COUNTRY-SPECIFIC RIGIDITIES AND INVESTMENT DECISIONS: QUANTITY COMPETITION AND DEMAND UNCERTAINTY

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Country-specific rigidities and investment decisions: quantity competition and demand uncertainty

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Abstract

This paper develops a two-stage quantity competition game between two firms in two different countries. Under demand uncertainty, firms initially install physical capacity. Once final demand has realized, they adjust their production levels by producing above or below capacity. We assume that countries adopt different capital and labour regulations in order to assess how institutions impact firms’ investment decisions. Rigidity in the labour market impacts adjustment costs either with higher overtime wages or with higher temporary lay-off costs. What emerges is a potential explanation for excess of capacity, as the optimal investment in capacity is increasing in labour rigidity and decreasing in capital costs. Also, this model suggests that firms prefer to invest more in physical capacity, as a way to gain higher expected profits.

As an extension, we differentiate firms’ adjustment costs assuming that it is more costly to produce below capacity rather than above. In terms of optimal capacity installation, results confirm the substitution effect of the baseline model. Still, firms’ performances are affected by the cost structure.

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1 Introduction

During economic downturns, drops in final demand have strong repercussions on firms’ profitability. Among the several transmission channels from financial crises on real economy, the 2008 financial crises revealed the severe impact of over capacity in many industrialized countries. Overcapacity also has many social and economic implications, in terms of employment, plant closures, massive lay-offs and supply chain disruptions. As an example, in less than 3 years the capacity utilization rate of Italian automotive plants dropped from a break-even level of 80% to 50%.\footnote{Il Sole 24 ore.}

The installation of plants and productive facilities is perhaps the most relevant investment decision firms have to make. How large should plants be and what optimal potential output should firms achieve? What factors do firms take into account at this preliminary stage? To this purpose, there has always been a significant interest in understanding the impact of institutional rigidity on firms’ investment decisions, but the approach has been so far mainly empirical. Considerable attention has been devoted to the effect of labour market rigidity on firms’ capital-labour ratio: for instance, Autor et al. (2007) identify a positive relation between the level of Employment Protection Legislation, henceforth EPL, and the capital-labour ratio of US firms. This result is opposite to the empirical finding of Cingano et al. (2010), who find evidence of a negative impact of EPL on the capital-labour ratio of financially constrained European firms.

These contrasting evidences have been recently reconciled by the theoretical framework suggested by Janiak and Wasmer (2012), where a generally negative link emerges. Still, this relation can be positive if the two factors of production are sufficiently complementary. To contextualize this analysis, they relate the cross-country EPL to the capital-labour ratio index provided by Caselli (2005). As Figure (1) shows, there is a U-shaped relationship between EPL and the capital-labour ratio: the capital-labour ratio is increasing in EPL up to a certain threshold,\footnote{EPL equal to 2.5, where EPL ranges from 0, absence of labour protection, to 6, maximum protection.} but then it starts decreasing. For instance, the United Kingdom and the United States are on the left side of the curve, whereas Italy and Greece are on the descending side.

Notwithstanding these empirical contributions, the existing theoretical literature fails to relate institutional rigidities to firms’ investment decisions, as explained by Cingano et al. (2010): “while theoretical models offer clear predictions regarding the effects of adjustment costs on job turnover, they provide no guidance on the expected effects of employment protection laws on capital investment, the capital-labour ratio and productivity”.

Throughout this paper, we attempt to fill this gap by modeling the role of country-specific rigidities on the determination of firms’ investment decisions, in terms of the installation of production capacity. To do this, we set up a two-stage model of quantity competition between two firms in two different
countries. At the first stage, firms must simultaneously and non cooperatively make their capacity investment decisions according to their expectations over final demand. Once demand uncertainty has resolved, firms can adjust their output targets according to final demand, by producing above or below the level of capacity previously chosen. This specific setting allows us to provide a theoretical foundation for the over-investment in capacity and to pave the way for policy guidelines reconciling labour regulators and firms’ shareholders.

More specifically, we introduce country specific institutions, and hence cost asymmetries, alternatively in the capital or labour market. A more rigid credit market implies higher capacity installation costs, whereas more rigid labour regulations imply more costly output adjustments. These adjustment costs have a twofold characterization: in the good state, they reflect overtime wages firms must pay to produce above capacity, and in the bad state they reflect temporary lay-off mechanisms to keep the plant partially idle, as capacity cannot be fully exploited. By applying backward induction, we derive the profit-maximizing investment in capacity and consequently assess the impact of the above mentioned institutions.

What emerges is that the optimal investment in capacity is indeed affected by the country’s institutional setting. Interestingly, we observe a substitution effect between the two factors of production that could provide a rational explanation for over-investment in capacity. Under demand uncertainty, as labour becomes more rigid and output adjustments more costly, firms prefer in fact to increase capacity so as to gain future market shares from their previous output.

3We assume that one exogenous shock symmetrically hits demand before the second stage.
4And thus reflect the returns on capital firms have to pay to lending institutions.
commitment.

In order to provide some policy suggestions, our analysis goes beyond this substitution effect and investigates why firms over invest in capacity. To answer this question, we look at firms’ profits and observe that over investment in capacity generally leads to higher expected profits. Still, this model only looks at firms perspective, without taking into account the social implications of producing above or below capacity. Future research should thus include a measure of welfare and evaluate the trade-off between commitment and flexibility from an aggregate point of view.

