6. Economic Aspects of Automation

Piercarlo Ravazzi, Agostino Villa

The increasing diffusion of automation in all sectors of the industrial world gives rise to a deep modification of labor organization and requires a new approach to evaluate industrial systems efficiency, effectiveness, and economic convenience. Until now, the evaluation tools and methods at disposal of industrial managers are rare and even complex. Easy-to-use criteria, possibly based on robust but simple models and concepts, appear to be necessary. This chapter gives an overview of concepts, based on the economic theory but revised in the light of industrial practice, which can be applied for evaluating the impact and effects of automation diffusion in enterprises.

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Automation implementation and perception of its convenience in the electronics sector is different from in the automotive sector. The electronics sector, however, is rather specific since it was born together with — and as the instrument of — industrial automation. All other industrial sectors present a typical attitude of strong but cautious interest in automation. The principal motivation for this caution is the difficulty that managers face when evaluating the economic impact of automation on their own industrial organization. This difficulty results from the lack of simple methods to estimate economic impact and obtain an easily usable measure of automation revenue.

The aim of this chapter is to present an evaluation approach based on a compact and simple economic model to be used as a tool dedicated to SME managers, to analyze main effects of automation on production, labor, and costs.

The chapter is organized as follows. First, some basic concepts on which the evaluation of the automation effects are based are presented in Sect. 6.2. Then, a simple economic model, specifically developed for easy interpretation of the impact of automation on the enterprise, is discussed and its use for the analysis of some industrial situations is illustrated in Sect. 6.3. The most important effects of automation within the enterprise are considered in Sect. 6.4, in terms of its impact on production, incentivization and control of workers, and costs flexibility. In the final part of the chapter, mid-term effects of automation in the socioeconomic context are also analyzed. Considerations of such effects in some sectors of the Italian industrial system are discussed in Sect. 6.6, which can be considered as a typical example of the impact of automation on a developed industrial system, easily generalizable to other countries.
Economic Aspects of Automation

Part A6

Australia (3)
- Real estate, renting & business activities
- Transport & storage
- Wholesale trade
- Retail
- All industries

Austria
- Construction
- Manufacturing
- Real estate, renting & business activities
- Transport, storage & communication
- Wholesale & retail trade
- All industries

Belgium
- Construction
- Manufacturing
- Real estate, renting & business activities
- Transport, storage & communication
- Wholesale trade
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Canada
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- Manufacturing
- Real estate, renting & business activities
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Czech Republic
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Denmark
- Construction
- Wholesale & retail trade
- All industries

Finland
- Construction
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- All industries

Germany
- Construction
- Manufacturing
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- Wholesale & retail trade
- All industries

Greece
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- Manufacturing
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Hungary
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Iceland (2006)
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Japan
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- Manufacturing
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- All industries
6.1 Basic Concepts in Evaluating Automation Effects

The desire of any SME manager is to be able to evaluate how to balance the cost of implementing some automated devices (either machining units or handling and moving mechanisms, or automated devices to improve production organization) and the related increase of revenue.

To propose a method for such an economic evaluation, it is first necessary to declare a simple catalogue of potential automation typologies, then to supply evidence of links between these typologies and the main variables of a SME which could be affected by process and labor modifications due to the applied automation. All variables to be analyzed and evaluated must be the usual ones presented in a standard balance sheet.

Analysis of a large number of SME clusters in ten European countries, developed during the collaborative demand and supply networks (CODESNET) project [6.1] funded by the European Commission, shows that the most important typologies of automation implementations in relevant industrial sectors can be classified as follows:

1. **Robotizing**, i.e., automation of manufacturing operations
2. **Flexibilitization**, i.e., flexibility through automation, by automating setup and supply
3. **Monitorizing**, i.e., monitoring automation through automating measures and operations control.

These three types of industrial automation can be related to effects on the process itself as well as on personnel. **Robotizing** allows the application of greater operation speed and calls for a reduced amount of direct work hours. **Flexibilitization** is crucial in mass customization, to reduce the lead time in the face of customer demands, by increasing the product mix, and by facilitating producer–client interaction. **Monitorizing** can indeed assure product quality for a wide range of final items through diffused control of work operations. Both automated flexibility and automated monitoring, however, require higher skills of personnel (Table 6.1).

However, a representation of the links between automation and either process attributes or personnel working time and skill, as outlined in Table 6.1, does not correspond to a method for evaluating the automation-induced profit in a SME, or in a larger enterprise. It only shows effects, whereas their impact on the SME balance sheet is what the manager wants to know.

To obtain this evaluation it is necessary:

1. To have clear that an investment in automation is generally relevant for any enterprise, and often critical for a SME, and typically can have an impact on mid/long-term revenue.
2. To realize that the success of an investment in terms of automation depends both on the amount of investment and on the reorganization of the workforce in the enterprise, which is a microeconomic effect (meaning to be estimated within the enterprise).
3. To understand that the impact of a significant investment in automation, made in an industrial sector, will surely have long-term and wide-ranging effects on employment at the macroeconomic level (i.e., at the level of the socioeconomic system or country).

All these effects must be interpreted by a single evaluation model which should be used:

- For a microeconomic evaluation, made by the enterprise manager, to understand how the two

<table>
<thead>
<tr>
<th>Automation typology induces ...</th>
<th>... effects on the process ...</th>
<th>... and effects on personnel</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Robotizing</td>
<td>Operation speed</td>
<td>Work reduction</td>
</tr>
<tr>
<td>(b) Flexibilitization</td>
<td>Response time to demand</td>
<td>Higher skills</td>
</tr>
<tr>
<td>(c) Monitorizing</td>
<td>Process accuracy and product quality</td>
<td></td>
</tr>
</tbody>
</table>

Then automation calls for ...

- Investments

Investments and new labour positions should give rise to an expected target of production, conditioned on investments in high technologies and highly skill workforce utilization.
above-mentioned *principal factors*, namely investment and workforce utilization, could affect the expected target of production, in case of a given automation implementation

- For a *macroeconomic evaluation*, to be done at the level of the industrial sector, to understand how relevant modification of personnel utilization, caused by the spread of automation, could be reflected in the socioeconomic system.

These are the two viewpoints according to which the automation economic impact will be analyzed upon the introduction of the above-mentioned interpretation model in Sect. 6.2.

### 6.2 The Evaluation Model

#### 6.2.1 Introductory Elements of Production Economy

Preliminary, some definitions and notations from economics theory are appropriate (see the basic references [6.2–6]):

- A *production technique* is a combination of factors acquired by the market and applied in a product/service unit.
- *Production factors* will be simply limited to the capital $K$ (i.e., industrial installation, manufacturing units, etc.), to labor $L$, and to intermediate goods $X$ (i.e., goods and services acquired externally to contribute to production).
- A *production function* is given by the relation $Q = Q(K, L, X)$, which describes the output $Q$, production of goods/services, depending on the applied inputs.
- *Technological progress*, of which automation is the most relevant expression, must be incorporated into the capital $K$ in terms of process and labor innovations through investments.
- *Technical efficiency* implies that a rational manager, when deciding on new investments, should make a choice among the available innovations that allow him to obtain the same increase of production without waste of inputs (e.g., if an innovation calls for $K_0$ units of capital and $L_0$ units of labor, and another one requires $L_1 > L_0$ units of labor, for the same capital and production, the former is to be preferred).
- *Economic efficiency* imposes that, if the combination of factors were different (e.g., for the same production level, the latter innovation has to use $K_1 < K_0$ capital units), then the rational manager’s choice depends on the cost to be paid to implement the innovation, thus accounting also for production costs, not only quantity.

Besides these statements it has to be remarked that, according to economic theory, production techniques can be classified as either *fixed-coefficients technologies* or *flexible-coefficients technologies*. The former are characterized by nonreplaceable and strictly complementary factors, assuming that a given quantity of production can only be obtained by combining production factors at fixed rates, with the minimum quantities required by technical efficiency. The latter are characterized by the possibility of imperfect replacement of factors, assuming that the same production could be obtained through a variable, nonlinear combination of factors.

#### 6.2.2 Measure of Production Factors

Concerning the measure of production factors, the following will be applied.

