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Production mix as an intervening factor in the equivalence relations in costing models

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Abstract

The research aims to evaluate the interference of the production mix in the equivalence relation in costing models. In theoretical terms, we identified the proposals to the modeling of costing, mainly using equivalence, based on conditions and intervenient factors. We used a mostly quantitative approach to analyzing data, investigate the relationship between variables, and evaluate the interference of the production mix between these variables, longitudinally, using panel data and the mixed model (fixed and random effects). The results indicate that the production mix factor significantly interferes on the equivalence relations in costing models. Thus, we accept the alternative hypothesis and conclude that we should consider the effects this variable in the production processes, especially when applying this costing model in companies with diversified production.

KEYWORDS: Equivalence relation. Costing models. Mix of Production.

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Mix de produção como fator interveniente nas relações de equivalência em modelos de custeio

Resumo

O presente estudo tem como objetivo avaliar a interferência do *mix* de produção na relação de equivalência em modelos de custeio. Em termos teóricos, identificaram-se proposições quanto à modelagem no custeio alicerçadas em equivalência com base em condições e fatores intervenientes. Por meio de uma abordagem predominantemente quantitativa, cujo modo de investigação foi o relacionamento entre variáveis, avaliou-se a interferência do *mix* nas relações de forma longitudinal, com dados em painel e modelo misto (efeitos fixos e aleatórios). Os resultados apontam que o fator *mix* de produção interfere de forma significativa, estatisticamente, nos pesos estabelecidos para os produtos do caso estudado. Assim, aceitou-se a hipótese alternativa e concluiu-se que se deve considerar a presença dessa variável nos processos produtivos, sobretudo quando da aplicação da equivalência em empresas com produção diversificada.

Palavras-chave: Relação de equivalência. Modelos de custeio. *Mix* de produção.

Mix de producción como factor interviniente en las relaciones de equivalencia en modelos de costeo

Resumen

El presente estudio tiene como objetivo evaluar la interferencia del *mix* de producción en la relación de equivalencia en modelos de costeo. En términos teóricos, se identificaron proposiciones en cuanto al modelaje en el costeo basadas en equivalencia con base en condiciones y factores intervinientes. Por medio de un abordaje predominantemente cuantitativo, cuyo modo de investigación fue el relacionamiento entre variables, se evaluó la interferencia del *Mix* en las relaciones de forma longitudinal, con datos en panel y modelo mixto (efectos fijos y aleatorios). Los resultados apuntan que el factor *Mix* de producción interfiere de forma significativa, estadísticamente, en los pesos establecidos para los productos del caso estudiado. Así, se aceptó la hipótesis alternativa y se concluyó que se debe considerar la presencia de esa variable en los procesos productivos, sobre todo cuando hay aplicación de la equivalencia en empresas con producción diversificada.

Palabras clave: Relación de equivalencia. Modelos de costeo. MIX de producción.

INTRODUCTION

The management of resources used in production processes and, particularly, the need for monetary representation of manufactured goods has led to the development of various costing models, with different purposes, such as the equivalence-based methods. According to Levant and Zimnovitch (2013), these models simplify complex production systems and facilitate measuring them. In models such as the GP Method, the Value Added Unit (VAU), and the Unit of Production Effort (UPE), the equivalence is achieved through using weights or indexes within the different products, maintaining consistency over time (PERRIN, 1971; LEVANT and ZIMNOVITCH, 2013).

The Perrin's (1971) GP method has the characteristic of using equivalence, based on the stability of indexes. In this case, regardless of the cost per unit and the production efforts developed for the various basic theoretical operations of work in a factory, there are equivalent relations that are stable over time.

However, the criticism toward the GP Method and other models built throughout the history of cost accounting – models such as Activity-Based Costing (ABC) and Time –Driven Activity-Based Costing (TDABC) – emphasizes the way costs at the departmental level are calculated. According to Levant and Zimnowitch (2013), the form of calculation in these models is only valid if the resource mix is homogeneous for each activity and if the operations are conducted within the department. Thus, costing models may be affected by unforeseen factors that potentially influence the cost allocation bases, and may not represent the proper costs or the activities performed (LEVANT and ZIMNOWITCH, 2013).

For Brimson (1996), some factors influence the activities by reducing the time to carry out a task or decreasing the consumable resources. Datar and Gupta (1994) and Cardinaels and Labro (2008) argue that there are factors that interfere in the measurement of time and in costing models. According to Cardinaels and Labro (2008), this influence changes the cost modeling regarding the representation of reality. From this perspective, the authors question the emphasis given to time as the main driver of activity cost in the TDABC model.

