i / p_j]^{1/(1-\rho)}\), multiplying by \(p_j\), integrating over \(j\) and using the BC:
MQS case: properties

Constant price elasticity of demand

\[ \varepsilon_p = \frac{\partial q_i}{\partial p_i} \frac{p_i}{q_i} \]
\[ = \frac{1}{\rho - 1} = -\frac{1}{1 - \rho} \quad \forall i \in \Omega \]

Unitary income elasticity of demand

\[ \varepsilon_r = \frac{\partial q_i}{\partial E} \frac{E}{q_i} = 1 \quad \forall i \in \Omega \]
Demand: AQS case

\[ q_i = \varphi[\varphi^{-1}(q_j) \frac{p_i}{p_j}] \]

\[ \text{AQS} \equiv \varphi \varphi^{-1}(q_j) + f\left(\frac{p_i}{p_j}\right) \]

\[ = q_j + \frac{1}{\alpha} \ln\left[\frac{p_i}{p_j}\right] \quad \forall i, j \in \Omega \]
Demand: AQS case

Multiplying both sides by $p_j$, integrating over $j$ and using the BC:

$$
\int_j q_i p_j dj = \int_j p_j q_j dj + \int_j \frac{1}{\alpha} \ln\left(\frac{p_j}{p_i}\right) p_j dj
$$

$$
q_i \int_j p_j dj = E + \frac{1}{\alpha} \int_j \ln\left(\frac{p_j}{p_i}\right) p_j dj
$$

$$
q_i = \frac{E + \frac{1}{\alpha} \int_\Omega \ln\left(\frac{p_j}{p_i}\right) p_j dj}{\int_\Omega p_j dj}
$$
Demand: AQS case

Multiplying both sides by $p_j$, integrating over $j$ and using the BC:

$$
\int_j q_i p_j dj = \int_j p_j q_j dj + \int_j \frac{1}{\alpha} \ln\left(\frac{p_j}{p_i}\right) p_j dj
$$

$$
q_i \int_j p_j dj = E + \frac{1}{\alpha} \int_j \ln\left(\frac{p_j}{p_i}\right) p_j dj
$$

$$
q_i = \frac{E + \frac{1}{\alpha} \int_\Omega \ln\left(\frac{p_j}{p_i}\right) p_j dj}{\int_\Omega p_j dj}
$$

Let’s $\int_\Omega p_j dj \equiv P$ be the aggregate on prices. Notice that each firm is negligible and has no impact on the price aggregate (constant).
Variable price elasticity of demand

\[ \varepsilon_p = \frac{\partial q_i}{\partial p_i} \frac{p_i}{q_i} = - \frac{1}{\alpha} \frac{p_i}{p_i q_i} = - \frac{1}{\alpha q_i} \]

not constant

Variable income elasticity of demand

\[ \varepsilon_r = \frac{\partial q_i}{\partial E} \frac{E}{q_i} = \frac{1}{\int_{\Omega} p_j d_j} \frac{E}{q_i} \]

not constant
The problem of the firm

Assumptions

1. Labor is the only production factor.
2. $F$ and $m$ are measured in terms of labor.
3. Labor market is perfectly competitive $\Rightarrow w$ is given.
4. Assume $L$ consumers in the economy $\Rightarrow$ total demand for variety $i$ is $Lq_i$. 

Remark: $q_i$ is different depending on $\phi$ MQS or AQS.
The problem of the firm

Assumptions

1. Labor is the only production factor.
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3. Labor market is perfectly competitive $\Rightarrow w$ is given.
4. Assume $L$ consumers in the economy $\Rightarrow$ total demand for variety $i$ is $Lq_i$.