With regard to labor, the working time $h$ (hours) done by personnel in the production system, is assumed to be a *homogeneous factor*, meaning that different skills can be taken into account through suitable weights.

In case of $N$ persons in a shift and $T$ shifts in unit time (e.g., day, week, month, etc.), the labor quantity $L$ is given by

$$L = hNT.$$  

(6.1)

In the following, the capital $K$ refers to machines and installations in the enterprise. However, it could also be easily measured in the case of fixed-coefficient technologies: the capital stock, indeed, could be measured in terms of *standard-speed machine equivalent hours*. The capital $K$ can also be further characterized by noting that, *over a short period*, it must be considered a fixed factor with respect to production quantity: excess capacity cannot be eliminated without suffering heavy losses.

Labor and intermediate goods should rather be variable factors with respect to produced quantities: excess
6.3 Effects of Automation in the Enterprise

6.3.1 Effects of Automation on the Production Function

The approach on which the following considerations are based was originally developed by Luciano and Ravazzi [6.23], assuming the extreme case of production only using labor, i.e., without employing capital (e.g., by using elemental production means). In this case, a typical human characteristic is that a worker can produce only at a rate that decreases with time during his shift. So, the marginal work productivity is decreasing. Then, taking account of the work time $h$ of a worker in one shift, the decreasing efficiency of workers with time suggests the introduction of another measure, namely the efficiency unit $E$, given by

$$E = h^\alpha ,$$

(6.3)

where $0 < \alpha < 1$ is the efficiency elasticity with respect to the hours worked by the worker.
Condition (6.3) includes the assumption of decreasing production rate versus time, because the derivative of $E$ with respect to $h$ is positive but the second derivative is negative.

Note that the efficiency elasticity can be viewed as a measure of the worker’s strength.

By denoting $\lambda_E$ as the production rate of a work unit, the production function (6.2) can be rewritten as

$$Q = \lambda_E \, \text{ENT}.$$  \hspace{1cm} (6.4)

Then, substitution of (6.1) and (6.3) into (6.4), gives rise to a representation of the average production rate, which shows the decreasing value with worked hours

$$\lambda_L = Q / L = \lambda_E h^{\alpha - 1},$$  \hspace{1cm} (6.5)

with $d\lambda_L / dh = (\alpha - 1) \lambda_E h^{\alpha - 2} < 0$.

Let us now introduce the capital $K$ as the auxiliary instrument of work (a computer for intellectual work, an electric drill for manual work, etc.), but without any process automation.

Three questions arise:

1. How can capital be measured?
2. How can the effects produced by the association of capital and work be evaluated?
3. How can capital be included in the production function?

With regard to the first question, the usual industrial approach is to refer to the utilization time of the production instruments during the working shift. Then, let the capital $K$ be expressed in terms of hours of potential utilization (generally corresponding to the working shift).

Utilization of more sophisticated tools (e.g., through the application of more automation) induces an increase in the production rate per hour. Denoting by $\gamma > 1$ a coefficient to be applied to the production rate $\lambda_L$, in order to measure its increase due to the effect of capital utilization, the average production rate per hour (6.5) can be rewritten as

$$\lambda_L = \gamma \lambda_E h^{\alpha - 1}.$$  \hspace{1cm} (6.6)

The above-mentioned effect of capital is the only one considered in economics theory (as suggested by the Cobb–Douglas function). However, another significant effect must also be accounted for: the capital’s impact on the workers’ strength in terms of labor (as mentioned in the second question above).

Automated systems can not only increase production rate, but can also strengthen labor efficiency elasticity, since they reduce physical and intellectual fatigue. To take account of this second effect, condition (6.6) can be reformulated by including a positive parameter $\delta > 0$ that measures the increase of labor efficiency and whose value is bounded by the condition $0 < (\alpha + \delta) < 1$ so as to maintain the hypothesis of decreasing production rate with time

$$\lambda_L = \gamma \lambda_E h^{\alpha + \delta - 1}.$$  \hspace{1cm} (6.7)

According to this model, a labor-intensive technique is defined as one in which capital and labor cooperate together, but in which the latter still dominates the former, meaning that a reduction in the labor marginal production rate still characterizes the production process ($\alpha + \delta < 1$), even if it is reduced by the capital contribution ($\delta > 0$).

The answer to the third question, namely how to include capital in the production function, strictly depends on the characteristics of the relevant machinery. Whilst the workers’ nature can be modeled based on the assumption of decreasing production rates with time, production machinery does not operate in this way (one could only make reference to wear, although maintenance, which can prevent modification of the production rate, is reflected in capital cost).

On the contrary, it is the human operator who imposes his biological rhythm (e.g., the case of the speed of a belt conveyor that decreases in time during the working shift). This means that capital is linked to production through fixed coefficients: then the marginal production rate is not decreasing with the capital.

Indeed, a decreasing utilization rate of capital has to be accounted for as a consequence of the decreasing rate of labor. So, the hours of potential utilization of capital $K$ have to be converted into productive hours through a coefficient of capital utilization $\theta$ and transformed into production through a constant capital-to-production rate parameter $v$

$$Q = \theta K / v = \theta \lambda_K K,$$  \hspace{1cm} (6.8)

where $\lambda_K = 1 / v$ is a measure of the capital constant productivity, while $0 < \theta < 1$ denotes the ratio between the effective utilization time of the process and the time during which it is available (i.e., the working shift).

Dividing (6.8) by $L$ and substituting into (6.7), it follows that

$$\theta = v \gamma \lambda_E h^{\alpha + \delta - 1},$$  \hspace{1cm} (6.9)

thus showing how the utilization rate of capital could fit the decreasing labor yield so as to link the mechanical rhythm of capital to the biological rhythm of labor.

Condition (6.9) leads to the first conclusion: in labor-intensive systems (in which labor prevails over
capital), decreasing yields occur, but depending only on the physical characteristics of workers and not on the constant production rates of production machinery.

We should also remark on another significant consideration: that new technologies also have the function of relieving labor fatigue by reducing undesirable effects due to marginal productivity decrease.

This second conclusion gives a clear suggestion of the effects of automation concerning reduction of physical and intellectual fatigue. Indeed, automation implies dominance of capital over labor, thus constraining labor to a mechanical rhythm and removing the conditioning effects of biological rhythms.

This situation occurs when \( \alpha + \delta = 1 \), thus modifying condition (6.7) to

\[
\lambda_L = \frac{Q}{L} = \gamma \lambda E,
\]

which, in condition (6.9), corresponds to \( \theta = 1 \), i.e., no pause in the labor rhythm.

In this case automation transforms the decreasing yield model into a constant yield model, i.e., the labor production rate is constant, as is the capital production rate, if capital is fully utilized during the work shift. Then, capital-intensive processes are defined as those that incorporate high-level automation, i.e., \( \alpha + \delta \to 1 \).

A number of examples of capital-intensive processes can be found in several industrial sectors, often concerning simple operations that have to be executed a very large number of times. A typical case, even if not often considered, are the new intensive picking systems in large-scale automated warehouses, with increasing diffusion in large enterprises as well as in industrial districts.

Section 6.6 provides an overview in several sectors of the two ratios (capital/labor and production/labor) that, according to the considerations above, can provide a measure of the effect of automation on production rate. Data are referred to the Italian economic/industrial system, but similar considerations could be drawn for other industrial systems in developed countries. Based on the authors’ experience during the CODESNET project development, several European countries present aspects similar to those outlined in Sect. 6.6.

### 6.3.2 Effects of Automation on Incentivization and Control of Workers

Economic theory recognizes three main motivations that suggest that the enterprise can achieve greater wage efficiency than the one fixed by the market [6.24]:

1. The need to minimize costs for hiring and training workers by reducing voluntary resignations [6.25, 26]
2. The presence of information asymmetry between the workers and the enterprise (as only workers know their ability and diligence), so that the enterprise tries to engage the best elements from the market through ex ante incentives, and then to force qualified employees to contribute to the production process (the moral hazard problem) without resulting in too high supervision costs [6.27–29]
3. The specific features of production technologies that may force managers to allow greater autonomy to some worker teams, while paying an incentive in order to promote better participation in teamwork [6.30–32].

