International Journal of Business and Management; Vol. 12, No. 7; 2017
ISSN 1833-3850 E-ISSN 1833-8119
Published by Canadian Center of Science and Education

Blood Components as Joint Products: A Literature Review of Cost-Allocation Methods

Alessia D'Andrea[1]

[1] Department of Management, Università Politecnica Delle Marche, Ancona, Italy

Correspondence: Alessia D'Andrea, Department of Management, Università Politecnica delle Marche, Piazzale Martelli, 8-60121-Ancona, Italy. Tel: 39-071-220-7233. E-mail: a.dandrea@staff.univpm.it

Received: March 31, 2017 Accepted: May 10, 2017 Online Published: June 7, 2017
doi:10.5539/ijbm.v12n7p46 URL: https://doi.org/10.5539/ijbm.v12n7p46

Abstract

The object of this review is to present and to shed light on joint cost-allocation methods that are used in the healthcare sector for pricing purposes or cost-effectiveness purposes in different countries. The concept of jointness is illustrated through joint products and joint costs as found in the example of blood component production. The descriptive review, fundamentally concept-centric, highlights that the cost of blood products or blood price-setting is an issue in legislative proposals at the national and state levels and represents a matter of public interest and of public regulation. In applying economic models (based on economic principles and behavior axioms) rather than accounting methodology (based on physical measures or on market value of the split/final products), scholars have brought to light the problems arising from the continuous search for a neutral method for allocating joint costs in the blood production sector. Numerous studies have focused on the blood costs for the health system. Nevertheless, the cost accounting and reimbursement system effectively underlying the acquisition, screening, and transfusion of blood appears, in practice, to be largely obscure. Moreover, the literature provides little insights into the level of "relative importance" assigned to each product in the costing setting. The current status of the discussion offers opportunities for future researches, which could be directed toward investigating the relationships between national systems of healthcare services and the cost-allocation methods used to determine the cost/price of blood components, analyzing the effect of public regulation on blood costs and, lastly, developing a method based more on the benefit-value to users.

Keywords: blood components, cost-allocation methods, healthcare system, joint products, joint costing, public interest

1. Introduction

There is a joint-cost allocation problem in matters of public interest, particularly as concerns the health and economic relevance of blood product costs (Cumming, Wallace, Surgenor, Mierzwa, & Smith, 1974; Dixon & Trenchard, 2001; Lowe, 1997; Trenchard & Dixon, 2003). Blood products mainly consist of red cells, plasma, and platelets. One raw material (whole blood) can yield these three products, using two different techniques but sharing some steps of the manufacturing processes (World Health Organization WHO , 2002).

According to the latest statistical data reported by WHO, 112.5 million blood donations are collected globally from voluntary unpaid donors (in increasing percentages of the total), from family/replacement donors, or from paid donors. This supply meets the needs of patients for transfusions required in supportive care in cardiovascular surgery, transplant surgery, massive trauma, and therapy for solid and hematological malignancies (principally in high-income countries) and to manage pregnancy-related complications and severe childhood anaemia (typically used in low- and middle-income countries) (WHO, 2016).

Over the last few decades, a number of accounting and economic analyses have been conducted, worldwide, to highlight the cost of blood components for clinical use. Each of these studies has had different aims and has adopted different perspectives and methods. Several research studies, focused on the U.S. context, accounted the cost of blood transfusions incurred by a hospital entity (Custer, Agapova, & Martinez, 2010; Forbes et al., 1991; Sullivan & Wallace, 2005; Surgenor, Wallace, Cumming, Mierzwa, & Smith, 1973; Toner et al., 2011), highlighting the acquisition cost or price paid by the hospital for a unit of blood products (principally red cells) and identifying the cost variation (by year and/or by region) in blood services. They analyzed the blood product cost from a payer's perspective: the final price charged by suppliers (non-profit or profit providers, such as the