Firm problem

$$\max_{p_i} \pi_i \equiv Lq_i[p_i - mw] - Fw$$

Remark: $q_i$ is different depending on $\varphi$ MQS or AQS.
Price equilibrium in MQS case

Maximization problem

$$\max_{p_i} \{ LE(p_i)^{\frac{1}{\rho-1}} \left[ \int_{\Omega} (p_j)^{\rho/(\rho-1)} dj \right]^{-1} [p_i - mw] - F_w \}$$

FOC

$$\frac{\rho}{\rho - 1} \left( p_i \right)^{\frac{1}{\rho-1}-1} \left[ p_i - \frac{mw}{\rho} \right] \left[ \int_{\Omega} (p_j)^{\rho/(\rho-1)} dj \right]^{-1} = 0$$

A distribution \( p \) satisfying the previous FOC for all \( i \in \Omega \) will be called a MQS price equilibrium.
Solution

\[ p_i = \frac{mw}{\rho} \quad \forall i \in \Omega \]
Price equilibrium in MQS case

Solution

\[ p_i = \frac{mw}{\rho} \quad \forall i \in \Omega \]

Properties

1. The price set by firm \( i \) doesn’t depend on the prices set by the other firms \( \Rightarrow \) the price equilibrium is symmetric and unique

2. The price equilibrium has a constant mark-up over marginal cost

\[ p^{MQS} = \frac{mw}{\rho} > mw \quad \text{because} \quad \rho < 1 \]

3. The price equilibrium is increasing in marginal cost, and independent of both expenditure \((E)\) and the mass of competing firms \((N)\).
Proposition: when $\varphi$ is MQS, the price equilibrium is symmetric and unique. The profit-maximizing price is increasing in marginal cost, and independent of both expenditure and the mass of competing firms.

Proof: previous discussion.
Price equilibrium in AQS case

Maximization problem

$$\max_{p_i} \{ L \frac{1}{P} (E - \frac{1}{\alpha} \int_{\Omega} \ln\left( \frac{p_i}{p_j} \right) p_j dj)(p_i - mw) - Fw \}$$

FOC

$$\alpha E = \frac{p_i - mw}{p_i} P + \int_{\Omega} \ln\left( \frac{p_i}{p_j} \right) p_j dj$$

A price distribution $p$ satisfying the FOC for all $i \in \Omega$ will be called an AQS price equilibrium.
Price equilibrium in AQS case

**Remark 1:** although no individual firm has an impact on the price aggregate, price aggregate has an impact on each individual firm $\Rightarrow$ weak strategic interdependence.

**Remark 2:** the FOC cannot be used to tell a priori whether or not the AQS price equilibrium is symmetric and unique.
**Proposition:** when \( \varphi \) is AQS, the price equilibrium is symmetric and unique. The profit-maximizing price is increasing in expenditure, increasing in marginal cost, and decreasing in the mass of competing firms. Furthermore, it converges to marginal cost at a rate of \( 1/N \).

**Proof:**

**SYMMETRY**

Assume \( \mathbf{p} \) AQS price equilibrium such that \( \bar{p} = \max_i p_i > \min_i p_i = p \)
By definition of equilibrium,

\[ \alpha E = \frac{\bar{p} - mw}{\bar{p}} P + \int_{\Omega} \ln\left(\frac{\bar{p}}{p_j}\right)p_j \, dj \]

Subtracting,

\[ 0 = P \left[ \ln\left(\frac{\bar{p}}{p}\right) + \frac{mw(\bar{p} - p)}{\bar{p}p} \right] \]

Can’t hold \( \Rightarrow \) every price equilibrium must satisfy \( \bar{p} = p \)
UNIQUENESS
Evaluating the FOC at a symmetric price:

\[ \alpha E = \frac{p - mw}{p} P + \int_{\Omega} \frac{\ln\left(\frac{p}{p}\right)}{p} pdj = 0 \]

\[ \alpha E = \frac{p - mw}{p} Np \]

\[ p^{AQS} = mw + \frac{\alpha E}{N} \]
Price equilibrium in AQS case

Properties

\[ p^{AQS} = mw + \frac{\alpha E}{N} \]

1. Pro-competitive effect
2. Competitive limit
Price equilibrium in AQS case

Properties

\[ p^{AQS} = mw + \frac{\alpha E}{N} \]