The first motivation will be discussed in Sect. 6.4, concerning the flexibility of labor costs, while the last one does not seem to be relevant. The second motivation appears to be crucial for labor-intensive systems, since system productivity cannot only be dependent on technologies and workers’ physical characteristics, but also depends greatly on workers propensity to contribute.

So, system productivity is a function of wages, and maximum profit can no longer be obtained by applying the economic rule of marginal productivity equal to wages fixed by market. It is the obligation of the enterprise to determine wages so as to assure maximum profit.

Let the production rate of a work unit \( \lambda_E \) increase at a given rate in a first time interval in which the wage \( w_E \) per work unit plays a strongly incentive role, whilst it could increase subsequently at a lower rate owing to the reduction of the wages marginal utility, as modeled in the following expression, according to the economic hypothesis of the effort function

\[
\lambda_E = \lambda E(w_E), \quad \text{where} \quad \lambda E(0) = 0; \quad d\lambda E/dw_E > 0; \quad \text{and} \quad d^2\lambda E/dw_E^2 \geq 0 \text{ if } w_E \geq \tilde{w}; \quad d^2\lambda E/dw_E^2 \leq 0 \text{ if } w_E \leq \tilde{w};
\]

where \( \tilde{w} \) is the critical wages which forces a change of yield from increasing to decreasing rate.

In labor-intensive systems, the average production rate given by (6.7) can be reformulated as

\[
\lambda_L = \gamma \lambda E/h.
\]

Now, let \( M = V_s - wL \) be the contribution margin, i.e., the difference between the production added value \( V_s \) and the labor cost; then the unitary contribution margin...
per labor unit \( m \) is defined by the rate of \( M \) over the labor \( L \)
\[
m = \frac{M}{L} = \hat{p} \lambda_L - w .
\]  
where \( \hat{p} = (p - p_X) \beta \) is the difference between the sale price \( p \) and the cost \( p_X \) of a product’s parts and materials, transformed into the final product according to the utilization coefficient \( \beta = X/Q \).

It follows that \( \lambda_L \), is a measure of the added value, and that the wages \( w_E \) per work unit must be transformed into real wages through the rate of work units \( E \) over the work hours \( h \) of an employee during a working shift, according to
\[
w = w_E E/h .
\]  
The goal of the enterprise is to maximize \( m \), in order to gain maximum profit, i.e.,
\[
\max(m) = [\hat{p} \gamma \lambda_E(w_E) - w_E] E/h .
\]  
The first-order optimal condition gives
\[
\frac{\partial m}{\partial h} = \left[ \hat{p} \gamma \lambda_E(w_E) - w_E \right] \frac{\partial(E/h)}{\partial h} = 0
\Rightarrow \lambda_E(w_E) = w_E/\hat{p} ,
\]  
\[
\frac{\partial m}{\partial w_E} = (E/h) \left[ \hat{p} \gamma (\partial \lambda_E/\partial w_E) - 1 \right] = 0
\Rightarrow \hat{p} \gamma (\partial \lambda_E/\partial w_E) = 1 .
\]  
By substituting (6.17) into (6.16), the maximum-profit condition shows that the elasticity of productivity with respect to wages \( \epsilon_L \) will assume a value of unity
\[
\epsilon_L = (\partial \lambda_E/\partial w_E)(w_E/\lambda_E) = 1 .
\]  
So, the enterprise could maximize its profit by forcing the percentage variation of the efficiency wages to be equal to the percentage variation of the productivity \( \partial \lambda_E/\lambda_E = \partial w_E/\lambda_E \). If so, it could obtain the optimal values of wages, productivity, and working time.

As a consequence, the duration of the working shift is an endogenous variable, which shows why, in labor-intensive systems, the working hours for a worker can differ from the contractual values.

On the contrary, in capital-intensive systems with wide automation, it has been noted before that \( E/h = 1 \) and \( \lambda_E = \hat{\lambda}_E \), because the mechanical rhythm prevails over the biological rhythm of work. In this case, efficiency wages do not exist, and the solution of maximum profit simply requires that wages be fixed at the minimum contractual level
\[
\max(m) = \hat{p} \lambda_L - w = \hat{p} \gamma \lambda_E - w \Rightarrow \min(w) .
\]  
As a conclusion, in labor-intensive systems, if \( \lambda_E \) could be either observed or derived from \( \lambda_L \), incentive wages could be used to maximize profit by asking workers for optimal efforts for the enterprise. In capital-intensive systems, where automation has canceled out decreasing yield and mechanical rhythm prevails in the production process, worker incentives can no longer be justified. The only possibility is to reduce absenteeism, so that a share of salary should be reduced in case of negligence, not during the working process (which is fully controlled by automation), but outside.

In labor-intensive systems, as in personal service production, it could be difficult to measure workers’ productivity: if so, process control by a supervisor becomes necessary.

In capital-intensive systems, automation eliminates this problem because the process is equipped with devices that are able to detect any anomaly in process operations, thus preventing inefficiency induced by negligent workers. In practice automation, by forcing fixed coefficients and full utilization of capital (process), performs itself the role of a working conditions supervisor.

### 6.3.3 Effects of Automation on Costs Flexibility

The transformation of a labor-intensive process into a capital-intensive one implies the modification of the cost structure of the enterprise by increasing the capital cost (that must be paid in the short term) while reducing labor costs.

Let the total cost \( C_T \) be defined by the costs of the three factors already considered, namely, intermediate goods, labor, and capital, respectively,
\[
C_T = p_X X + w L + c K .
\]  
where \( c_K \) denotes the unitary cost of capital.

Referring total cost to the production \( Q \), the cost per production unit \( c \) can be stated by substituting the conditions (6.2) and (6.10) into (6.20), and assuming constant capital value in the short term
\[
c = C_T/Q = p_X X + w L + c K/Q .
\]  
In labor-intensive systems, condition (6.21) can also be rewritten by using the efficiency wages \( w_E^* \) allocated in order to obtain optimal productivity \( \lambda_E^* = \gamma \lambda_E^*(w_E^*) \beta^{a+b-1} \), as shown in Sect. 6.3.1,
\[
c = p_X X + w_E^* \lambda_E^* + c K/Q .
\]  
On the contrary, in capital-intensive systems, the presence of large amounts of automation induces the following effects:
1. Labor productivity $\lambda_A$ surely greater than that which could be obtained in labor-intensive systems ($\lambda_A > \lambda^*_L$)

2. A salary $w_A$ that does not require incentives to obtain optimum efforts from workers, but which implies an additional cost with respect to the minimum salary fixed by the market ($w_A \geq w^*_E$), in order to select and train personnel

3. A positive correlation between labor productivity and production quantity, owing to the presence of qualified personnel who the enterprise do not like to substitute, even in the presence of temporary reductions of demand from the final product market

$$\lambda_A = \lambda_A(Q), \frac{\partial \lambda_A}{\partial Q} > 0, \frac{\partial^2 \lambda_A}{\partial Q^2} = 0$$

(6.23)

4. A significantly greater cost of capital, due to the higher cost of automated machinery, than that of a labor-intensive process ($c_{KA} > c_K$), even for the same useful life and same rate of interest of the loan.

According to these statements, the unitary cost in capital-intensive systems can be stated as

$$c_A = pX + w_A/\lambda_A(Q) + c_{KA}K/Q$$

(6.24)

Denoting by profit per product unit $\pi$ the difference between sale price and cost

$$\pi = p - c$$

(6.25)

6.4 Mid-Term Effects of Automation

6.4.1 Macroeconomics Effects of Automation: Nominal Prices and Wages

The analysis has been centered so far on microeconomics effects of automation on the firm’s costs, assuming product prices are given, since they would be set in the market depending on demand–offer balance in a system with perfect competition.

Real markets however lack a Walrasian auctioneer and are affected by the incapacity of firms to know in advance (rational expectations) the market demand curve under perfect competition, and their own demand curve under imperfect competition. In the latter case, enterprises cannot maximize their profit on the basis of demand elasticity, as proposed by the economic theory of imperfect competition [6.34–36]. Therefore, they cannot define their price and the related markup on their costs.

