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Profit Model for Incorporating AR Technology in Assembly Tasks of Aeronautical Maintenance

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Abstract

It has been observed a huge advance in information technologies development, which has gotten a severe change in the mode to undertake the maintenance and assembly tasks. However it has been difficult to reach a right economic and outcome assessment of the contribution of this and other technologies to enterprise profit because traditional methods of evaluation have not been able to quantify the related intangible benefits with enough rigor. Taking the Microeconomics as a theoretical reference framework for making plant capacity decisions, we deploy various general concepts and production function; but a review of the (Microeconomic) Production Theory which states that the production factors, governed by The Law of Diminishing Returns, coexist in diverse combinations, reveals that the enterprise operates in the short term under a series of parametric determinants that does not seem to respond to the socio-economic and technological reality faced in the new century. This investigation proposes a model of profit deducted by considering a microeconomic effect analysis of augmented reality technology incorporation into aeronautical maintenance assembly tasks.

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1. Introduction

In a business environment, it is possible to speak about categorization and general concepts about the company as a microeconomic entity. The company aims to seek union of capital, labour and machinery (capital goods), for then produce goods and services, so that they then generate an economic value added.

The company seeks to achieve certain goals within the production process, several of which (to be met) are:

A) Maximize economic efficiency.
B) Maximize technical efficiency.
C) Maximize growth.
D) Maximize utility.

Therefore the factors of production will have to coexist in a constant movement (various combinations), which economists call it substitution of production factors, considered in the so-called marginal rates of substitution.

| Nomenclature | Description |
|--------------|-------------|
| AR           | Augmented Reality (or RA as its acronym in Spanish) |
| Qp           | Production Quantity or Total Production (PT, due to the term PRODUCCION TOTAL, in Spanish), so a PT displacement is DESPLAZAMIENTO DEL PRODUCTO TOTAL, in Spanish) |
| L            | Labour (Labor) |
| D            | Demand (Demanda, in Spanish) |
| Of           | Offer curve (Oferta, in Spanish). So, an Offer displacement is DESPLAZAMIENTO DE LA OFERTA |
| CMg          | Marginal Cost (MC) |
| UAR          | Profit at AR level, or $U_{RA}$ (as its acronym in Spanish) |
| IT           | Total Income (as its acronym Total Deposit in Spanish) |
| CT           | Total Cost (as its acronym Total Cost in Spanish) |
| IRR          | Internal Rate of Return |

1.1. Related work

In this fragment of the article, where a review of previous work is effectuated, three parts are included: inputs, The Law of Diminishing Returns and production function in order to try to initiate by examining some important microeconomic concepts.

Inputs

Inputs are recognized as goods and services that a company need from another to build their own production. In the traditional economy, coinciding with Levenson y Solon [1] and Salvatore [2] we used the term "factor of production", but the most modern and concise term, input is being used increasingly for the same concept; determined that the input is any good or service that is used in technological processes for production.

A classification can provide inputs in the production process as follows (Figure 1):
Law of Diminishing Returns

The fundamental assumption of the theory of production is the law of diminishing returns, which states that if one factor of production is increased by small constant amounts, while the amounts of all other factors remain unchanged, after a certain point the results of production increases are becoming smaller. Before this point is reached, production can grow in constant amounts. In this law is considered that variable factor units are identical. See Figure 2 in Section 2, below.

Production Function

Production function is the name given to the relationship between physical yields and inputs of a company. A production function must be specified for certain time (short or long). These depend on the flow of inputs that result in a flow of income for a period already established. The production function refers to the relationship between the physical product and the resulting physical inputs. The mathematical equation for the production function consists of inputs: labor, capital and a simpler representation is:

$$Q = f(L,K)$$  \hspace{1cm} (1)

where:

- $Q_p = Q$ = production rate per unit time.
- $K$ = Flow of services derived from the existence of capital per unit of time.
- $L$ = Flow of the company human resource services per unit of time.

According to Löfgren [3], it has not been taken into account in traditional evaluation methods, yields caused by assembling production assisted by emerging technologies (as some of the information and communications technologies, called ICTs; see Milis and Mercken [4].

1.2. Plan for the rest of this paper

Assembly production, the impact of the factors on total production and costs for the operation level are to be outlined in Section 2, human capital theory and total product shift is to be explored in Section 3 and a Profit model that reveals a technological shift of the offer is developed in Section 4 to conclude in Section 5.
2. Assembly production. Impact on the total production

To analyze the microeconomic implications in the firm, developer of technology-based projects can initially be presented the curve of total production or total product TP obtained when operating or using some method of assembly, as shown in Figure 2.