The paper is structured as follows: section (2) introduces the main related literature; section (3) describes the consumption and cost sides of this model; section (4) develops the main model, whereas section (5) extends the model by assuming that adjustments costs vary with the direction of the adjustment: more specifically, in subsection (5.1) we look at asymmetries between positive and negative adjustments, whereas in subsection (5.2) we include a quadratic component when the adjustment is negative. Last, section (6) draws the main conclusions.

2 Literature review

This paper heavily relies on the seminal contributions of Spence (1977), Dixit (1979), Dixit (1980), who investigate the role of strategic interaction within quantity competition. According to Spence (1977)'s Stackelberg model, the incumbent’s quantity commitment, which is assumed to be invariant with respect to the entrant’s decision\(^5\), is an effective entry deterrence tool; still, the quantity chosen at the first stage might lead to second stage excess of capacity, with respect to final demand. By preserving this constant commitment assumption\(^6\), Dixit (1979) further examines the role of quantity pre-commitment as an effective entry-deterrence strategy chosen by the incumbent. His duopoly model mainly analyzes the role of product differentiation in the entry accommodation or deterrence; in an extension to this model, he studies how an excessive commitment would credibly threaten the inactive firm, by intimidating it with a predatory output in case of entry. In his seminal contribution, Dixit (1980) allows for ex-post adjustments\(^7\) to the pre-entry investment decision. In this way, the established firm could alter the initial conditions of the game\(^8\) by changing the post-entry structure of its marginal costs.

The implications of product differentiation within quantity competition have been further analyzed by Kreps and Scheinkman (1983), who extend Dixit (1980) by implementing product differentiation in a two stage game: firms simultaneously set their capacity and, once aware of the competitor’s optimal

\(^5\)That is, the quantity commitment is constant even in case of no-entry in the second stage.
\(^6\)The Sylos Postulate
\(^7\)Even though the only admitted adjustment is positive, so that investments can only increase.
\(^8\)Which are however assumed to be exogenous.
investment, they engaged in price competition. The fundamental prediction of
this model is that the equilibrium is not only unique but it corresponds exactly
to the standard Cournot outcome.

The role of output commitment has also be analyzed by Spencer and Bran-
der (1992), who look at how firms solve the commitment-flexibility trade-off
in a context of economic uncertainty. They consider alternative contexts of
oligopolistic competition and demonstrate that demand uncertainty affects
the solution to this trade-off, and stress the importance of pre-commitment as an
entry-deterrent strategy.

This trade-off has also been analyzed by Dewit et al. (2013), but with a focus on
firm’s location decisions. They consider in fact a two-period setting, in which
firms initially have to choose where to produce and then engage in either quan-
tity or price competition. At the time of picking their production location, they
must choose between a country with a flexible labour legislation and a country
with a rigid employment protection. The underlying level of employment pro-
tection makes employment adjustment more or less costly: as a consequence,
they interpret employment levels chosen by firms as a source of commitment.
As far as quantity competition is concerned, they observe, as we do, that the
inflexible location is strategically more attractive as employment, acting as a
source of commitment, enables the firm in the rigid country to attain a greater
market share once production effectively takes place, to the detriment of the
firm in the flexible country. Results are instead reversed when price competi-
tion is assumed, since strategic pricing by the firm in the flexible country harms
the firm in the rigid country.

Lu and Poddar (2006) set up a two-stage quantity competition game be-
tween a public and a private firm. Thanks to demand uncertainty, they look
at how the decision to under or over invest in physical capacity is the outcome
of strategic interaction. In their analysis, there is a symmetric outcome as long
as demand is relatively high or low; if instead demand realization is medium,
there is an asymmetric outcome and the public firm, that is maximizing total
welfare, is under investing in capacity, leaving a greater share of the market to
the private firm, which is more efficient from a marginal cost point of view.

Besanko et al. (2010) embed the analysis of positive and negative capacity
adjustments in a context of dynamic oligopoly games. In their framework, two
firms face two types of uncertainty: an exogenous one, related to the state of
demand, and an endogenous one, reflecting strategic interaction and considering
the rival’s adjustment probability. In their numerical analysis, multiple equi-
libria exist: at one extreme, one large firm would adapt its capacity to meet
demand fluctuations, whereas at the other extreme only smaller firms would

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9Modeled as an exogenous, demand additive, shock.
10In their context, the effects of strategic pricing are ruled out if both the firms choose the
flexible country.
11They both under invest for a high demand realization and they both over invest for a low
demand realization.
12Note that firms can only observe the rival’s adjustment probability, not the adjustment
in capacity itself.
change their capacities, thus acting as swing producers.

3 Model specification

This section introduces the main assumption on the consumption and production side, and describes in more detail the timing of the model.

3.1 Consumption side

Preferences in the two countries are defined over a homogenous good $x$. Since this model displays a free trade setting, consumers in the two countries can equivalently purchase the same good, regardless of its origin.\(^{13}\) Final demand is thus a linear function,

$$ p = A - x + \varepsilon $$

where $\varepsilon$ is an exogenous, demand additive\(^{14}\) shock occurring right before second stage production, with $E(\varepsilon) = 0$ and $E(\varepsilon) = \sigma^2$. The magnitude of this shock is $\varepsilon$ in either state, but it is positive in the good one and negative in the bad one, which occur with probability $\gamma$ and $1 - \gamma$ respectively. Market clearing in the goods market must always hold, regardless of the realization of demand:

$$ x = x_i + x_j $$

where $x_i$ is the overall output of firm $i$, which is in turn given by the sum of installed capacity, $k_i$, and the second stage adjustment $q_i$,\(^{15}\) namely $x_i = k_i + q_i$.