Against this backdrop and supported by the studies from Brimson (1996), Cardinaels and Labro (2008), and Levant and Zimnowitch (2013), it is possible to stress that intervening factors are part of a process, and some of these factors stand out when it comes to modeling or costing. Such factors occur throughout production and can be related to the organizations' internal or external environment (BRIMSON, 1996). In addition, their impacts are not always represented in costing models (COOPER and KAPLAN, 1988). Levant and Zimnowitch (2013) state that some factors may interfere with cost allocation bases, and this may cause "non-equivalence" of relationships over time in costing models that use weights or indexes in their modeling, such as in the GP, VAU, UPE, and TDABC models.

Some of the assumptions found in Perrin (1971), Brimson (1996), Meyssonnier (2003), De La Villarmois (2004), Cardinaels and Labro (2008), and Levant and Zimnowitch (2013) support this study, particularly the idea that some factors interfere in the equivalence relations in costing models, the most cited factor in the literature is the mix of production in multi-producer companies. Thus, in a modern context of diversified production, where different activities are performed simultaneously, the mix of production may result in some variation regarding the use of available resources.

In short, the assumption that equivalence relations of costing models remain stable over time may not always be valid. The equivalence relation may be influenced by the mix of production, for instance, which entails numerous activities, the definition of several production batches and sizes, different setup times, demand, and more. Therefore, the research question guiding the analysis carried out in this study is: What is the interference of the mix of production in the equivalence relation in costing models?

As for the theoretical background, the research is based on Perrin (1971), Cooper and Kaplan (1988), Bornia (1988), Cooper (1989), Miller and Napier (1993), Brimson (1996), Meyssonnier (2003), Levant and De La Villarmois (2004), Cauvin and Neuman (2007), Cardinaels and Labro (2008), De La Villarmois and Levant (2011), and Levant and Zimnovitch (2013) who discuss the usefulness of costing models in management. In practical terms, studying whether factors that interfere with equivalence relations can jeopardize the consistency of information offered by costing models may help improve the establishment of standards for diversified production in companies.

Moreover, this study intends to fill a gap identified in the literature, since Perrin (1971), Bornia (1988), Brimson (1996), Meyssonnier (2003), De La Villamois (2004), Cardinaels and Labro (2008), and Levant and Zimnowitch (2013) pointed out factors that may affect equivalence relations, but failed to provide empirical evidence.

THEORETICAL FRAMEWORK

In the study of costing models, the pattern of equivalence is usually presented through the structure of costs or time, applying weights or indexes to unify diversified production (PERRIN, 1971; LEVANT and ZIMNOWITCH, 2013). Also, equivalence is used as one of the alternatives to reduce randomness in the process of cost proportion/sharing by-products (LEVANT and ZIMOWITCH, 2013).

Equivalence in costs is used in the studies by Levant and De La Villarmois (2001, 2004, 2007), Meyssonnier (2003), Alcouffe, Berland and Levant (2008), and De La Villarmois and Levant (2011). However, there is no consensus among these authors regarding the methods supported by the concept of equivalence. The research by Levant and De La Villarmois (2001) and De La Villarmois and Levant (2011) attribute the equivalence standard to the models GP, VAU, ABC, TDABC, Homogeneous Sections, UPE, and the points method. Cauvin and Neuman (2007) point out the use of equivalence in the models GP, Homogeneous Sections, and ABC. For Meyssonnier (2003), equivalence is used in the models GP and VAU, whereas for Mévellec (2003), only VAU uses equivalence. Finally, Lavillarmois and Levant (2007) and Levant and Zimnowitch (2013) cite the UPE model – which is widespread in Brazil – as a method that uses equivalence standards.

It is noteworthy that Levant and De La Villarmois (2001), De La Villarmois and Levant (2007, 2011), and Levant and Zimnowitch (2013) mention the GP Method as the origin of the equivalence methods, followed by developments for the unit of production, value-added unit, and in the Brazilian case, to the Unit of Production Effort.

According to Levant and Zimnovitch (2013), equivalence methods have evolved and can be classified into three levels: (i) as simple methods – for each object, an equivalence is established with the unit of reference, whose weighting uses an overall rate of equivalence of the observed product; (ii) as cost center – a cluster of several cost centers use equivalence; (iii) as complex methods – autonomous models designed to obtain costs in complex processes by calculating equivalence relation that bring all manufactured products to a multiple of a basic element.

Equivalence of costing model

Equivalence in cost modeling is connected to better representation for a complex organizational reality, for which several models can be established for different purposes. In this context, Miller and Napier (1993) and Alcouffe, Berland and Levant (2008) argue that there is no uniform costing model that can offer a basis for the history of accounting. Notwithstanding, there are different forms of economic calculations implemented according to the particular goals or ideals of organizations and their internal and external actors.

It is possible to say, therefore, that the discursive nature of Management Accounting is constituted in the world of practice, and that is necessary to identify approaches able to determine the conditions within these practices (MILLER and NAPIER, 1993). Therefore, the intention to simplify stands out, i.e., to change complex cost-division calculations into simple ones, whose equivalence is a possible solution.