Red Cross or blood banks) to hospitals when acquiring blood represents one of the many cost elements making up the total costs related to blood services. Another group of scholars accounted the cost of blood products and blood transfusions from a social perspective (Abram & Sun, 2012; Glenngård, Persson, & Söderman, 2005; Shander et al., 2010; Varney & Guest, 2003), including the following cost elements: cost incurred by the donor to donate blood and the opportunity cost of time spent making a donation, the cost of blood collection and processing, and the hospital services costs incurred in transfusing and follow-up activities. Finally, efforts to determine the cost of blood products were also conducted from a provider's perspective. Accounting scholars, economists, scholars in medical matters, and practitioners focused on the costs related to donor recruitments, collection, screening, processing, storage, and distribution of blood components (Cumming et al., 1974; Dixon & Trenchard, 2001; Eandi et al.; 2015; Fragoulakis, Stamoulis, Grouzi, & Maniadakis, 2014; Lowe, 1997; Mafirakureva et al., 2016; Trenchard & Dixon, 2003). They presented different insights, points of view, and objectives in investigating the cost of blood products. They determined the cost of blood unit production from a managerial perspective and/or a cost-related pricing perspective. In these views, the objectives are to develop a cost-allocation model as the basis for blood pricing or blood tariffs (in a regulated public health system) and to apply accounting, sociology, or economic theories to the complex issues of blood costs originating from joint processes.

In this matter, both accounting scholars (Bhimani, Horngren, Datar, & Rajan, 2015; Drury, 1996; Gordon, 1967; Horngren, 2011) and economists (Balachandran & Ramakrishnan, 1996; Thomas, 1974) maintain that the allocation of joint costs is arbitrary, but – at the same time – that practices of cost allocation appear to have remained in use, mainly in product costing, inventory valuation, and performance measurements.

The main objective and contribution of this paper is to review the extant literature on cost-allocation methods applied to the joint costs of producing blood components, in order to offer a synthesis of the current status of the discussion and a base for further research in this field. To this end, the paper is structured as follows. A general overview of the concepts of joint product and joint costing is discussed in the next section. Then, a technical discussion of the manufacturing process for blood components and of its cost elements further clarifies the complex problem of jointness in blood services. After this introduction, the method used for the literature review is presented. In the last two sections, the findings are presented and discussed, and the conclusions are drawn.

2. General Overview of the Joint Product and Joint Costing Concepts

This section constitutes the basis for determining the key words used for searching the literature and presents the general framework which was used for selecting the studies to be included in the review. The reader will be introduced to the concept of joint costing, along with the associated terminology, cost allocation methods, and issues that should be considered in the calculation of joint product costs. Furthermore, the background information will be useful to better understand the joint cost setting in the blood sector.

2.1 Joint Product and Joint Cost Concepts

When a common process (or series of processes) of a single input or set of inputs yields two or more products simultaneously, these products are referred to as joint products (JPs) (Bhimani et al., 2015; Gordon, 1967). There are innumerable cases of joint products in practice: examples are beef and hides from cattle, lumber and pulp from logs, coke, gas, and other goods from coal, gasoline and fuel oil from petroleum, etc. In each of these examples, no individual product can be produced without the accompanying products (Horngren, 2011). The two or more products are considered joint because there is a fixed relationship between each unit of common input and the expected output for each of the resulting products (Hemmer, 1996). According to Gordon (1967), joint processing situations are connected with fixed yields (the JP are derived in proportions which are fixed by formula); materials-determined yields (the percentage yields of each of the JP depends on the quality or composition of the joint materials inputs); processing-determined yields (the relative yields of various JPs can be varied by alteration in the processing method employed). The joint products are indistinguishable as separate products until the processing reaches a split-off point (Schneider, 1986). At this juncture in the process, one or more products become separately identifiable (Bhimani et al., 2015; Horngren, 2011). In the JP setting, the accounting literature has distinguished joint products (in the strictest sense of the word), by-products, main product and scrap. Blocker and Weltmer (1954) describe the difference between joint product and by-product as follows: "If a firm is manufacturing or processing two or more commodities from one basic raw material and if one or more of these commodities are considered of less relative importance that the others, the firm is said to be producing under by-product conditions, and the commodity or commodities of less relative importance than the others are termed by-products. However, if the products obtained are of relatively the same value, the firm is said to be operating under joint-product conditions, and the units of production are termed joint products" (p. 270).