3.2 Production side

As displayed in figure (2), firms must decide their optimal capacity $k_i$ in the first stage of the game, basing their choices on the expected final demand. In the second stage, production takes place: according to the realization of demand, firms can adjust the previously installed capacity, by producing above $k_i$, with $q_i > 0$ and $x_i = k_i + q_i$, or below capacity, with $q_i < 0$ and $x_i = k_i - |q_i|$, by keeping the plant partially idle.

To make the initial investment in capacity, firms need to borrow liquidity from the financial market, at a cost $c_i > 0$, which reflects the unitary borrowing rate. The overall first stage cost is assumed to be quadratic, with $ck_i^2$.\(^{16}\) Second stage adjustments display a linear cost, $\theta_i |q_i|$, where $\theta_i$, with $i = 1, 2$, mirrors the country $i$ level of employment protection, invariant with respect to the adjustment direction. In the extended model, we introduce different adjustment

\(^{13}\)Individual preferences are $u(x) = Ax - \frac{bx^2}{2}$, with $A, b > 0$. The indirect demand function is $p = \frac{L(A - bx)}{\lambda}$, where $L$ is the overall population size and $\lambda$ is the marginal utility of income. We assume $\lambda = 1$ and $L = b = 1$.

\(^{14}\)As in Spencer and Brander (1992) and in Dewit et al. (2013).

\(^{15}\)With $q_i < 0$ for $\varepsilon < 0$.

\(^{16}\)A first stage CRS technology was also taken into account, but to no avail.
An exogenous shock $\varepsilon$ hits demand

Firms invest in capacity choosing $k_i$  

Firms observe final demand and decide the output adjustment $q_i$

Figure 2: Timing of the model

costs according to the type of shock realization.

The cost function that describes this baseline setting is

$$C(k_i, q_i) = \theta_i|q_i| + c_i k_i^2$$  \hfill (2)

To extend this analysis, in section (5) we also consider that the good and bad state scenarios imply different cost structures; moreover, we distinguish between two cases. In the first one, we consider good and bad state costs as, respectively,

$$C_i(q_i, k_i)^G = \beta_i q_i + c_i k_i^2$$
$$C_i(q_i, k_i)^B = \theta_i q_i + c_i k_i^2$$  \hfill (3)

assuming that, in country 1, $\theta_1 = \beta_1 = \beta^{17}$, and in country 2 firm faces $\theta_2 > \beta_2 = \beta^{18}$.

We further extend the analysis of adjustment-related cost structures by assuming that both firms incur some additional quadratic costs whenever they have to dismantle some of their production capacity$^{19}$. In this case the good and bad state costs are reflected by, respectively,

$$C_i(q_i, k_i)^G = \theta_i q_i + c_i k_i^2$$
$$C_i(q_i, k_i)^B = \theta_i q_i + \alpha(x_i - q_i)^2 + c_i k_i^2$$  \hfill (4)

where the bad state cost function is similar to the cost function assumed by Lu and Poddar (2006). By focusing on a country-specific rigidity at a time, the purpose of this model is to understand how alternative institutional settings impact and affect the individual firms investment decisions.

4 The model

The model is solved through backward induction. Starting from the second stage, we derive the profit-maximizing level of output adjustment that firms

\footnote{17}We assume that in country 1 the firm incurs the same adjustment cost, $\beta$, regardless of the direction of the adjustment.

\footnote{18}Firm in country 2 has the same good state adjustment cost of country 1, $\beta$, but incurs a higher bad state adjustment cost, $\theta_2$

\footnote{19}That happens when the previously installed capacity is greater than the effective level of production.
would choose in either states of the world. The respective optimal short-run adjustments are then introduced in the first-stage optimization problem, that maximizes expected profits $E(\pi_i)$ with respect to capacity.

### 4.1 Optimal investment in capacity

Once final demand has realized, the two firms can accommodate demand fluctuations by adjusting their production targets: to do this, they play Cournot competition over the second stage production level, $q_i$. To distinguish their reactions according to the state of the world, we separately analyze each state.

If the exogenous shock is positive, demand is ex-post higher and the second stage problem can be written as

$$
\max \quad (a + \varepsilon - (k_i + q_{i,g}) - (k_j + q_{j,g})) (k_i + q_{i,g}) - \theta_i q_{i,g} - c_i k_i^2)
$$

(5)

where $i = 1, 2$, $i \neq j$ and $g$ denotes the good state of the world. Each firm’s reaction function is

$$
q_{i,g} = \frac{a + \varepsilon - \theta_i - k_j - q_{j,g}}{2} - k_i
$$

and the optimal good state adjustment is

$$
q_{i,g}^* = \frac{a + \varepsilon - 2\theta_i + \theta_j}{3} - k_i > 0
$$

In the bad state, the second stage adjustment is negative and firms have to decrease their capacity by keeping the plant partially idle. The related profit maximization problem is

$$
\max \quad (a + \varepsilon - (k_i - |q_{i,b}|) - (k_j - |q_{j,b}|)) (k_i - |q_{i,b}|) - \theta_i |q_{i,b}| - c_i k_i^2)
$$

(6)

where the subscript $b$ denotes the bad state scenario. The reaction function and the optimal adjustment for each firm are, respectively,

$$
|q_{i,b}| = k_i - \frac{\theta_i + a - k_j - |\varepsilon| + |q_{j,b}|}{2}, \quad |q_{i,b}^*| = k_i - \frac{\theta_j + 2\theta_i + a - |\varepsilon|}{3}
$$

The optimal output adjustments of the second stage are brought back to the first stage, when firms simultaneously and non-cooperatively choose their optimal level of physical capacity by maximizing their expected profits

$$
\max \quad E(\pi_i) = \gamma E(\pi_{i,g}) + (1 - \gamma) E(\pi_{i,b})
$$

---

20The derivative with respect to $q_{i,b}$ yields $-\text{signum}(q_{i,b})((a + \theta_i - 2k_i - k_j + |\varepsilon| + 2|q_i| + |q_j|))$, but since $q_{i,b} < 0$ the signum = $-1$.  