However, Mévellec (2003) criticizes equivalence methods considering that management tools should not be used to simplify organizational complexity, but contribute to its management. For a model to represent the complex reality of an organization – from the perspective of cost management – it has to observe and identify the factors that may interfere in equivalence relation and serve as a basis for information and assistance to management decisions (MÉVELLEC, 2003).

When discussing the equivalence method, Levant and De La Villarmois (2001) stress the need to understand the advantages and disadvantages perceived by organizations that have implemented the VAU model, for example. The authors point out the lack of a broader study on this matter. The equivalence methods are attractive due to their simplicity and low cost, but they still lack reliable theoretical foundations.

Meyssonnier (2003) criticizes the notion of stability indexes, which is the main characteristic of the GP method, where it is assumed that the relations of costs within production areas are stable over time. In addition, GP or VAU methods cannot be associated with the contribution margin or the setting of a margin on specific costs. For the author, this is a major managerial shortcoming since costs based on equivalent production are far from being as simple and robust as advocated by the same scholars.

Levant and Zimnovitch (2013) argue that equivalence methods have lost their appeal – concerning their capacity of simplification – over time. However, concerning their ability to direct costing to analyze variable and fixed costs, the equivalence methods are still considered significant.

The models identified by Levant and Zimnovith (2013) based on equivalence – GP Method, developed by Perrin in 1945; the ABC proposed by Johnson and Kaplan in 1987; the VAU, developed by Fiévez, Kiefer and Zaya in 1999; and the TDABC proposed by Anderson and Kaplan in 2004 – establish weighted equivalence relations among the various production processes of multi-producer companies. This means that there are conditions, principles, rules to maintain the stability of indexes over time (which is the basis of equivalence). Perrin (1971) defines the notion of stability of indexes as the basic rule of the GP Method.

Principles and conditions of equivalence

In the principle of stability of indexes attributed to Perrin (1971), which is a central issue in this study, it is possible to observe a normative connotation, i.e., the organization of rules regarding the use of equivalence in costing models. The literature, however, does not present an explicit proposition defining such equivalence, but rather rules and axioms for its establishment. Thus, Meyssonnier (2003) criticizes the VAU method for the principle of equivalent relations, identifying as a paradox when a company is in a context of increasing, generalized, and relatively uniform prices. In this case, the architecture of VAU is compromised by not maintaining equivalence relations.

De La Villarmois and Levant (2011) corroborate, stating that the findings observed in the literature do not provide an answer to eliminate the uncertainties of the equivalence method techniques, such as the possible impact of the choice of the reference product, or the assumed stability of the VAU or GP numbers in the equivalence relations. The authors also cite the studies by Gervais and Levant (2007, 2008) and Gervais (2009), which follow the same line of thought.

Bornia (1988) analyzes the principles of equivalence to improve the implementation and operation of the UPE model. The author lists as one of the specific objectives the confirmation of possible deviations of the principle of stability of indexes. Bornia's (1988) methodological strategy, proposes the development of a generic situation, partially simulating a factory and a mathematical form. Thus, the author analyzed the resulting equations and concluded that the UPE model brings more stable and reliable outcomes for companies with similar (homogeneous) production areas than with those of a diverse nature (heterogeneous). Therefore, variations in units of production effort are smaller in companies with homogeneous products or the same family than in companies with different items.

Finally, Meyssonnier (2003) notes that, for the analysis of equivalence relations, there are questionable assumptions regarding elements such as innovation, improvement, technological advances, and the economic situation, which are factors that influence production. As for the association with economic data, Levant and De La Villarmois (2004) corroborate the opinion concerning the questionable assumptions. When considering the contributions of these authors, it is possible to state that there are influences of intervening factors in the so-called stability of indexes, i.e., the stability of a model is likely to be affected in some way, or to some extent.

Intervening factors

Costing models are commonly associated with a level of homogeneity and stability in production processes (LEVANT and DE LA VILLARMOIS, 2001). However, there is a need to verify factors that interfere with stability, and whether the assigned weights are consistent to consider the applied equivalence. Bornia (1988) analyzed the principles governing the GP method – known in Brazil as Unit of Production Effort (UPE) – and concluded that this equivalence method presents more reliable results when the production areas are similar. However, given the complexity of the production processes and changes that occur over time, the production areas may present a certain degree of heterogeneity.

The literature presents factors that affect the equivalence relation of costing models and possibly interfere with the stability of indexes/weights. Some of these factors are the mix of production, technology, experience, and continuous improvements, cited by authors such as Meyssonier (2003), De La Villarmois (2004), and Levant and Zimnovitch (2013). Some factors interfere with the activities and drivers, as pointed out by Brimson (1996), Cardinaels and Labro (2008), and Levant and Zimnovitch (2013).