Below we suggest an alternative approach, which could be described as technological–managerial.

The balance price is not known a priori and price setting necessarily concerns enterprises: they have to submit to the market a price that they consider to be profitable, but not excessive because of the fear that competitors could block selling of all the scheduled production. Firms calculate the sale price $p$ on the basis of a full unit cost $c$, including a minimum profit, considered as a normal capital remuneration.

The full cost is calculated corresponding to a scheduled production quantity $Q^*$ that can be allegedly sold on the market, leaving a small share of productive ca-
capacity \( \bar{Q} \) potentially unused

\[
Q^e \leq \bar{Q} = \theta_K \lambda_K \tilde{K} = \theta_K \tilde{K} / v ,
\]

(6.27)

where \( \theta_K = 1 \) in the presence of automation, while \( v = 1 / \lambda_K \) is – as stated above – the capital–product connection defining technology adopted by firms for full productive capacity utilization.

The difference \( \bar{Q} - Q^e \) therefore represents the unused capacity that the firm plans to leave available for production demand above the forecast.

To summarize, the sales price is fixed by the enterprise, resorting to connection (6.21), relating the break-even point to \( Q^e \)

\[
p = c(Q^e) = px \beta + w / \lambda_L + cK v^e ,
\]

(6.28)

where \( v^e = \tilde{K} / Q^e \geq v \) (for \( Q^e \leq \bar{Q} \)) is the programmed capital–product relationship.

In order to transfer this relation to the macroeconomics level, we have to express it in terms of added value (\( Q \) is the gross saleable production), as the gross domestic product (GDP) results from aggregation of the added values of firms. Therefore we define the added value as

\[
P = P^Y = pQ - pX = (p - pX \beta)Q ,
\]

where \( P \) represents the prices general level (the average price of goods that form part of the GDP) and \( Y \) the aggregate supply (that is, the GDP). From this relation, \( P \) is given by

\[
P = (p - pX \beta) / \theta_Y ,
\]

(6.29)

where \( \theta_Y = Y / Q \) measures the degree of vertical integration of the economic system, which in the medium/short term we can consider to be steady \( \theta_Y = \bar{\theta}_Y \).

By substituting relation (6.28) into (6.29), the price equation can be rewritten as

\[
P = w / \bar{\lambda} + cK \bar{v} ,
\]

(6.30)

where work productivity and the capital/product ratio are expressed in terms of added value (\( \bar{\lambda} = \theta_Y \lambda_L = Y / L \) and \( \bar{v} = v^e / \theta_Y = \tilde{K} / Q^e \)).

In order to evaluate the effects of automation at the macroeconomic level, it is necessary to break up the capital unit cost \( c_K \) into its components:

- The initial purchase unit price of capital \( P^0_K \)
- The sample gross profit \( p^* \) sought by firms (as a percentage to be applied to the purchase price), which embodies both amortization rate \( d \) and the performance \( r^* \) requested by financiers to remunerate debt (subscribed by bondholders) and risk capital (granted by owners).

So the following definition can be stated

\[
c_K = p^* P^0_K = \left[ l^* P^0_K + (1 - l^*) P_K \right] / \sigma \rho_{lr} .
\]

(6.31)

where

- \( 0 < l^* = D^* / (P^0_K \tilde{K}) < 1 \) is the leverage (debt amount subscribed in capital stock purchase)
- \( 1 - l^* \) is the amount paid by owners
- \( P_K > P^0_K \) is the substitution price of physical capital at the deadline and
- \( \sigma \rho_{lr} \) is the discounting back factor.

Relation (6.31) implies that the aim of the firm is to maintain unchanged the capital share amount initially brought by owners, while the debt amount is recovered to its face (book) value, as generally obligations are refinanced at a fixed interest rate stated in the contract.

It is also noteworthy that the indebtedness ratio \( l \) is fixed at its optimal level \( l^* \), and the earning rate depends on it, \( r^* = r(l^*) \), because \( r \) decreases as the debt-financed share of capital increases due to advantages obtained from the income tax deductibility of stakes [6.37, 38], and increases as a result of failure stakes costs [6.39–41] and agency costs [6.42], which in turn grow as \( l \) grows. The optimal level \( l^* \) is obtained based on the balance between costs and marginal advantages.

The relation (6.31) can be rewritten by using a Taylor series truncated at the first term

\[
c_K = (d + r^*) \left[ l^* P^0_K + (1 - l^*) P_K \right] ,
\]

(6.32)

which, in the two extreme cases \( P^0_K = P_K \) and \( P_K = P^0_K \), can be simplified to

\[
c_K = (d + r^*) P_K ,
\]

(6.33a)

\[
c_K = (d + r^*) P^0_K .
\]

(6.33b)

This solution implies the existence of monetary illusion, according to which capital monetary revaluation (following inflation) is completely abandoned, thus impeding owners from keeping their capital intact.

This irrational decision is widely adopted in practice by firms when inflation is low, as it rests upon the accounting procedure codified by European laws that calculated amortization and productivity on the basis of book value. Solution (6.33a) embodies two alternatives:

- Enterprises’ decision to maintain physical capital undivided [6.43], or to recover the whole capital...
market value at the deadline, instead of being restricted to the capital value of the stakeholders, in order to guarantee its substitution without reducing existing production capacity; in this case the indebtedness with repayment to nominal value (at fixed rate) involves an extra profit $\Pi$ for owners (resulting from debt devaluation), which for unity capital corresponds to the difference between relation (6.33a) and (6.32)

$$\Pi = (d + r^*)\hat{\lambda} (P_k - P_k^0),$$  

(6.34)

as clarified by Cohn and Modigliani [6.44].

- Subscription of debts at variable interest rate, able to be adjusted outright to inflation rate to compensate completely for debt devaluation, according to Fisher’s theory of interest; these possibilities should be rules out, as normally firms are insured against debt cost variation since they sign fixed-rate contracts.

Finally the only reason supporting the connection (6.33a) remains the first (accounting for inflation), but generally firms’ behavior is intended to calculate $c_k$ according to relation (6.33b) (accounting to historical costs). However, rational behavior should compel the use of (6.32), thereby avoiding the over- or underestimation of capital cost ex ante.

In summary, the prices equation can be written in a macroeconomics level by substituting (6.32) into (6.30)

$$P = w/\hat{\lambda} + (d + r^*)\hat{\lambda} [\mu^* P_k^0 + (1 - l^*)(P_k - P_k^0)].$$  

(6.35a)

This relation is simplified according to the different aims of the enterprises:

1. **Keeping physical capital intact**, as suggested by accountancy for inflation, presuming that capital price moves in perfect accordance with product price ($P_k^0 = P_k = p_k P$ over $p_k = P_k / P > 1$ is the capital-related price compared with the product one)

$$P_a = \frac{w/\hat{\lambda}}{1 - (d + r^*)\hat{\lambda} p_k} = (1 + \mu^*_a)w/\hat{\lambda}. $$  

(6.35b)

2. **Integrity of capital conferred by owners**, as would be suggested by rational behavior ($P_k = p_k P > P_k^0$)

$$P_b = \frac{w/\hat{\lambda} + l^*(d + r^*)\hat{\lambda} P_k^0}{1 - (1 - l^*)(d + r^*)\hat{\lambda} p_k}. $$  

(6.35c)

3. **Recovery of nominal value of capital**, as so only to take account of historical costs ($P_k = P_k^0$)

$$P_c = w/\hat{\lambda} + (d + r^*)\hat{\lambda} P_k^0. $$  

(6.35d)

Only in the particular case of (6.35b) can the price level be obtained by applying a steady profit-margin factor $(1 + \mu^*_a)$ to labor costs per product unit $(w/\hat{\lambda})$.