8
where $\text{Prob}(\varepsilon > 0) = \gamma$. The solution to this problem directly yields the optimal investment of capacity, that is

$$ k_i = \frac{\theta_i(2\gamma - 1)}{2c_i} \begin{cases} > 0 \text{ for } \gamma \in (\frac{1}{2}, 1] \\ = 0 \text{ for } \gamma \in [0, \frac{1}{2}] \end{cases} $$

(7)

The first result that emerges from equation (7) is that firms, under demand uncertainty, are going to invest in capacity if and only if firms expect with a sufficiently high probability an increase in final demand. If instead decreases in final demand are more likely to occur, firms prefer not to install capacity. This result does no imply firms’ exit, rather it states that firms prefer to be totally flexible and incur only second stage adjustment costs. Then, to investigate the effect of cost asymmetries on the investment of capacity, we distinguish between rigidities on the capital and labour market respectively. Different costs of installing physical capacity merely reflect the different access to credit institutions firms in the two different countries experience.

If we think of this capacity installation decision as a trade-off between commitment and flexibility, equation (7) reveals a substitution effect between capacity and labour. A more restricted access to the credit market makes firm opt for flexibility by preferring labour over capacity. If instead asymmetries and rigidities reflect the labour market legislation, higher labour costs make firms prefer capacity over labour and commit to a higher level of output. Moreover, between-country asymmetries imply that the two firms will choose different level of capacity according to the magnitude of their cost structure, as Proposition (1) confirms.

**Proposition 1** As long as $\gamma \in \left(\frac{1}{2}, 1\right]$, the optimal investment in capacity is positive and equal to $k_i = \frac{\theta_i(2\gamma - 1)}{2c_i}$, with $i = 1, 2$ and $i \neq j$. If:

1. $c_1 > c_2$ and $\theta_1 = \theta_2$, then $k_2 > k_1$;
2. $c_1 = c_2$ and $\theta_1 > \theta_2$, then $k_1 > k_2$;

Last, expected profits are given by

$$ E(\pi_i) = \frac{a^2 + \sigma^2 + (2\theta_i - \theta_j)^2 + 2a(2\theta_i - \theta_j)(1 - 2\gamma)}{9} + \frac{\theta_i^2(2\gamma - 1)^2}{4c_i}, $$

(8)

where $\sigma^2$ is demand variance.

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21 Firms wait for demand realization and eventually produce or outsource production. The no capacity scenario is described in section 4.3.

22 As in Spencer and Brander (1992).
4.2 Firms’ profits

In this part, we compare firms’ performances to assess whether over-investment in capacity pays off or not.

4.2.1 Expected profits under asymmetries in the capital market

Whenever we concentrate on different capacity installation costs, we assume that \( c_1 > c_2 \) and \( \theta_1 = \theta_2 = \theta \); the equation for expected profits simplifies to

\[
E(\pi_i) = \frac{a^2 + \sigma^2 + \theta^2 + 2a\theta(1 - 2\gamma) + \theta_1^2(2\gamma - 1)^2}{9} + \frac{\theta_1^2(2\gamma - 1)^2}{4c_i}
\]

In this case, the firm in the rigid country is investing less in capacity and attaining lower expected profits, as the following Proposition confirms:

**Proposition 2** As long as \( c_1 > c_2 \) and \( \theta_1 = \theta_2 = \theta \), \( k_2 > k_1 \) and \( E(\pi_1) < E(\pi_2) \), \( \forall c_1, c_2, \theta > 0 \).

4.2.2 Expected profits under asymmetries in the labour market

Labour market rigidities imply that \( c_1 = c_2 = c \) and \( \theta_1 > \theta_2 \), with expected profits equal to

\[
E(\pi_i) = \frac{a^2 + \sigma^2 + (2\theta_i - \theta_j)^2 + 2a(2\theta_i - \theta_j)(1 - 2\gamma) + \theta_j^2(2\gamma - 1)^2}{9} + \frac{\theta_j^2(2\gamma - 1)^2}{4c}
\]

As a consequence, the difference between the two firms’ expected profits boils down to

\[
E(\pi_1) > E(\pi_2) \iff \theta_1 > G - \theta_2 \tag{9}
\]

where \( G = \frac{8ac(2\gamma - 1)}{4c + 3(2\gamma - 1)^2} \) and \( G > \theta_2 \).

The comparison between the two firms’ expected profits ultimately depends on the relation between \( \theta_2 \) and \( G \): in case a, \( G - \theta_2 > \theta_2 \), or \( G > 2\theta_2 \), and in case b, \( \theta_2 > G - \theta_2 \), or \( G < 2\theta_2 \), respectively. In either case, the comparison of expected profits reveal 3 different scenarios, as reported in Proposition (3).