Finally, it is possible to say that product diversity is an inherent feature of multi-producing companies (LEVANT and ZIMNOITCH, 2013), and the diversification of activities and resources involved in production is associated with the complexity encountered by managers throughout production (BANKER and JOHNSTON, 1993). From this perspective, and with the initial concern of Perrin (1971) regarding the management of multi-producing companies, this study focuses on the factor "mix of production."

Mix of production

Meyssonier (2003), De La Villarmois (2004), and Levant and Zimnovitch (2013), considering the perspective of equivalence, recognize the mix of production as a factor that affects the control of activities and the calculation of costs, influencing the equivalence relations of costing models. The authors highlight the number of items produced as a variable that interferes with the stability of indexes and weights attributed to equivalence methods. They argue that the diversification and quantity of items generate higher costs for production processes.

Brimson (1996) corroborates with this point of view, particularly when emphasizing that diversification in production is a creative factor that influences costs, given the variety of activities. However, the measurement of the activity represents the factor by which the costs of a given process tend to vary more directly, and it is not the determinant of the costs. For the author, the determinant is the factor that creates cost. The activity is, therefore, a dependent variable in a regression analysis.

The works by Shank and Govindarajan (1997) and Kotler (2000) are developed in the same direction regarding the aspects of strategic management and cost drivers. They emphasize that the diversification of products and services (mix of production), as well as the complexity of production processes, increase costs. For the authors, in addition to the extensive product line, decisions such as demand or production capacity and high market share interfere with the controls and costs involved in the processes.

When working on the decision-making on the mix of production and costing models, Nélo (2008) identified the best model between the Theory of Constraints (TOC), the ABC and the General Model (GM), where the decision of the mix of production is linked to external factors such as competition, substitute or complementary products; and internal factors, such as entrepreneurial capacity, product consumption demand, human resources, and others that directly influence costs. Saraiva Junior (2010), however, built a quantitative model to support the decision-making regarding the product mix.

In parallel, Kee and Schmidt (2000) built a model based on the concepts of TOC and ABC, which they called the "General Model" (GM). They concluded that companies have different degrees of control over labor resources and overhead, affecting these models. Furthermore, Zhuang and Chang (2017) proposed a mixed-integer programming (MIP) model, based on the TDABC method. Using time as a driver for elements of cost while addressing the numerous resource constraints can optimize a decision. For the authors, the TDABC avoids some limitations of TOC and ABC. They argue that the TDABC avoids aggregation errors (judgments in estimating the proportion of time) for each activity, which implies that the TDABC is a better option in comparison to the TOC and the ABC. However, the authors say that costing models may be influenced by the mix of production due to the number of items, diversification, product demand, among other decisions made during the management of companies.

METHODOLOGICAL PROCEDURES

This is a descriptive study, where researchers describe the phenomenon without interfering in the causal relationships among variables (GIL, 2008). The analysis, dedicated to examine and validate the data, used quantitative and qualitative strategy, adopting mixed methods, which is justified since some sources of data may be considered insufficient (CRESWELL and CLARCK, 2013). Thus, research results may need quantitative and qualitative explanations, as a second method helps to improve the first.

Once the weights and indexes are established, considering an equivalence method (physical condition) and under the interference of the mix of production, the study collected data on the number of batches, and setup times attributed throughout the production process. After that, the interference of the factor mix of production in the equivalence relations was statistically assessed.

At the beginning of the data collection, the identification was conducted based on internal reports on production controls prepared by the departments of cost, production, and accounting. The reports refer to the acquisition of new technology (machines), employee turnover, and diversification of production (mix of production). The study used semi-structured interviews based on a previously prepared script to collect data. The interviews were separated into technical questions (production process; activities alignment, and forms of production) and management questions (use of costing models based on equivalence, decision making). The interview guided the collection of information and perceptions regarding the phenomenon of equivalence, approaching the commercial director, the person responsible for managing costs and their assistant, the controller, and the production engineer, responsible for the production process. Also, the research examined data from accounting reports such as balance sheets and statements and spreadsheets provided by the cost and production department.

Information regarding the company was obtained through fortnightly and monthly meetings. Once granted the authorization to conduct the research, data about the production was collected considering three consecutive years (2014, 2015 and 2016), recognized as the years where the phenomenon was more present, without the interference of other important factors such as learning and technological change. Therefore, the research selected a period in which only the change in the mix of production stood out.

About the unit of analysis

The unit of analysis is part of a worldwide corporation, leader in the production and distribution of motorcycle parts in Latin America. It produces, on average, 3,000 different items per month, using 133 resources such as machines, tools, and manual labor, applied to 124 different manufacturing activities. The production focuses on parts (sealing gaskets) for the moped/motorcycle sectors.

For the analysis of the mix of production, the research observed all activities and items of a product line – gasket kit – that employed the same resources throughout the period analyzed, and that presented significant changes in the mix of production.