The markup $\mu^*_a$ desired by enterprises (the percentage calculated on variable work costs in order to recover fixed capital cost) results in the following expressions for the three cases above:

1. **Keeping physical capital intact**; in this case, the mark-up results independent of the nominal wage level $w$

$$\mu^*_a = P_a\hat{\lambda}/w - 1 = \frac{(d + r^*)p_k}{1 - (d + r*)\hat{\lambda} p_k}. $$  

(6.36a)

2. **Integrity of capital conferred by owners**,

$$\mu^*_b = P_b\hat{\lambda}/w - 1 = \frac{(d + r^*)\lambda P_k^0\hat{\lambda}/w + (1 - l^*)p_k}{1 - (1 - l^*)(d + r^*)\hat{\lambda} p_k}. $$  

(6.36b)

3. **Recovery of nominal value of capital**,

$$\mu^*_c = P_c\hat{\lambda}/w - 1 = (d + r^*)\hat{\lambda} P_k^0\hat{\lambda}/w. $$  

(6.36c)

Note that in case 1, enforcing automation generally implies adoption of manufacturing techniques whose relative cost $p_k$ increases at a rate greater than proportionally with respect to the capital–product rate reduction $\hat{\lambda}$. The desired markup must then be augmented in order to ensure coverage of capital. In relation (6.35b) this effect is compensated because of productivity growth due to greater automation, so that on the whole the effect of automation on the general price level is beneficial: for given nominal salary, automation reduces price level.

In cases 2 and 3 of rational behavior, referring to (6.35c) in which the enterprise is aware that its debt is to be refunded at its nominal value, and even more so in the particular case (6.35d) in which the firm is enduring monetary illusion, the desired markup is variable, a decreasing function of monetary wage.

Therefore the markup theory is a simplification limited to the case of maintaining physical capital intact, and neglecting effects of capital composition (debt refundable at nominal value).

Based on the previous prices equations it follows that an increase of nominal wages or profit rate sought by enterprises involves an increase in prices general level. In comparison with $w$, the elasticity is only unity in (6.35b) and diminishes increasingly when passing to (6.35c) and (6.35d).

A percentage increase of nominal salaries is therefore transferred on the level of prices in the same
Nominal Prices and Wages: Some Conclusions

Elasticity of product price decreases if the term \( \hat{P} \lambda / \hat{w} \) increases, representing the ratio between the nominal value of capital (\( P_k^0 \lambda \)) and labor cost (\( \hat{w}L \)). Since automation necessarily implies a remarkable increase of this ratio, it results in minor prices sensibility to wages variation. In practice, automation implies beneficial effects on inflation: for increasing nominal wages, a high-capital-intensity economy is less subject to inflation shocks caused by wage rises.

### 6.4.2 Macroeconomics Effects of Automation in the Mid-Term: Actual Wages and Natural Unemployment

In order to analyze effects of automation on macroeconomic balance in the mid-term, it is necessary to convey the former equations of prices in terms of real wages, dividing each member by \( P \), in order to take account of \( \hat{w} = w/P \), which represents the maximum wage that firms are prepared to pay to employees without giving up their desired profit rate.

1. Keeping physical capital intact (\( P_k^0 = P_k = p_k P \))

\[
\hat{\omega}_a = \hat{\lambda}(1 - (d + r^*) \hat{v} p_k) = \hat{\lambda}/(1 + \mu_k^*) \quad (6.37a)
\]

2. Wholeness of capital granted by owners (\( P_k = p_k P > P_k^0 \))

\[
\hat{\omega}_b = \hat{\lambda}(1 - (d + r^*) \hat{v} [p_k - l^*(p_k - P_k^0 / P)])
\]

\[
(6.37b)
\]

3. Recovery of capital’s nominal value (\( P_k = P_k^0 \))

\[
\hat{\omega}_c = \hat{\lambda}[1 - (d + r^*) \hat{v} P_k^0 / P]
\]

\[
(6.37c)
\]

In the borderline case of keeping physical capital intact (6.37a) only one level of real salary \( \omega_a \) exists consistent with a specified level of capital productivity \( r^* \), given work productivity \( \hat{\lambda} \), amortization rate \( d \), capital/product ratio \( \hat{v} \) (corresponding to normal use of plants), and relative price \( p_k \) of capital with respect to product. The value of \( \omega_a \) can also be expressed as a link between work productivity and profit margin factor \( (1 + \mu_k^*) \) with variable costs, assuming that the desired markup is unchanging in comparison with prices.

In the rational case of corporate stock integrity and in the generally adopted case of recovery of capital nominal value, an increasing relation exists between real salary and general price level, with the desired markup being variable, as shown in connections (6.36b) and (6.36c).

The elasticity of \( \omega \) with respect to \( P \) turns out to increase from (6.37a) to (6.37c)

\[
\begin{align*}
\eta_a &= (\partial \omega / \partial P) P/\omega = 0 \\
\eta_b &= (\hat{\lambda} / \omega_b) [(d + r^*) \hat{v} P_k^0 / P]
\end{align*}
\]

\[
(6.37d)
\]

In cases 2 and 3 growth in the prices general level raises the added value share intended for normal capital remuneration, leaving firms a markup to be used in bargaining in order to grant employees a pay rise in real salary, even while keeping normal profit rate (the calculated level with programmed production) steady.

This markup of real wage bargaining depends on the choice of the capital recovery system: it is higher in the case of fund illusion and lower in the case in which capital stock is intended to be maintained undivided.

**Remark:** In all three cases above, the level of real salary depends on the degree of production process automation: in economic systems where this is high, productivity of work \( \hat{\lambda} \) and capital \( (1/\hat{v}) \) are necessarily higher than the related price of capital \( (p_k / P_k^0 / P) \), so the real wage that the firms are willing to concede in bargaining is higher than the one affecting work-intensive economic systems. In substance, automation weakens firms’ resistance in wage bargaining, making them more willing to concede higher real wages.

In order to qualify the positive role of automation we complete the mid-term period macroeconomic model with the wage equation from the workers’ side.

Macroeconomics theory believes that, in the mid term, nominal wages \( w \) asked for by workers in syndicated or individual bargaining (or imposed by firms in order to select and extract optimal effort in production process) depend on three variables: the unemployment rate of man power \( u \), other factors absorbed in a synthetic variable \( z \), and the expected level of prices \( P^e \).

So it is possible to write

\[
w = \omega(u, z) P^e.
\]

\[
(6.38)
\]
Higher unemployment is supposed to weaken workers’ contractual strength, compelling them to accept lower wages, and vice versa that a decrease of unemployment rate leads to requests for an increase of real wages ($\partial w/\partial u < 0$).

The variable $z$ can express the effects of unemployment increase, which would compel workers to ask for a pay raise, because any termination would appear less risky in terms of social salary (the threshold above which an individual is compelled to work and under which he is not prepared to accept, at worst choosing unemployment). Similar effects would be induced by legal imposition of minimum pay and other forms of worker protection, which – making discharge more difficult – would strengthen workers’ position in wage bargaining.

Regarding the expected level of prices, it is supposed that

$$\partial w/\partial P^e = w/P^e > 0 \Rightarrow (\partial w/\partial P^e)(P^e/w) = 1$$

to point out that rational subjects are interested in real wages (their buying power) and not nominal ones, so an increase in general level of prices would bring about an increase in nominal wages in the same proportion. Wages are however negotiated by firms on nominal terms, on the basis of a price foresight ($P^e$) for the whole length of the contract (generally more than 1 year), during which monetary wages are not corrected if $P \neq P^e$.

To accomplish this analysis, in the mid-term period, wage bargaining is supposed to have real wage as a subject (excluding systematic errors in expected inflation foresight), so that $P = P^e$ and (6.38) can be simplified to

$$\omega = \omega(u, z).$$

(6.39)

Figure 6.2 illustrates this relation with a decreasing curve WS (wage setting), on Cartesian coordinates for a given level of $z$.

Two straight lines, PS (price setting), representing price equations (6.37a), considering mainly the borderline case of maintaining physical capital intact, are reported:

- The upper line PS$_A$ refers to an economic system affected by a high degree of automation, or by technologies where $\theta = 1$ and work and capital productivity are higher, being able to contrast the capital’s relative higher price; in this case firms are prone to grant higher real wages.