Where now, in the case of production by assembling, we have:

\[
PT = Qp = f (L,K)
\]

Where:
- \(PT\) = number of assemblies produced per unit time
- \(L\) = Amount of Labor (Labour) per unit time
- \(K\) = Number of services derived from the existence of capital per unit of time

![Figure 2 Production (Qp = PT) and Marginal Products (pMAL) and Medium (PMEL) vs. L, maintaining constant K](image)

Figure 2 Production (Qp = PT) and Marginal Products (pMAL) and Medium (PMEL) vs. L, maintaining constant K

NOTE: the starting point of diminishing returns area is changing concavity on the upper graph.

In the case of a unit or technology-based business division dedicated to assisted assembly by Augmented Reality (AR), production (development) of the AR involves a plant size related to facilities and equipment required (factor K) for some number of modelers and programmers who are their labor (factor L).
2.1 The Cost Function and the Determination of the Level of Operation of a Company

The costs of a company can be defined as the careful estimate, in monetary terms, of the expenditures required to remunerate the services of their factors of production when they achieve a certain level of production. These costs therefore depend on the behavior of the production function and its estimation is critical for decision-making related to the level of operation of the company.

The theoretical and conceptual review of microeconomic theory shows a number of operational considerations that limit, in our view, the application of this theory to situational analysis and decision-making at management level, as far as determining the level operation of the company concerned.

This restriction has to do, in large part, to the way it sets the boundary between the short and long term. As is clear from the review of the theory (micro) of production, already mentioned, the company operates in the short run under a series of parametric determinants that do not seem to respond to the socio-economic and technological reality facing companies of this century.

These limitations are assumed both exogenous (input prices and products), at an endogenous level under the tight constraints imposed by the so-called fixed factors in the short term (capital and technology), which implies that the ability to take decisions in the short term remains bounded by the only nonparametric condition that is the behavior of the factor called variable that is identified by definition and functionally with the labor (L).

According to this approach, the behavior of this factor L responds to two assumptions, which in the current situation of the companies are very weak:

• First, it is assumed that the quality of labor (human resources) is homogeneous.
• The other is that their supply is perfectly elastic (Bronze Law of Wages), i.e. at market price (salary) the employer can arbitrarily change staffing levels, which, under current employment schemes is obviously highly unlikely to be met especially for the case of technical manpower very specialized (scarce) and implies that ultimately at management level, the ability to maneuver to change production levels based on adjustments on the size of the workforce is much more limited than the theory seems to suggest.

In this last aspect, paragraph b), this research attempts to present a possible alternative analysis regarding the conceptual categorization called "variable factor". To that end we will resume the approaches on this subject that provides the so-called Human Capital Theory, for which we present a synthesis that helps us support our proposal.

Furthermore, with respect to subsection a): the quality of labor (human resources) is not homogeneous because it changes with training and education even in the short term, as in the case we study, by means of assisted Assembly by Augmented Reality (EnsRA).

3. Human Capital Theory. Total Product Shift

A project engineer, who is responsible for the adaptation of mill after making a correspondent electrical routine inspection, documented the analysis and distribution of power electricity (which internally flows inside the equipment) and outsourced a technician who prepared the diagram with different electrical circuits. Once he obtained the schemes, for the correspondent routes propounded in Fig. 6b) or for those modified (adapted), he could use them for a functional and exploratory test (in addition to the mechanical plan) which can be assisted by AR.

The development of human capital theory recognizes that the explanation of macroeconomic phenomena, such as national income growth, it is necessary to include, in addition to the factors: capital and labor, a third factor, which considers all skills and capabilities of workers. The studies by Theodore Schultz [5] who believes that labor is not homogeneous, had much momentum, thanks to the theoretical developments made by Becker [6] and by Mincer [7].
Human capital ("mind work") has been defined by the Organization for Economic Cooperation and Development as: 
"... knowledge, skills and other attributes possessed by individuals and that are relevant to economic activity ... " OECD [8].

For the International Labour Organization, ILO [9], human capital theory and subsequent studies, that have been conducted, have shown that education is an essential good for the individual and for society as a whole because it expands the possibilities of action and choice of individuals and society in general. Human capital, as it is an economic potential that is deposited in the capabilities of people to economic acts, is strongly influenced by the economy, the environment of the person, and in the specific labor market in which the person develops. In sum, it appears that human capital constitutes an intangible set of skills and abilities that contribute to raise and maintain productivity, innovation and competitiveness of a person or a company.

Based on these approaches also we consider that human capital theory finds in computer-assisted training an application (microeconomic) to transfer knowledge of procedures assisted by Augmented Reality (AR) technology, through the engineering and innovation in emerging technologies and systems of the company. Thus the classification scheme of inputs is reset to the assembly process assisted by AR in Figure 3.

![Figure 3 Inputs in the assembly process assisted by Augmented Reality](image)

It has restructured the classical taxonomy of inputs, because additional capital has appeared by incorporating an emerging technology in the production process of assembly.

According to Brynjolfsson and Hitt [10], Information Technology is defined as computers as related to digital communication and has the broad power to reduce the costs of coordination, communications, and information processing, among others. Thus, it is not surprising that the massive reduction in computing and communications costs by using emergent technologies has provoked a substantial restructuring of the microeconomic environment.