Description of data and variables

This topic describes the manufacturing process of the product line “HDA CG 125 gasket kit” (code 109Z), whose items are produced through activities such as stamping, ring-closing, and washing. According to reports provided by the unit’s cost department, there were changes in activities over the period. Also, some of the factors cited in the literature on changes in the mix of production were observed during the period, such as product and batch differentiation, and minor changes of operators in some activities.

As for the cost calculation, the company accumulates the data based on cost centers (CC). Among the characteristics of the examined production line, stands out the occurrence of 47 types of activities, which used 22 resources in the production of 2,996 different items over the period.

The reports clarify that the resources were purchased before the research started, which shows that there was no acquisition of new technologies (machinery) during the period analyzed. After identifying the activities and resources used, the researchers collected data from reports provided by the company. These sources allowed to define, annually and monthly, the total operation of each activity, the time spent (including the setup), as well as the recognition of costs accrued in the cost center.

The weights were attributed according to the number of operations of the activities. In this sense, the most frequent activity during the analyzed period was the "D1 (stamping with 12T press)," which was considered as the base activity for weight calculations and the establishment of equivalences. Table 1 shows the composition of costs per activity and the attribution of weight considering the values of January of the first year analyzed, for activities D1 and Q7 (closing ring with a rotary press), related to product 109Z.

TABLE 1

Composition of cost per activity

ACT	R	CC	ET	TOP	CHM	COP	CACT	WACT
D1	008	3111	6.0833	4,169	14.59	88.80	0.02130	
	015	3511	1.5000	10,000	17.22	25.84	0.00258	
	022	3221	71.8167	153,000	35.70	2.564.47	0.01676	
	024	3112	102.8333	109,596	14.59	1.501.00	0.01370	
	026	3111	3.7500	4,500	32.99	123.71	0.02749	
	047	3111	9.1833	24,624	32.99	302.96	0.01230	
	068	3111	5.5833	4,905	32.99	184.19	0.03755	
	069	3112	45.6000	15,802	14.59	665.60	0.04212	
	ZZ	3111	212.7333	353,484	32.99	7,018.09	0.01985	
Tot. D1			459.0833	680,080		12,474.66	0.01834	1.0000
Q7	003	3221	73.8333	153,000	35.70	2,636.48	0.01723	
Tot. Q7			73.8333	153,000	35.70	2,636.48	0.01723	0.9395

Source: Elaborated by the authors.

Key: ACT= Activities; R=Resources; CC=Cost center; ET= Effective time; TOP= Total operations; CHM=Cost hour month; COP=Cost per operation; CACT=Cost per activity; WACT= Weight attributed per activity.

Thus, the cost per operation was established, with activity D1 (stamping with 12T press), resource 008, effective time of operation 6.0833 multiplied by the hourly cost of BRL 14.5965, which resulted in BRL 88.80. This amount divided by the number of operations/

activities resulted in a cost per activity of BRL 0.02130. As the activities are performed using different resources throughout the month, the procedure adopted was to identify all activities D1 in the production line for each resource and, from that, determine the monthly cost per activity. Thus, the effective monthly time for activity D1 was 459.0833h, to carry out 680,080 operations, at a total cost of BRL 12,474.66, which results in BRL 0.01834 per product unit.

Given the representativeness of activity D1 over the period studied, it was considered the standard activity to establish weights, receiving the weight 1.000. On the other hand, activity Q7 (closing ring with a rotary press) has a total cost of BRL 2,636.48 to carry out 153,000 operations/activities, resulting in a unit cost of BRL 0.01723. Based on these values, the weight of this activity for the month under analysis was formed by dividing its cost BRL 0.01723 by the cost of the standard activity D1 (BRL 0.01834), obtaining the index or weighted value of 0.9395 for Q7. In other words, activity Q7 is equivalent to 0.9395 of activity D1.

The procedures described above were performed for all 47 activities over three years, allowing to establish the weight table and to analyze the variables. Other procedures were also needed, such as to identify the total operations conducted during the month, for all activities.

The procedures adopted to facilitate the understanding of the data analysis process and the demands related to the research question, considering the characteristics exposed above, required the following definition:

a) **Dependent variable** – weights;
b) **Independent variable** – mix of production; and
c) **Activities** – operations carried out (cross-section = D1; D2; H0...) over the period studied (across time).

The data received statistical treatment for the use of dependence techniques, such as panel data regression analysis, mixed models, based on the concepts by Bates (2010) and subsequent identification of significance through the *t*-test.

Supported by the literature reviewed, data collected, and field observations, the research found that other intervening variables, such as the operator experience and the technology, may influence variable weight. Stock and Watson (2004) emphasize that, in these situations, it is possible to observe the behavior of several individuals over time and verify the influence exercised on the observed phenomenon. The authors suggest the use of panel data (longitudinal data), which is also recommended by Fávero, Belfiore, Silva, et al. (2009). Each cross-section unit that composed the activities, such as D1 – stamping with 12T press; D2 – stamping with 15T press; D3 – automatic F1 cut; H0 – Cleaning and storing, were observed in two or more periods (across-time) comprising the three years and their respective months. The research observed, therefore, 47 activities, in a total of 1,692 observations (47 activities multiplied by 36 months).