**Figures (3) and (4) display the corresponding regions.**

**Proposition 3** As long as \( G - \theta_2 > \theta_2 \):

1. For \( \theta_2 > \theta_1 > 0 \), then \( k_1 < k_2 \) and \( E(\pi_1) < E(\pi_2) \);
2. For \( G - \theta_2 > \theta_1 > \theta_2 \), then \( k_1 > k_2 \) and \( E(\pi_1) < E(\pi_2) \);
3. For \( \theta_1 > G - \theta_2 \), then \( k_1 > k_2 \) and \( E(\pi_1) > E(\pi_2) \);

If instead \( \theta_2 > G - \theta_2 \):

1. For \( G - \theta_2 > \theta_1 > 0 \), then \( k_1 < k_2 \) and \( E(\pi_1) < E(\pi_2) \);

As we are in the capacity installation scenario, that is with \( \gamma \in \left(\frac{1}{2}, 1\right] \).
2. For $\theta_2 > \theta_1 > G - \theta_2$, then $k_1 < k_2$ and $E(\pi_1) > E(\pi_2)$;

3. For $\theta_1 > \theta_2$, then $k_1 > k_2$ and $E(\pi_1) > E(\pi_2)$;

Regions 1 and 3 are common, and symmetric, to the two scenarios: as long as $\theta_1 < \theta_2$, or $\theta_1 < G - \theta_2$, firm 1, which is the low-cost firm, invests less in capacity and achieves lower expected profits. These regions confirm the predictions of Proposition (1): greater labour costs imply a substitution effect in favor of capacity and, eventually, more capacity is installed in the rigid country. In region 2 results are somehow reversed: in either cases, with either $\theta_1 \in (\theta_2, G - \theta_2)$ or $\theta_1 \in (G - \theta_2, \theta)$, the firm in low-cost country\textsuperscript{24} invests in capacity and attains greater expected profits.

4.2.3 Profits in the good and bad state

As a last step, we evaluate the effective performance of each firm in either state of the world. We thus compare the good state profits with the bad state profits and try to understand under which circumstances over-investment in capacity effectively pays-off. In the previous section we in fact looked only at the impact of capacity installation and of demand uncertainty on the expected profits, with an ex-ante perspective. This ex-post analysis allows us to better comprehend the consequences of strategic interaction and to evaluate output

\textsuperscript{24}Respectively country 2 and country 1.
adjustment dynamics. For sake of interest, in the remaining of this section we will be considering only second stage asymmetries: $c_1 = c_2 = c$ and $\theta_1 > \theta_2$.

Good state profits for firm $i$, with $i = 1, 2$, are represented by

$$\pi_{i,g} = \frac{-9 \left(3 - 8\gamma + 4\gamma^2\right) \theta_i^2 + 4c \left(a^2 + \sigma^2 + (2\theta_i - \theta_j)^2 + 2a\theta_j - 4\theta_ia\right)}{36c}$$

and it is easy to show that over-investment in capacity pays-off in the good state as long as the magnitude of the adjustment cost asymmetry is sufficiently high, with

$$\pi_1^g > \pi_2^g \iff \theta_1 > \frac{8ac}{(-9 + 4c + 24\gamma - 12\gamma^2) - \theta_2 > \theta_2}.$$ 

Bad state profits of firm $i$ are represented by

$$\pi_{i,b} = \frac{1}{9} \left(a^2 + \sigma^2 + (2\theta_i - \theta_j)(2\theta_i - \theta_j + 2a) + \frac{9z\theta_i^2(z - 1)}{c}\right)$$

where $z = \frac{(2\gamma - 1)}{2}$. In this specific case, we still have that the firm with an initial greater commitment is attaining grater profits also in the bad state, although this results depend on the values of $\gamma$ and $c$: for $\gamma = 1/2$ in fact

$$\pi_1^b > \pi_2^b \iff \forall \theta_1 > \theta_2 \text{ and for } c > 0$$

in instead $\gamma = 1$

$$\pi_1^b > \pi_2^b \iff \forall \theta_1 > \theta_2 \text{ and for } c > \frac{9}{4}$$

This means that the level of installation cost needed to make the rigid firm attain greater bad state profits is increasing in the probability of the good shock: as the positive shock becomes more and more likely, higher installation costs are needed to make over-investment be a winning strategy.

4.3 Expected profits with and without capacity

As previously discussed, firms invest in capacity only if they expect with sufficient probability an increase in final demand. Otherwise, firms do not exit but rather wait for demand realization and produce, either on their own or outsourcing, incurring only the second stage costs.

The purpose of this section is to compare the profits of firms investing in capacity with the profits when no capacity is installed. We show that, under some specific parametric assumptions, firms achieve greater profits when capacity is installed and conclude that firms prefer to incur the sunk investment cost rather than being totally flexible.

When considering the no capacity scenario, we thus assume that $\gamma \in (0, \frac{1}{2})$. Aware of $k_i = 0$, we can retrieve directly equilibrium output and profits:

$$q_{i,k}^{n} = \frac{a - 2\theta_i + \theta_j}{3} \pm \frac{|\varepsilon|}{3} \quad \pi_{i,k}^{n} = \frac{(a - 2\theta_i + \theta_j \pm |\varepsilon|)^2}{9}$$

25Since there is no additional burden for dismantling capacity.
with $\pi_{2k}^n > \pi_{1k}^n \iff \theta_1 > \theta_2$. Expected profits under capacity are given by equation (8) and expected profits with no capacity are

$$E(\pi_i|k_i=0) = \frac{(a-(2\theta_i-\theta_j))^2 + \sigma^2}{9}$$

From the mere comparison of $E(\pi_i|k_i>0)$ and $E(\pi_i|k_i=0)$, we can derive two parametric conditions, one for each cost component, for which capacity installation does pay-off, as reported in Proposition (4):