Figure 4 shows a representation (simulation type) deduction graph of a production function affected by an emerging technology (such as AR) taking as fixed factor capital (K) and as human resource variable factor (L), showing the investment (principal additional spent for moving $\Delta K = K_{TT} - K_{RA}$) in training (in the computer aided assembly process) for aircraft (MRO) aided by Augmented Reality.
This approach is reinforced by the previous concept established by Atkinson & Stiglitz [11], who propose a similar plot in the introduction to their work.

Figure 5 shows the production curve versus technical manpower capital increasing according to Diminishing Returns Law. And a representation (simulation) graph of the deduction of an assembly production function taking as traditional fixed factors capital (K) and human resources (L), and as the variable investment (additional capital \( \Delta K = K_{RA} - K_{TT} \)) the amount of training in AR technology (in the assembly process assisted by computer) for aeronautical maintenance (MRO) assisted by Augmented Reality could be constructed as shown in Figure 5.

By reducing assembly time increases the amount of assemblies obtained, so a vertical displacement occurs of QTT to QRA that it is shown as an orange line in Figure 4, which is seen as a horizontal displacement (Figure 6) from QTT to QRA while maintaining same value of L. Stressing that to reach the level QRA via traditional way
following the green curve of KTT will require a huge effort costs toward reaching the amount L2, of level of technical manpower that would produce a quantity (cantidad, in Spanish) such that Q = QRA.

Where:

QTT = Number of assemblies produced by Traditional Technique (TT)
QRA = Number of assemblies produced by Augmented Reality (AR) or (RA, Spanish acronym)

In Figure 2, this example represents a simulated conservative case, we are operating above the starting point of diminishing returns zone (where is the change of concavity) shows the effect generated by changing the traditional technique to assemble assisted by augmented reality technology. Therefore note the increased production (ΔQp) from QTT to QRA which is expressed as:

\[ ΔQp = QRA - QTT \] (3)

This increase ΔQp is caused by the investment share \( ΔI = IRA \) i.e. the amount of investment in an emerging technology such as AR, which generates concatenated impacts as follows:

\[ ΔI = CFRA - CFTT = IRA \] (4)

\[ IRA \Rightarrow ΔQ \Rightarrow ΔCvU \] (5)

Where: CFRA= Fixed Cost using RA, CFTT= Fixed Cost using TT

CvuTT = unit variable cost via TT; CvuRA = unit variable cost via RA

In addition:

\[ K_{proy} RA = ΔK = KRA - KTT \] (6)

\[ \Delta L = \Delta K \Rightarrow BAI \] (7)

Where: BAI = Annual Benefit Intangible

Also:

\[ ΔL \Rightarrow \text{Save RA / TT} + BAI \]

Where: Save RA / TT = Savings when incorporating AR displacing TT.

4. Profit Model with Shift of The Offer

This effect on the variable cost (VC) is reflected in the following two graphs. In Figure 6 the marginal cost (MC or CMg or Precio, in Spanish) is constituted by the assembly service offer (process) by TT (green continuous Of curve), which moves to the right (blue discontinuous Of’ curve) representing, in this case, the assembly process assisted by AR. An Offer displacement is named DESPLAZAMIENTO DE LA CURVA DE OFERTA, in Spanish.
Note that the increase in production is offered the same increment, namely:
\[ \Delta Q_p = \Delta Q_o = Q_{RA} - Q_{TT} \quad (8) \]

The \( Q_{TT} \) shift to \( Q_{RA} \) is horizontal. In the referred conservative case when moving the offer \( Of \) to the right lowering \( MC = \frac{d(TC)}{dQ} \), reflected in a decrease of total cost \( CT \) slope going from \( CT_{TT} \) to \( CT_{RA} \) (Figure 7).
5. Conclusions

In the conservative example there is a shift on the breakpoint (breakeven), from the intersection ITT- CTT to ITRA-CTRA noticing not only the decrease in the slope of the total income IT but also a greater degree in the total cost CT, lowering unit variable cost Cvu.

Failures in electric systems of production equipment are among the different typical problems where an electrical test is required due to insufficient maintenance or wrong adaptation of a machine.

The model takes into account an efficient investment policy: it is considered (empirical rule), for some companies as an administrative praxis (but depending on financial criteria and the stage at which they are), thus an investment is efficient when it meets e.g. a pragmatic relation as:

$$URA \geq 1.3 \text{ UTT}$$  \hspace{1cm} (9)

It can be seen in Figure 7 that URA is sufficiently greater than UTT, that is, URA size is 3 times UTT (approximately) which is higher than 1.3 times the value given by equation (9).

In other cases the criteria could be an $U_{RA}$ such that produces an enough $IRR > MARR$. Where, MARR is defined as the minimum attractive rate of return (MARR by its acronym in English).

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