Given the arguments of Croissant and Millo (2008) and Bates (2010), the analysis of the problem adopted the mixed-effects model. For Baayen, Davidson and Bates (2008), mixedeffect model software is widely available, including the ‘R software,’ which adopts an open-source statistical programming environment. The R software was then used for analysis under the mixed-effects model approach, as well as the “lme4” package, which includes the “lmer” function (mixed model regression).

RESEARCH HYPOTHESIS

The connotation given to costing models suggests that the equivalence relations can only be considered if, and only if, the conditions in terms of resources are homogeneous for activities or production efforts, and that these conditions remain stable during the production process (PERRIN, 1971; BORNIA, 1988; LEVANT and ZIMNOWITCH, 2013). However, intervening factors, identified in the literature, can significantly affect these relations (BRIMSON, 1996; MEYSSONNIER, 2003; DE LA VILLARMOIS, 2004; CARNINAELS and LABRO, 2008; LEVANT and ZIMNOWITCH, 2013).

Among the factors recognized in this study, and as a result of different approaches, this research focuses on the mix of production. Thus, if the mix of production significantly interferes with the equivalence relations, the information resulting from costing models may lead to poorer decisions. In this sense, and based on the approaches presented here, the following hypothesis to be explored is “the mix of production interferes in the equivalence relation in costing models.”

Based on the procedures and paths outlined so far, the study tested the hypothesis according to the representation: $\begin{cases} H_0 : \beta_1 = 0 \\ H_1 : \beta_1 \neq 0 \end{cases}$

When the hypothesis is null hypothesis, the mix of production does not interfere with the equivalence relation in costing models. As for the alternative hypothesis, it means that the mix of production influences the equivalence relation in costing models.

DATA ANALYSIS

Over the 1,692 (36 months x 47 activities) observations, there were activities with value 0.00. The observations other than 0.00 resulted in 847, which is an unbalanced panel. As for data homogeneity, it was necessary to treat data given that it is not always presented in the right form for immediate analysis (CHATTERJEE and HADI, 2015).

Regression and transformation of variables

The R software allowed to carry out the transformation of the variables and analysis (such as outliers), considering the mixed models used in the regression. Also, the “lme4” package and the “lmer” regression function were adopted, according to the models named m1 (m1<-lmer(WEIGHTS~PROP*MIX* + (1|ACTIVITIES), data=*Mix*mensal) and m2 (m2<-lmer(log(WEIGHTS+1)~log(PROP*MIX*) + (1|ACTIVITIES), date=*Mix*mensal).

In the m1 model, the regression outputs based on the mixed-effects models and without the use of the log transformation were assessed. The assessment of the transformation of the variables was done for the m2 model. Table 2 presents the output of the regression model with random and fixed (mixed) effects.

TABLE 2

Regression: mixed-method, non-transformed data

Random effects			Fixed effects			
Group names	**Variance**	**Standard deviation**	**Coefficient estimation**		**Standard error**	**t value**
Activities (Intercept)	165.0	12.85	(Intercept)	7.597	2.038	3.727
Residual	109.5	10.46	PROP*MIX*	-28.318	19.124	-1.481

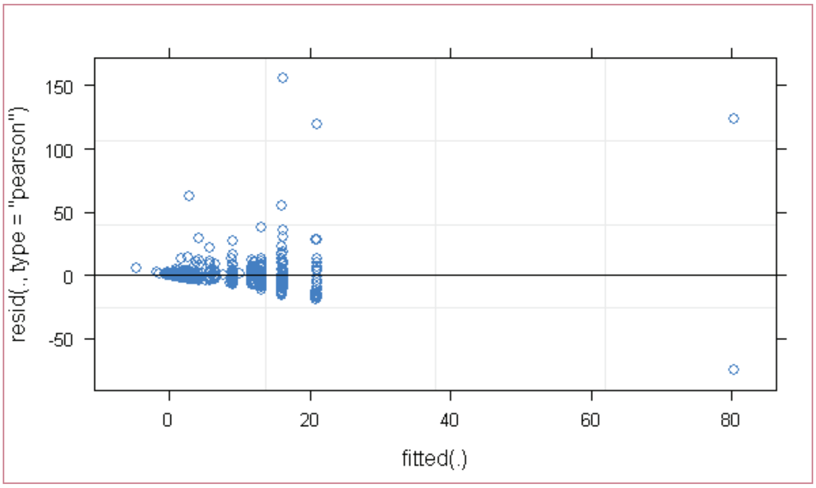
Source: Elaborated by the authors.