The intersection between the curve WS and the line PS indicates one equilibrium point $E$ for each economic system (where workers’ plans are consistent with those of firms), corresponding to the case in which only one natural unemployment rate exists, obtained by balancing (6.37a) and (6.39)

$$\lambda \left[1 - (d + r^*\hat{\nu}p_k)\right] = \omega(u, z) \Rightarrow u^A_n < u^a_n,$$

(6.40a)

assuming that $[1 - (d + r^*\hat{\nu}p_k)]d\lambda + \hat{\lambda}(d + r^*)p_kd\hat{\nu} > \lambda(d + r^*)\hat{\nu}dp_k$.

Remark: In the case of a highly automated system, wage bargaining in the mid-term period enables a natural unemployment rate smaller than that affecting a less automated economy: higher productivity makes enterprises more willing to grant higher real wages as a result of bargaining and the search for efficiency in production organizations, so that the economic system can converge towards a lower equilibrium rate of unemployment ($u^A_n < u^a_n$).

The uniqueness of this solution is valid only if enterprises aim to maintain physical capital undivided.

In the case of rational behavior intended to achieve the integrity of capital stock alone (6.37b), or business procedures oriented to recoup the accounting value of capital alone (6.37c), the natural unemployment rate theory is not sustainable. In fact, if we equalize these two relations to (6.39), respectively, we obtain in both cases a relation describing balance couples between unemployment rate and prices general level, indicating that the equilibrium rate is undetermined and therefore
that the adjective natural is inappropriate
\[
\hat{\lambda} \left[ 1 - (d + r^*) \hat{u} \left( p_k - \lambda^t (p_k - \bar{P}_K^{0} / P) \right) \right] = \omega(u, z) \\
\Rightarrow u_n = u_n^0(P), \quad (6.40b) \\
\hat{\lambda} \left[ 1 - (d + r^*) \hat{u} \bar{P}_K^{0} / P \right] = \omega(u, z) \\
\Rightarrow u_n = u_n^0(P), \quad (6.40c)
\]
where \( \partial u_n / \partial P < 0 \), since an increase in \( P \) increases the margin necessary to recover capital cost and so enterprises can pay out workers a higher real salary (\( \partial \omega / \partial P > 0 \)), which in balance is compatible with a lower rate of unemployment.

Summing up, alternative enterprise behavior to that intended to maintain physical capital intact does not allow fixing univocally the natural rate of unemployment. In fact, highly automated economic systems cause a translation of the function \( u_n = u_n(P) \) to a lower level: for an identical general level of prices the unemployment balance rate is lower since automation allows increased productivity and real wage that enterprises are prepared to pay.

### 6.4.3 Macroeconomic Effects of Automation in the Mid Term: Natural Unemployment and Technological Unemployment

The above optimistic conclusion of mid-term equilibrium being more profitable for highly automation economies must be validated in the light of constraints imposed by capital-intensive technologies, where the production rate is higher and yields are constant.

Assume that in the economic system an aggregated demand is guaranteed, such that all production volumes could be sold, either owing to fiscal and monetary policies oriented towards full employment or hoping that, in the mid term, the economy will spontaneously converge through monetary adjustments induced by variation of the price general level.

In a diffused automation context, a problem could result from a potential inconsistency between the unemployment natural rate \( u_n \) (obtained by imposing equality of expected and actual prices, related to labor market equilibrium) and the unemployment rate imposed by technology \( \bar{u} \)
\[
\bar{u} = 1 - L^d / L^s = 1 - (\bar{Y} / \hat{\lambda}) / L^s \geq u_n, \quad (6.41)
\]
where \( L^d = \bar{Y} / \hat{\lambda} \) is the demand for labor, \( L^s \) is the labor supply, and \( \bar{Y} \) is the potential production rate, compatible with full utilization of production capacity.

A justification of this conclusion can be seen by noting that automation calls for qualified technical personnel, who are still engaged by enterprises even during crisis periods, and of whom overtime work is required in case of expansion. Then, employment variation is not proportional to production variation, as clearly results from the law of Okun [6.45], and from papers by Perry [6.46] and Tatom [6.47].

**Remark:** From the definition of \( \bar{u} \) it follows that economic systems with high automation level, and therefore characterized by high productivity of labor, present higher technological unemployment rates
\[
(\partial \bar{u} / \partial \lambda) (\hat{\lambda} / \bar{u}) = (1 - \bar{u}) / \bar{u} > 0 .
\]

On one hand, automation reduces the natural unemployment rate \( u_n \), but on the other it forces the technological unemployment rate \( \bar{u} \) to increase. If it holds that \( \bar{u} \leq u_n \), the market is dominant and the economic system aims to converge in time towards an equilibrium characterized by higher real salary and lower (natural) unemployment rate, as soon as the beneficial effects of automation spread.

In Fig. 6.3, the previous Fig. 6.2 is modified under the hypothesis of a capital-intensive economy, by including two vertical lines corresponding to two potential unemployment rates imposed by technology (\( \bar{u} \) and \( \bar{u}_A \)). Note that \( \bar{u} \) has been placed on the left of \( u_n \) whilst \( \bar{u}_A \) has been placed on the right of \( u_n \). It can be seen that the labor market equilibrium (point \( E \)) dominates when technology implies a degree of automation compatible with a nonconstraining unemployment rate \( \bar{u} \). Equilibrium could be obtained, on the contrary, when technology (for a given production capacity of the eco-

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**Fig. 6.3** Mid-term equilibrium with high automation level and two different technological unemployment rates
development and impacts of automation

part a

6.4

part a

larger weakness when wages are negotiated by work-

er results, such that it amounts to 100% if

imperfect information (6.43a) can be simplified to

which is a linear version of the Phillips curve; according to

this form, the current inflation rate depends positively on

inflation expectation, markup level, and the variable

z, and negatively on the unemployment rate.

For \( \pi^c = 0 \), the original curve which Phillips and

Samuelson–Solow estimated for the UK and USA is

obtained.

For \( \pi^c = \pi^u - 1 \) (i.e., extrapolative expectations)

a link between the variation of inflation rate and the

unemployment rate (accelerated Phillips curve), showing

better interpolation of data observed since 1980s, is derived

\[
\pi - \pi^u = (1 + \mu^*)\alpha_0 z - (1 + \mu^*)\alpha_1 u \ .
\]

(6.44)

Assuming \( \pi = \pi^c = \pi^u - 1 \) in (6.43b) and (6.44), an

estimate of the natural unemployment rate (without sys-

tematic errors in mid-term forecasting) can be derived

\[
u_n = \alpha_0 z / \alpha_1 \ .
\]

(6.45)

Now, multiplying and dividing by the \( \alpha_1 \) term \((1 + \mu^*)\alpha_0 z \) in (6.44), and inserting (6.45) into (6.44), it results that, in the case of extrapolative expectations, the inflation rate reduces if the effective unemployment rate is greater than the natural one \((d \pi > 0 \text{ if } u > u_n)\); it increases in the opposite case \((d \pi < 0 \text{ if } u < u_n)\); and it is zero \((\text{constant inflation rate})\) if the effective unemployment rate is equal to the natural one \((d \pi = 0 \text{ if } u = u_n)\).

\[
\pi - \pi^u = -(1 + \mu^*)\alpha_1 (u - u_n) \ .
\]

(6.46)

Remark: Relation (6.44) does not take into account effects induced by automation diffusion, which imposes on the economic system a technological unemployment \(u_A\) that increases with increasing automation.

It follows that any econometric estimation based on (6.44) no longer evaluates the natural unemployment rate (6.45) for \( \pi - \pi^u = 0 \), because the latter varies in time, flattening the interpolating line \((\text{increasingly high unemployment rates related to increasingly lower real wages, as shown above})\). Then, as automation process spreads, the natural unemployment rate \((\text{which, without systematic errors, assures compatibility between the real salary paid by enterprises and the real salary either demanded by workers or supplied by enterprises for efficiency motivation})\) is no longer significant.

In Fig. 6.4a the Phillips curve for the Italian eco-

nomic system, modified by considering inflation rate variations from 1953 to 2005 and the unemployment rate, is reported; the interpolation line is decreasing but very flat owing to \(u_A\) movement towards the right.