**Proposition 4** $E(\pi_i|k_i>0) > E(\pi_i|k_i=0)$ iff $c_i > 0$ and $\theta_i > \tilde{\theta}_i$, with $\tilde{\theta}_i \equiv \frac{4c_i}{9(2\gamma - 1)^2} \left(4a(1-\gamma) + \sqrt{16a^2(1-\gamma)^2 + 9a(1-\gamma)(2\gamma - 1)^2} \right) > 0$

Under some conditions, firms are thus better off when investing in capacity. These gains occur for any non-negative investment cost $c_i$, but, more interestingly, they occur for sufficiently high adjustment costs.

### 4.4 Comparative statics

We perform comparative statics on the optimal level of capacity installation, equation (7), as well as on expected profits, equation (8). As long as we consider capacity, we quantify the marginal effect of $c_i$ and $\theta_i$: whereas the marginal effect of $\theta_i$ is positive, an increase in $c_i$ has a negative marginal effect on the installation decision. These results confirm the substitution effect between capacity and labour already discussed in the previous section.

$$\frac{\partial k_i}{\partial \theta_i} = \frac{2\gamma - 1}{2c_i} > 0 \iff \gamma > \frac{1}{2}$$

$$\frac{\partial k_i}{\partial c_i} = -\frac{\theta_i(2\gamma - 1)}{2c_i^2} < 0 \iff \forall c_i, \theta_i > 0, \gamma > \frac{1}{2}$$

We also look at the marginal effect of $c_i$, $\theta_i$ and $\theta_j$ on $E(\pi_i)$: the marginal effect of $c_i$ is once again negative, whereas the marginal effect of $\theta_i$ is positive only if $\theta_i$ are high enough. An increase in $\theta_i$ makes firms prefer capacity over labour, but the effect on expected profits is positive if and only if these costs are high enough. In other words, the substitution effect in favor of capacity might be potentially detrimental to the firm’s profitability. Last, the marginal effect of $\theta_j$ is negative if and only if $\theta_j$ is sufficiently small. If firm $j$ faces low adjustment costs $\theta_j$, firm $j$ would prefer flexibility over commitment; as the the firm with more capacity attains higher expected profits, an increase $\theta_j$ makes firm $j$ install
more in capacity and thus expected profits of firm \( i \) decrease.

\[
\frac{\partial E(\pi_i)}{\partial c_i} = -\frac{\theta_i^2(1-2\gamma)^2}{4c_i^2} < 0 \iff \forall c_i, \theta_i, \gamma > 0
\]

\[
\frac{\partial E(\pi_i)}{\partial \theta_i} > 0 \iff \theta_i > \frac{8c_i[a(2\gamma - 1) + \theta_j]}{9(1-2\gamma)^2 + 16c_i} > 0
\]

\[
\frac{\partial E(\pi_i)}{\partial \theta_j} < 0 \iff 0 < \theta_j < \theta_i - a(2\gamma - 1)
\]

5 Shock related adjustment costs

In the baseline model, we provide a rationale for excess capacity. In this section, we ask whether firms still choose commitment when it is more costly to reduce capacity than to produce beyond capacity. More specifically, we think of two different cost structures: in the first one, we consider the cost structure represented by (3), according to which adjustment costs for firm 1 are identical in the good and bad state scenario and we let firm in country 2 incur a higher adjustment cost in the bad state of the world. In the second approach instead, we introduce a bad state quadratic adjustment cost, related to the distance between installed capacity and the effective production level, as represented by the cost structure (4).

5.1 Positive and negative adjustment asymmetries

As before, we apply backward induction and solve the model from the second state of the game. In this new setting, we still consider quadratic installation costs in the first stage. As far as output adjustments are concerned, we distinguish adjustment costs according to the adjustment direction. To introduce cost asymmetries, we assume that in country 1 negative and positive adjustments costs are identical, that is \( \beta_1 = \theta_1 = \beta \). In country 2, positive adjustments cost as in country 1, with \( \beta_1 = \beta_2 = \beta \), whereas negative adjustments cost instead more, with \( \theta_2 > \theta_1 = \beta \).

\[
C(q_1,k_1)^{c>0} = C(q_1,k_1)^{c<0} = \beta q_1 + c_1k_1^2
\]
\[
C(q_2,k_2)^{c>0} = \beta q_2 + c_2k_2^2
\]
\[
C(q_2,k_2)^{c<0} = \theta_2 q_2 + c_2k_2^2
\]

In the good state, the reaction functions of firm 1 and 2 are respectively given by

\[
q_1^g = \frac{1}{2}(a + \varepsilon - 2k_1 - k_2 - q_2 - \beta) \quad q_2^g = \frac{1}{2}(a + \varepsilon - k_1 - 2k_2 - q_1 - \beta)
\]
whereas in the bad state they are
\[ q_1^b = \frac{1}{2} (-a + \epsilon + 2k_1 + k_2 - q_2 - \beta) \quad q_2^b = \frac{1}{2} (-a + \epsilon + k_1 + 2k_2 - q_1 - \theta_2) \]

Once solved for strategic interaction\(^{26}\), we can look at the maximization of expected profits in the first stage.