The fixed effects presented the average intercept of 7.597, with a negative coefficient of -28.318. There was a correlation with the independent variable.

The residual plot (Figure 1) presents scattered points of the X-axis, and heteroscedasticity (non-constant variance).

FIGURE 1

Residual plot (m1)



Source: Elaborated by the authors.

Given the need for transformation of the variables, the model 2 (m2) function was applied in the regression. Because of the values closer to zero, where the log function is not defined, the transformation log (Weight +1) was adopted. Table 3 presents the outputs.

TABLE 3

Regression of transformed data

Random effects			Fixed effects			
Group names	Variance	Standard deviation	Coefficient estimation		Standard error	t value
Activities (Intercept)	0.5009	0.7077	(Intercept)	-0.1168	0.138	-0.845
Residual	0.2083	0.4564	PROP*MIX*	-0.2100	0.013	-15.333

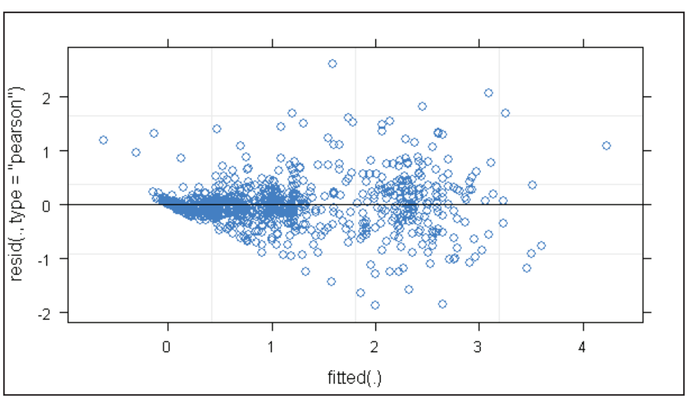
Source: Elaborated by the authors.

The output with the "log" variables has a lower degree of variability compared to previous data. For the residuals, there was also a decrease in variance from 109.5 (m1) to 0.2083 (m2). This modeling is used in statistics to designate that part of variability that is not explained or modeled with the other terms. Even so, these data, after adjusting the model, are considered "leftover" (BATES, 2010). In the standard deviation from 10.46 (m1) to 0.4564 (m2), there was a decrease in the variance of residuals on the response variable. Thus, it is proved that the transformation of the variables statistically contributes to the normalization of the data. The fixed effects presented the average intercept of -0.1168, with a negative coefficient of -0.2100. It was observed that *t*, equivalent to -15.333 of the mix of production (Prop*mix*) variable, is higher than 2. Therefore, significant, according to Baayen (2008).

According to Barbetta (2001), after estimating the parameters for the model, the residuals are calculated by the difference between the observed values (Y) and the forecasted values ($\hat{y}$), by associating each X used in the analysis. However, the residual plot (Figure 2) shows the outliers on the X axis.

FIGURE 2

Residual plot (m2)



Source: Elaborated by the authors.

Data concentration was identified on the X axis. After the transformation, the data and the relationship between the variables were more homogeneous compared to Figure 1. Thus, it is proved that the transformation minimizes the distortions between the variables. However, some outliers that can cause significant changes in data analysis are still observed.

Chatterjee and Hadi (2015) argue that a point can only be considered outlier if it is detrimental. For the authors, when an elimination (alone or combined with other points) causes significant changes in the adjusted model, the exclusion of anyone, in general, is likely to cause changes. Those points that cause major changes must be observed. Figure 2 shows two outliers in comparison to the other points. Therefore, it is possible to check which activities correspond to these points and the months when the discrepancies occurred.

It is noteworthy that the regression in package R was performed without outliers, and these outputs did not show significant changes compared to the regression in Table 3. As explained by Chatterjee and Hadi (2015), when this situation occurs, the points must remain in the analyzes.

Statistical significance – *t*-test

The significance test verifies whether the data provided present evidence to confirm the research hypothesis (BARBETTA, 2001). Thus, if there is an interference of the mix of production in the equivalence relations – considering the established weights –, it is necessary to observe whether the interference is statistically significant, through a test on the angular coefficient of the model adopted. The analysis presented above and the outputs presented in Table 3 for the absolute value of *t* corresponding to 15.333, the significance tests were higher than 2. The value of *t* is outside the acceptance region for the null hypotheses (H_0), as well as the *p* value (*p*-value <2.2 e-16), which is much lower compared to 0.05 for the significance level. Therefore, it is possible to affirm that the interference of the mix of production is statistically significant, rejecting H_0 and confirming the alternative hypothesis: the production mix interferes with the equivalence relations in costing models, or $H_1 : \beta_1 \neq 0$.

In addition to the quantitative analysis of the interference of the factor mix of production in equivalence relations, the study conducted a qualitative analysis of the equivalence phenomenon. This analysis focused on technical and managerial aspects of the unit researched, based on the perception of the professionals that use the information presented in the costing models.