A natural unemployment rate between 7 and 8% seems to appear, but the intersection of the interpolation line with the abscissa is moved, as shown in the

The technological unemployment constraint implies

a large weakness when wages are negotiated by work-

ers, and it induces a constrained equilibrium \((\text{point } H)\)

in which the real salary perceived by workers is lower than that which enterprises are willing to pay. The latter can therefore achieve unplanned extra profits, so that au-

tomation benefits only generate capital owners’ income

which, in the share market, gives rise to share value increase.

Only a relevant production increase and equivalent

aggregated demand could guarantee a reduction of \( \bar{u}_A\),

thus transferring automation benefits also to workers.

These conclusions can have a significant impact on the Fisher–Phillips curve \((\text{Fisher} \ [6.48] \text{and Phillips} \ [6.49])\), first; theoretically supported by Lipsey \([6.50]\) and then extended by Samuelson and Solow \([6.51]\) describing the trade-off between inflation and unemployment.

Assume that the quality constraint between expected

prices and effective prices can, in the mid term, be neglected, in order to analyze the inflation dynamics. Then, substitute (6.38) into (6.35b), by assuming the hypothesis that maintaining capital intact implies constant markup

\[
P = (1 + \mu^*)\omega(u, z) P^e / \lambda .
\]

(6.42)

This relation shows that labor market equilibrium for imperfect information \((P^e \neq P)\), implies a positive link between real and expected prices.

By dividing (6.42) by \(P_{-1}\), the following relation results

\[
1 + \pi = (1 + \pi^e)(1 + \mu^*)\omega(u, z) / \lambda ,
\]

(6.43a)

where:

\(\pi = P / P_{-1} - 1\) is the current inflation rate

\(\pi^e = P^e / P_{-1} - 1\) is the expected inflation rate.

Assume moderate inflation rates, such that

\[
(1 + \pi) / (1 + \pi^e) \approx 1 + \pi - \pi^e
\]

and consider a linear relation between productivity and wages, such that it amounts to 100% if

\[
z = u = 0 : \omega_0(u, z) / \lambda = 1 + \alpha_0 z - \alpha_1 u (\alpha_0, \alpha_1 > 0) .
\]

Relation (6.43a) can be simplified to

\[
\pi = \pi^e + (1 + \mu^*)\alpha_0 z - (1 + \mu^*)\alpha_1 u .
\]

(6.43b)

on inflation expectation, markup level, and the variable
Automation has a first significant impact during the oil crisis, moving the intersection from 5.2% for the first post-war 20 years up to 8% in the next period. Extending the time period up to 2005, intersection moves to 9%; the value could be greater, but it has been recently bounded by the introduction of temporary work contracts which opened new labor opportunities but lowered salaries.

Note that Figs. 6.4a–c are partial reproductions of the Fig. 6.4, considering three different intervals of unemployment rate values. This reorganization of data corresponds to the three different periods of the Italian economic growth: (a) the economic miracle (1953–1972), (b) the petroleum shock (1973–1985), and (c) the period from the economic miracle until 2005 (1973–2005).

A more limited but comprehensive analysis, owing to lack of homogeneous historical data over the whole period, has been done also for two other important European countries, namely France (Fig. 6.5a) and Germany (Fig. 6.5b): the period considered ranges from 1977 to 2007.

The unemployment rate values have been recomputed so as to make all the historical series homogeneous. Owing to the limited availability of data for both countries, only two periods have been analyzed: the period 1977–1985, with the effects of the petroleum shock, and the whole period up to 2007, in order to
evaluate the increase of the natural unemployment rate from the intersection of the interpolation line with the abscissa.

As far as Fig. 6.5a is concerned, the natural unemployment rate is also increased in France – as in Italy – by more than one percentage point (from less than 6% to more than 7%). In the authors’ opinion, this increase should be due to technology automation diffusion and consequent innovation of organization structures.

Referring to Fig. 6.5b, it can be noted that even in Germany the natural unemployment rate increased – more than in France and in Italy – by about three percentage points (from 2.5 to 5.5%). This effect is partly due to application of automated technologies (which should explain about one percentage point, as in the other considered countries), and partly to the reunification of the two parts of Germany.

A Final Remark: Based on the considerations and data analysis above it follows that the natural unemployment rate, in an industrial system where capital intensive enterprises are largely diffused, is no longer significant, because enterprises do not apply methods to maintain capital intact, and because technological inflation tends to constraint the natural one.

Only structural opposing factors could slow this process, such as labor market reform, to give rise to new work opportunities, and mainly economic politics, which could increase the economy development.
trend more than the growth of productivity and labor supply. However, these aspects should be approached in a long-term analysis, and exceed the scope of this chapter.

6.5 Final Comments

Industrial automation is characterized by dominance of capital dynamics over the biological dynamics of human labor, thus increasing the production rate. Therefore automation plays a positive role in reducing costs related to both labor control, sometimes making monetary incentives useless, and supervisors employed to assure the highest possible utilization of personnel. It is automation itself that imposes the production rate and forces workers to correspond to this rate.

In spite of these positive effects on costs, the increased capital intensity implies greater rigidity of the cost structure: a higher capital cost depending on higher investment value, with consequent transformation of some variable costs into fixed costs. This induces a greater variance of profit in relation to production volumes and a higher risk of automation in respect to labor-intensive systems. However, the trade-off between automation yield and risk suggests that enterprises
should increase automation in order to obtain high utilization of production capacity. One positive effort in this direction has been the design and implementation of flexible automation during recent decades (e.g., see Chap. 50 on Flexible and Precision Assembly).

Moving from microeconomic to macroeconomic considerations, automation should reduce the effects on short-term inflation caused by nominal salary increases since it forces productivity to augment more than the markup necessary to cover higher fixed costs. In addition, the impact of automation depends on the book-keeping method adopted by the enterprise in order to recover the capital value: this impact is lower if a part of capital can be financed by debts and if the enterprise behavior is motivated by monetary illusion.

Over a mid-term period, automation has been recognized to have beneficial effects (Figs. 6.6–6.8) both on the real salary paid to workers and on the (natural) unemployment trend, if characteristics of automation technologies do not form an obstacle to the market trend towards equilibrium, i.e., negotiation between enterprises and trade unions. If, on the contrary, the system production capacity, for a compatible demand, prevents market convergence, a noncontractual equilibrium only dependent on technology capability could be established, to the advantage of enterprises and the prejudice of workers, thus reducing real wages and increasing the unemployment rate.

Empirical validation seems to show that Italy entered this technology-caused unemployment phase

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**Fig. 6.6** Employment growth by sector with special focus on computer and ICT (source: OECD Information Technology Outlook 2008, based on STAN database)

**Fig. 6.7** Share of ICT-related occupations in the total economy from 1995 and 2007 (source: OECD IT Outlook 2008, forthcoming)
6.6 Capital/Labor and Capital/Product Ratios in the Most Important Italian Industrial Sectors

A list of the most important industrial sectors in Italy is reported in Table 6.2 (data collected by Mediobanca [6.52] for the year 2005). The following estimations of the model variables and rates have been adopted (as enforced by the available data): capital $K$ is estimated through fixed assets; with reference to production, the added value $V_a$ is considered; labor $L$ is estimated in terms of number of workers.

Some interesting comments can be made based on Table 6.2, by using the production function models presented in the previous sections. According to the authors’ experience (based on their knowledge of the Italian industrial sectors), the following anomalous sectors can be considered:

- Sectors concerning energy production and distribution and public services for the following reasons: they consist of activities applying very high levels of automation; personnel applied in production are extremely scarce, whilst it is involved in organization and control; therefore anomalous values of the capital/labor ratio and of productivity result.