The maximization problems for firm 1 and 2\(^ {27}\) determines their optimal investment in capacity:
\[
k_1 = \frac{\beta(2\gamma - 1)}{2c_1} \quad k_2 = \frac{\gamma \beta + \theta_2(\gamma_1)}{2c_2},
\]
with \(k_1\) positive only for \(\gamma > \frac{1}{2}\), as in the baseline model, and \(k_2\) positive for \(\gamma > \frac{\beta_2}{\beta_1}\).

Equations (11) has two implications: first, firm in country 1 is going to install capacity only for \(\gamma > \frac{1}{2}\), as in the baseline specification, whereas firm in country 2, given the higher negative adjustment costs, needed an even higher probability of a positive shock, with \(\theta_2 > \frac{1}{2}\) as long as \(\theta_2 > \beta\). Second, firm 2 is also going to install capacity than firm 1, whereas in the baseline model we concluded that the firm incurring greater adjustment costs\(^{28}\) was installing a greater level of physical capacity. In addition to this departure, in this extension it is firm 2 to attain greater expected profits,\(^{29}\) with
\[
E(\pi_2) - E(\pi_1) > 0 \iff \frac{(\gamma - 1)(\beta - \theta_2)}{12c} [8ac + (\beta + \theta_2)(4c + 3(1 - 3\gamma))] > 0
\]

In terms of good and bad state profits, it is easy to see that firm 1, benefiting from its greater initial commitment, is able to attain a greater market share in the good state and thus gets higher good state profits, with
\[ \pi_1^g > \pi_2^g \iff \theta_2 > \beta \]

Intuitively, results are reversed in the bad state: the more flexible firm attains in fact more profits since it has to dismantle less capacity that firm 1, but this result holds only if the installation of capacity is sufficiently costly, with
\[ \pi_1^b < \pi_2^b \iff \theta_2 > \beta \text{ and } c > \frac{3}{2} \]

\(^{26}\)From which we can rewrite adjustment decisions as a function of capacity only, that is
\[ q_1^g = \frac{1}{8} (a + \epsilon - 3k_1 - \beta_2), \quad q_2^g = \frac{3}{8} + \frac{k_2}{8} - \frac{k_2}{8}, \quad q_1^b = \frac{1}{8} (-a + \epsilon + 3k_1 - 2\beta_2 + \theta_2) \quad \text{and} \quad q_2^b = \frac{3}{8} + \frac{k_2}{8} + k_2 + \frac{\beta_2}{8} - \frac{2\theta_2}{8} \]

\(^{27}\)Whose expected profits are respectively given by
\[
E(\pi_1) = \gamma \left( \frac{a^2}{\theta_1} + \frac{\sigma^2}{\theta_1} - c_1 k_1^2 - \frac{2a\beta_1}{\theta_1} + k_1 \beta_1 + \frac{\theta_1^2}{\theta_1} \right) + (1 - \gamma) \left( \frac{a^2}{\theta_2} + \frac{\sigma^2}{\theta_2} - c_1 k_1^2 + \frac{4a\beta_1}{\theta_2} - k_1 \beta_1 + \frac{4\theta_1^2}{\theta_2} - \frac{2a\theta_2}{\theta_2} - \frac{4k_1 \theta_1}{\theta_2} + \frac{\theta_1^2}{\theta_2} \right)
\]

and
\[
E(\pi_2) = \gamma \left( \frac{a^2}{\theta_2} + \frac{\sigma^2}{\theta_2} - c_2 k_2^2 - \frac{2a\beta_2}{\theta_2} + k_2 \beta_2 + \frac{\theta_2^2}{\theta_2} \right) + (1 - \gamma) \left( \frac{a^2}{\theta_2} + \frac{\sigma^2}{\theta_2} - c_2 k_2^2 - \frac{2a\beta_2}{\theta_2} + k_2 \beta_2 + \frac{\theta_2^2}{\theta_2} \right).
\]

\(^{28}\)Which were the same both in the bad ad good state.

\(^{29}\)As long as we assume that the two firms face the same first stage cost, that is with \(c_1 = c_2 = c\).
5.2 Quadratic adjustment costs

This analysis adds to the baseline cost specification a quadratic cost component firms have to pay as long as adjustments are negative. In either state, costs incurred by firms are alternatively

\[ C(q_i, k_i) > 0 = \theta_i q_i + c_i k_i^2 \]

\[ C(q_i, k_i) < 0 = \theta_i |q_i| + \alpha (k_i - |q_i|)^2 + c_i k_i^2 \]

where \( \alpha (k_i - |q_i|)^2 \) is an adjustment cost proportional to the distance between the initial installed capacity and the effective level of production that ought to take place at the second stage.

The second stage reaction functions are

\[ q_{i,g} = a + \varepsilon + 2k_i - k_j - q_{j,g} - \theta_i \]

\[ |q_{i,b}| = |\varepsilon| - a + 2k_i(1 + \alpha) + k_j - |q_{j,b}| - \theta_j \]

and the outcome of the first stage optimization problem is identical to the level of capacity of the baseline model, with

\[ k_i = \frac{\theta_i (2\gamma - 1)}{2c_i} \]

which confirms the results reported in Proposition (1). That is, despite the quadratic adjustment cost, capacity is going to be installed if and only if the positive shock occurs with a sufficiently high probability. Also, the patterns of the substitution effect are those of the baseline model.