Qualitative aspects of the research

The qualitative aspects regarding the phenomenon of equivalence (or non-equivalence) were collected through semi-structured interviews. Respondents (commercial director and production engineer) stated that the variation of activity occurred mainly in relation to the level of inventory to be maintained. This is explained by the fact that the decision about the mix of production considers the **demand** of the main customer; and by the inclusion of new models (**modeling**) and improvements in the processes (**continuous improvements**). Some of these elements have also been cited in the literature by authors such as Meyssonier (2003), Mévellec (2003), Kee and Schmidt (2000), Zhuang and Chang (2017), Brimson (1996), and Kotler (2000).

Factors such as **technology** and **process improvement** were also cited by the commercial director and the person responsible for providing information about costs. They stated that these factors led to changes in the times of activities. Meyssonnier (2003) supports this statement when criticizing the principle of stability of indexes that counts on the slowly and non-progressively technological advances favoring continuous improvements.

The respondents' perception of the mix of production and batch size (small, medium, and large), regarding the interference of the weights attributed to the activities, was due to the issue of time in relationship with the organization and interval of operations or phases (until a phase begins, the other is on hold). Both (Commercial and Production Director) considered that smaller batches generate higher costs. For the Cost Manager, the batch size interfered in the equivalence relations, because the bigger the batch, the lower the setup cost. Zhuang and Chang (2017) consider batch numbers and the time to prepare a machine in their analysis as if the times were stable. The authors considered that the decision for production with diversification (mix of production), may affect the relationship with the time and, thus interfere with TDABC model information, for example.

For all respondents, diversification mainly interfered when the volume of sales increased considerably. These considerations corroborate the assumptions of Brimson (1996), Shank and Govindarajan (1997), and Kotler (2000) when claiming that an extensive product line interferes with the controls and costs involved.

For respondents, the acceptable level of variability of the mix of production is 5%. According to Gervais (2006), 10% variability is considered significant; above that, it may affect the information provided when using the equivalence method.

CONCLUSION

The research hypothesis was proposed based on assumptions observed in the literature regarding factors influencing production and the diversification of production from the point of view of its activities (PERRIN, 1971; BRIMSON, 1996; MEYSSONNIER, 2003; DE LA VILLARMOIS, 2004; CARDINAELS and LABRO, 2008; LEVANT and ZIMNOWITCH, 2013; ZHUANG and CHANG, 2017).

As a result of the quantitative analysis – which emphasized the activity-based (cost per activity) equivalence method to attribute weights and to analyze the relationship between the variables weights and mix of production – the research identified that there was variability in the proportions of the mix of production. The study applied the activity-based equivalence method in the company researched, concluding that, in the quantitative aspect, the factor mix of production significantly interferes in the equivalence relations (weights) for costing and for the establishment of indexes or weights that allow comparison over time.

In qualitative terms, the respondent's perception collected through semi-structured interviews showed that there was a variability of activities in the months analyzed, and there were differences in proportions in the weights over the period. Some factors that caused the diversification in the activities stood out from the interviews with managers, including i) inventory level; ii) inclusion of new models/modeling; iii) continuous improvements; iv) mix of production – batch size; v) work shifts (1st, 2nd, and 3rd); vi) project to elaborate new items; and vii) maintenance of the machinery.

It was possible to conclude that the batch size and setups interfered in the times and, consequently, in the equivalence relations. Thus, the larger the batch, the lower the setup cost; the smaller the batch, the more setups are performed. Therefore, the variety of items and the diversification of production (mix) interfere in the variability of activities and equivalence relations, for reasons such as the constraints presented, the demand, or the use of more modern technology (faster machines), or the operator's behavior.

When considering both the qualitative and quantitative analysis, based on observed data collected in the field, it is possible to conclude that the mix of production significantly interferes with the equivalence relations of costing models for the case studied. Thus, the presence of this variable in the production process and the costing model of the organization cannot be ignored.This has been widely discussed in the literature (BRIMSON, 1996; SHANK and GOVINDARAJAN, 1997; KOTLER, 2000; MEYSSONNIER, 2003; DE LA VILLARMOIS, 2004; LEVANT and ZIMNOWITCH, 2013) and now validated in this research through empirical observation.

For academia, and particularly the field of studies on costs, the research results allow expanding the discussion about the interference of the mix of production and other variables – such as learning and technology – in the equivalence of costing models. Previous studies suggest factors that may affect relationships, besides the mix of production tested in the present research. These suggested factors, however, have not been systematized through empirical observations (BORNIA, 1988), which constitutes a challenge to be undertaken in the future.

Finally, although the results presented here are limited to the case studied, they present a theoretical contribution to the development of the literature on equivalence methods concerning the homogeneity of the processes and their representation as costing models. In addition, the discussion provided in this research opens space for in-depth reflections, considering the inclusion of new intervening factors.

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