- The transport sector, because the very high capital/product ratio depends on the low level of the added value of enterprises that are operating with politically fixed (low) prices.


during the last 20 years: this corresponds to a flatter Phillips curve because absence of inflation acceleration is related to natural unemployment rates that increase with automation diffusion, even if some structural modification of the labor market restrained this trend.
Table 6.2 Most important industrial sectors in Italy (after [6,52])

<table>
<thead>
<tr>
<th>Industrial sector (year 2005)</th>
<th>Fixed assets (million euro (a))</th>
<th>Added value (million euro (b))</th>
<th>Number of workers (× 1000) (c)</th>
<th>Capital/product (a/b)</th>
<th>Capital/labor (× 1000 euro (a/c))</th>
<th>Productivity (× 1000 euro (b/c))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial enterprises</td>
<td>309,689.6</td>
<td>84,373.4</td>
<td>933.8</td>
<td>3.7</td>
<td>331.6</td>
<td>90.4</td>
</tr>
<tr>
<td>Service enterprises</td>
<td>239,941.9</td>
<td>42,278.3</td>
<td>402.7</td>
<td>5.7</td>
<td>595.8</td>
<td>105.0</td>
</tr>
<tr>
<td>Clothing industry</td>
<td>2824.5</td>
<td>1882.9</td>
<td>30.4</td>
<td>1.5</td>
<td>93.0</td>
<td>62.0</td>
</tr>
<tr>
<td>Food industry: drink produc-</td>
<td>tion</td>
<td>5041.7</td>
<td>1356.2</td>
<td>14.3</td>
<td>3.7</td>
<td>352.1</td>
</tr>
<tr>
<td>Food industry: milk &amp; related products</td>
<td>1794.6</td>
<td>933.2</td>
<td>10.1</td>
<td>1.9</td>
<td>177.8</td>
<td>92.5</td>
</tr>
<tr>
<td>Food industry: alimentary pres-</td>
<td>2842.4</td>
<td>897.8</td>
<td>11.2</td>
<td>3.2</td>
<td>252.9</td>
<td>79.9</td>
</tr>
<tr>
<td>Food industry: confectionary</td>
<td>4316.1</td>
<td>1659.0</td>
<td>17.8</td>
<td>2.6</td>
<td>242.7</td>
<td>93.3</td>
</tr>
<tr>
<td>Food industry: others</td>
<td>5772.7</td>
<td>2070.2</td>
<td>23.9</td>
<td>2.8</td>
<td>241.4</td>
<td>86.6</td>
</tr>
<tr>
<td>Paper production</td>
<td>7730.9</td>
<td>1470.6</td>
<td>19.9</td>
<td>5.3</td>
<td>388.2</td>
<td>73.9</td>
</tr>
<tr>
<td>Chemical sector</td>
<td>16,117.7</td>
<td>4175.2</td>
<td>47.7</td>
<td>3.9</td>
<td>337.7</td>
<td>87.5</td>
</tr>
<tr>
<td>Transport means production</td>
<td>21,771.4</td>
<td>6353.3</td>
<td>121.8</td>
<td>3.4</td>
<td>178.8</td>
<td>52.2</td>
</tr>
<tr>
<td>Retail distribution</td>
<td>10,141.1</td>
<td>3639.8</td>
<td>84.2</td>
<td>2.8</td>
<td>120.4</td>
<td>43.2</td>
</tr>
<tr>
<td>Electrical household appliances</td>
<td>4534.7</td>
<td>1697.4</td>
<td>35.4</td>
<td>2.7</td>
<td>128.1</td>
<td>47.9</td>
</tr>
<tr>
<td>Electronic sector</td>
<td>9498.9</td>
<td>4845.4</td>
<td>65.4</td>
<td>2.0</td>
<td>145.1</td>
<td>74.0</td>
</tr>
<tr>
<td>Energy production/distribution</td>
<td>147,200.4</td>
<td>22,916.2</td>
<td>82.4</td>
<td>6.4</td>
<td>1786.8</td>
<td>278.2</td>
</tr>
<tr>
<td>Pharmaceuticals &amp; cosmetics</td>
<td>90,589.9</td>
<td>6085.2</td>
<td>56.3</td>
<td>1.5</td>
<td>160.8</td>
<td>108.0</td>
</tr>
<tr>
<td>Chemical fibers</td>
<td>2081.4</td>
<td>233.2</td>
<td>5.0</td>
<td>8.9</td>
<td>418.4</td>
<td>46.9</td>
</tr>
<tr>
<td>Rubber &amp; cables</td>
<td>3868.3</td>
<td>1249.7</td>
<td>21.2</td>
<td>3.1</td>
<td>182.1</td>
<td>58.8</td>
</tr>
<tr>
<td>Graphic &amp; editorial</td>
<td>2399.1</td>
<td>1960.4</td>
<td>18.0</td>
<td>1.2</td>
<td>133.3</td>
<td>108.9</td>
</tr>
<tr>
<td>Plant installation</td>
<td>1295.9</td>
<td>1683.4</td>
<td>23.2</td>
<td>0.8</td>
<td>56.0</td>
<td>72.7</td>
</tr>
<tr>
<td>Building enterprises</td>
<td>1337.7</td>
<td>1380.0</td>
<td>24.7</td>
<td>1.0</td>
<td>54.2</td>
<td>55.9</td>
</tr>
<tr>
<td>Wood and furniture</td>
<td>2056.1</td>
<td>689.2</td>
<td>12.8</td>
<td>3.0</td>
<td>160.2</td>
<td>53.7</td>
</tr>
<tr>
<td>Mechanical sector</td>
<td>18,114.1</td>
<td>9356.6</td>
<td>137.3</td>
<td>1.9</td>
<td>131.9</td>
<td>68.1</td>
</tr>
<tr>
<td>Hide and leather articles</td>
<td>1013.9</td>
<td>696.6</td>
<td>9.0</td>
<td>1.5</td>
<td>113.1</td>
<td>77.7</td>
</tr>
<tr>
<td>Products for building industry</td>
<td>11,585.2</td>
<td>2474.3</td>
<td>28.7</td>
<td>4.7</td>
<td>404.3</td>
<td>86.4</td>
</tr>
<tr>
<td>Public services</td>
<td>103,746.7</td>
<td>28,413.0</td>
<td>130.5</td>
<td>3.7</td>
<td>795.2</td>
<td>217.8</td>
</tr>
<tr>
<td>Metallurgy</td>
<td>18,885.6</td>
<td>5078.2</td>
<td>62.4</td>
<td>3.7</td>
<td>302.9</td>
<td>81.4</td>
</tr>
<tr>
<td>Textile</td>
<td>3539.5</td>
<td>1072.1</td>
<td>21.7</td>
<td>3.3</td>
<td>163.2</td>
<td>49.4</td>
</tr>
<tr>
<td>Transport</td>
<td>122,989.3</td>
<td>7770.5</td>
<td>142.1</td>
<td>15.8</td>
<td>865.2</td>
<td>54.7</td>
</tr>
<tr>
<td>Glass</td>
<td>2929.3</td>
<td>726.2</td>
<td>9.2</td>
<td>4.0</td>
<td>317.8</td>
<td>78.8</td>
</tr>
</tbody>
</table>

Notation: Labor-intensive sectors Intermediate Anomalous

- The chemical fibres sector, because at the time considered it was suffering a deep crisis with a large amount of unused production capacity, which gave rise to an anomalous (too high) capital/product ratio and anomalous (too small) value of productivity.

Sectors with a rate capital/production of 1.5 (such as the clothing industry, pharmaceutics and cosmetics, and hide and leather articles) has been considered as intermediate sectors, because automation is highly important in some working phases, whereas other working phases still largely utilize workers. These sectors (and the value 1.5 of the rate capital/production) are used as separators between capital-intensive systems (with high degrees of automation) and labor-intensive ones.

Sectors with a capital/production ratio of less than 1.5 have been considered as labor-intensive systems. Among these, note that the graphic sector is capital intensive, but available data for this sector are combined with the editorial sector, which in turn is largely labor intensive.
All other sectors can be viewed as capital-intensive sectors, even though it cannot be excluded that some working phases within their enterprises are still labor intensive.

Two potential correlations, if any, are illustrated in the next two figures: Fig. 6.9 shows the relations between the capital/labor and capital/production ratios, and Fig. 6.10 shows the relations between productivity and capital/labor ratio.

As shown in Fig. 6.9, the capital/labor ratio exhibits a clear positive correlation with the capital/production ratio; therefore they could be considered as alternative measures of capital intensity.

On the contrary, Fig. 6.10 shows that productivity does not present a clear correlation with capital. This could be motivated by the effects of other factors, including the utilization rate of production capacity and the nonuniform flexibility of the workforce, which could have effects on productivity.

Fig. 6.10 Relation between productivity (× 100 €) and capital/labor (rate)

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