1. Pro-competitive effect
2. Competitive limit

Price elasticity of demand

\[ \varepsilon_p = \left. \frac{\partial q_i}{\partial p_i} \frac{p_i}{q_i} \right|_{p_i=p} = -(1 + mw \frac{N}{\alpha E}) \]

When \( \uparrow N \Rightarrow \downarrow \) market power of each individual firm
Equilibrium mass of firms

Must satisfy the following two conditions:

1. Profits are zero due to free entry and exit:
   \[ \pi_i = Lq_i[p_i - mw] - Fw = 0 \Rightarrow E = w \]

2. Labor market clears:
   \[ \int_{\Omega} [mLq_i + F] di = L \]

When price equilibrium is symmetric, both conditions are the same.

- \[ Lqp - Lqmw - Fw = 0 \Rightarrow qmw = qp - \frac{Fw}{L} \Rightarrow qm = \frac{qp}{w} - \frac{F}{L} \]
- \[ NmLq + FN = L \Rightarrow Nmq = 1 - \frac{FN}{L} \Rightarrow mq = \frac{1}{N} - \frac{F}{L} \]

Combining both,

\[ \frac{qp}{w} = \frac{1}{N} \Rightarrow q = \frac{w}{Np} \], which holds in equilibrium

because by the BC \[ Npq = E = w \]
Equilibrium mass of firms: MQS

In equilibrium,

\[ q = \frac{w}{Np} \quad \text{MQS} \quad \frac{w}{N} \frac{\rho}{mw} = \frac{\rho}{Nm} \]

Therefore,

\[ \pi = L \frac{\rho}{Nm} \left[ \frac{mw}{\rho} - mw \right] - Fw = w \left[ \frac{L}{N} (1 - \rho) - F \right] \]

Applying the zero-profit condition,

\[ N_{MQS}^M = \frac{L(1 - \rho)}{F} > 0 \]

\[ \frac{w}{p} = \frac{w}{\frac{mw}{\rho}} = \frac{\rho}{m} \]
Equilibrium mass of firms: AQS

In equilibrium,

\[ q = \frac{w}{Np} = \frac{w}{Nm \alpha w} = \frac{1}{Nm + \alpha} \]

Therefore,

\[ \pi = \frac{L}{Nm + \alpha}[mw + \frac{\alpha w}{N} - mw] - Fw = w\left[\frac{\alpha L}{(\alpha + mN)N} - F\right] \]

Applying the zero-profit condition we get a quadratic equation, but just one solution is relevant

\[ N^{AQS} = \frac{\sqrt{4\alpha mFL + (\alpha F)^2} - \alpha F}{2mF} > 0 \]

\[ \frac{w}{p} = \frac{w}{mw + \frac{\alpha w}{N}} = \frac{N^{AQS}}{\alpha + mN^{AQS}} \]
Conclusions

- Properties of price
  1. MQS: no pro-competitive effects and no competitive limit
  2. AQS: pro-competitive effects and competitive limit

- Decreasing rate of profits
  1. MQS: $1/N$
  2. AQS: $1/N^2$, due to presence of pro-competitive effects

- Equilibrium mass of firms
  1. MQS: $N$ rises proportionally with population size $L$
  2. AQS: $N$ rises less than proportionally with population size $L$
AQS is reminiscent of traditional results in Bertrand and Cournot models, where price converges at least at a rate $1/N$ to marginal cost.

AQS result is similar to results of other models with linear random utility and heterogeneous consumers, but is different in the general equilibrium role of wage and expenditure.
Strong and weak points

Weak points

1. Labor as only production factor
2. Representative consumer

Strong points

1. Returns to scale (motive of trade)
2. Previously, pro-competitive effects with CES required the number of firms be relatively small. Now, we have pro-competitive effects with CARA.
Trade will occur because, in the presence of increasing returns, each variety will be produced in one different country. Gains from trade will occur because the world economy will produce a greater diversity than would either country alone.

- Flows
- Direction
- Transport costs
- Home-market effects on the pattern of trade