Once again, we compare the expected profits of the two firms to assess the pay-offs related to the over-investment in capacity. For interest’s sake, we concentrate only on labour market asymmetries.\textsuperscript{30}

Again, results are robust\textsuperscript{31} as the difference in the two firms expected profits boils down to

\[ E(\pi_1) - E(\pi_2) = \theta_1 + \theta_2 - \tilde{G} \]

where \( \tilde{G} > 0\textsuperscript{32} \), leading to a pattern similar to the baseline model:

1. As long as \( \tilde{G} - \theta_2 > \theta_2 \):
   (a) For \( \theta_2 > \theta_1 > 0 \): \( k_1 < k_2 \) and \( E(\pi_1) < E(\pi_2) \);
   (b) For \( \tilde{G} - \theta_2 > \theta_1 > \theta_2 \): \( k_1 > k_2 \) and \( E(\pi_1) < E(\pi_2) \);
   (c) For \( \theta_1 > \tilde{G} - \theta_2 > 0 \): \( k_1 > k_2 \) and \( E(\pi_1) > E(\pi_2) \);

2. If instead \( \theta_2 > \tilde{G} - \theta_2 \):
   (a) For \( \tilde{G} - \theta_2 > \theta_1 > 0 \): \( k_1 < k_2 \) and \( E(\pi_1) < E(\pi_2) \);
   (b) For \( \theta_2 > \theta_1 > \tilde{G} - \theta_2 \): \( k_1 < k_2 \) and \( E(\pi_1) > E(\pi_2) \);

\textsuperscript{30}With \( c_1 = c_2 = c \) and \( \theta_1 > \theta_2 \).

\textsuperscript{31}See equation (9).\textsuperscript{32}\( \tilde{G} \equiv \frac{8ac(-3 + 6\gamma + 4\alpha^2\gamma + \alpha(-3 + 11\gamma))}{3(3 + 8\alpha + 4\alpha^2)(1 - 2\gamma)^2 + 4c(3 + 4\alpha^2\gamma + \alpha(3 + 5\gamma))} \)}
(c) For $\theta_1 > \theta_2$: $k_1 > k_2$ and $E(\pi_1) > E(\pi_2)$.

The results and the predictions of this extended model are robust with respect to what emerged in the baseline analysis. Still, the regions describing the underlying profitability might now differ in size, since $G > \tilde{G}$ for $\forall \alpha > 0$. Figures (5) and (6) confirm this, respectively for $G - \theta_2 > G - \theta_2 > \theta_2$ and for $\theta_2 > G - \theta_2 > G - \theta_2$.

Figure 5: Expected profits, baseline vs. extended, case a

Figure 6: Expected profits, baseline vs. extended, case b

To conclude our analysis, we look at good and bad state profits. Also in this last setting, the firm with more capacity gains more in the good state,\textsuperscript{33} with

\[ \pi_1^g > \pi_2^g \iff \theta_1 > \frac{8ac}{(-9 + 4c + 24\gamma - 12\gamma^2)} - \theta_2 > \theta_2. \]

The new bad state cost structure makes the comparison of bad state profits less straightforward, with

\[ \pi_1^b - \pi_2^b = \theta_1 + \theta_2 + \frac{8ac(1 + \alpha)}{4c(1 + \alpha) + (3 + 8\alpha + 4\alpha^2)(1 - 4\gamma^2)}. \]

\textsuperscript{33}This scenario corresponds exactly to the baseline model.
where the numerator of the third term is always positive. Since we are dealing with capacity, we know that \( \gamma > 1/2 \) and \((1 - 4\gamma^2) < 0\) and we can conclude that firm 2, with less capacity, is attaining greater bad state profits\(^{34}\), but this advantage depends on both \(\gamma\) and \(c\). For \(\gamma = 1/2\), the more flexible firm attains higher bad state profits for any \(c > 0\). As \(\gamma\) increases, the threshold value of \(c\) for which this advantage is preserved increases as well: this means that during economic downturns under-investment, and thus flexibility, does pay-off, but this advantage is decreasing in first stage costs as economic upturns are ex-ante more likely.

6 Conclusions

This paper contributes to the quantity competition literature by relating firms’ investment decisions, in terms of physical capacity, to the institutional background in which they are to operate.

To do this, we set up a two stage game with demand uncertainty in which firms initially install capacity according to their expected demand, and then adjust their output levels after observing final demand. In this model, there are two factors of production only: physical capacity and labour, needed to adjust production targets. In order to introduce institutional rigidities and country cost asymmetries, we assume that the two countries face different cost structures and we also assess the impact of these institutional backgrounds on the level of capacity. More precisely, firms choose the level of capacity that maximizes their expected profits. What emerges is a substitution effect between the two factors: for high capital costs, firms invest less in capacity and prefer ex-post adjustments. For high labour costs instead, firms prefer to install more capacity and be less flexible with respect to demand realization.

Thus, the over-investment in capacity this paper tries to justify might be indeed related to the institutional framework of a given country. Also, this analysis shows that, on average, the firm with a greater capacity commitment is attaining higher expected profits, which could also further motivate the decision to excessively invest in production capacity. Results are robust to the introduction of adjustment costs that depend on the sign of the shock.

Many extensions to this model can be suggested. First, it could be generalized to a \(n\)—firm scenario, which could eventually allow for the introduction within countries asymmetries, in terms of sector specific characteristics. This generalized framework could be further extended to allow for product differentiation, to see whether this additional source of competition affects investment in capacity or not. We could also think of introducing some welfare implications, for instance by assessing the potential welfare loss related to an over-investment in capacity during an economic downturn. This last issue should be more carefully taken into account, as it might also pave the way to future policy guidelines.

\(^{34}\)As the firm with more capacity has to pay more that proportionally to keep its plant partially idle.
References