Other scholars recognize the "level of importance" related to the sales value and identify the by-products as the outputs with minor sales values compared to joint products or the main product (defined as the only product with a relatively high sales value); in this sphere, scrap has only a minimal sales value (Bhimani et al., 2015; Drury, 1996; Gordon, 1967). The distinction presented is important in accounting for the choice of the cost allocation method adopted. As for costs, all those incurred prior to the split-off point of the JP are joint costs (JCs), while costs incurred for further processing and disposal (if completed) are separable costs since they can be assignable to one or more individual products (Bhimani et al., 2015; Schneider, 1986). Before the split-off point, costs cannot be traced to each JP; instead, at or after the split-off point, costs for each identifiable product could be easily defined and each output could be the object of separate decisions for selling or for further processing (Drury, 1996). In all joint production processes (beyond the relative importance assigned to different products), the attention to the JC setting focuses on the allocation of costs to the JP and the uses of the allocation in output decisions (Biddle & Steinberg, 1984). The allocation of JCs to individual products supports managerial decisions in several contexts. Three main purposes of the literature in this field (Bhimani et al., 2005; Biddle & Steinberg, 1984; Blocker & Welmet, 1954; Drury, 1996; Gordon, 1967; Horngren, 2011) can be discerned:

- Price-setting purposes (calculating the profit-maximizing output levels, the selling prices, the rate or price regulation; defining the cost reimbursement for companies under cost-plus contracts with a government agency);
- Internal reporting purposes (analyzing divisional profitability, evaluating division managers' performance, addressing the stock evaluation);
- Financial accounting and tax reporting purposes (calculating ending inventory values, providing a cost-based analysis of the loss in value in insurance-settlement computations for damage claims related to JPs).

2.2 Cost allocation Methods and Boundaries Issues

The principal problem in accounting for joint products is determining the proportionate share of the total cost of production up to the split-off point that should be allocated to different products originating in the manufacturing process (Blocker & Weltmer, 1954). In addressing the calculation of the full costs of JPs, the cost accounting literature has developed two different approaches that can be used to apportion joint cost up to the split-off point, based on physical measures (weight, volume, etc.) or on the market value of the products (Bhimani et. al, 2015; Blocker & Weltmer, 1954; Drury, 1996; Gordon, 1967; Horngren, 2011; Schneider, 1986). The first approach, or physical measure-based method, allocates the JCs by apportioning the costs in proportion to volume, to weight, to quantity, or to other physical measures of the total production of each product. This method assumes that each output has no relationship to the ability of each product to generate revenues. The second approach can be adopted using three different methods:

- The sales value at the split-off;
- The estimated net realizable value (NRV);
- The constant gross-margin percentage NRV.

Using the sales value at the split-off method, the JCs are allocated in proportion to the estimated sales value of production (at the split-off point) on the assumption that higher selling prices indicate higher costs. The application of this method assumes that all products could sell at the split-off point; if, instead, one or more of the split products are processed beyond this point, a market value may not exist for the product at this stage. In this case, the estimated NRV method is typically preferred to the sales value method. The NRV method allocates the JCs proportionally to the net realizable values (selling prices of the final products minus the expected separable costs of production and marketing of the total production of the period) of the JPs. Applying the NRV method, the gross profit percentages are different for each product. The constant gross-margin percentage NRV method allows the allocation of JCs so that each final output achieves an identical gross-margin percentage. Its calculation requires three discrete steps: 1) compute the overall gross-margin percentage (by deducting the total cost of all products from the total sales of all products and expressing the profit as a percentage of sales); 2) apply the overall gross-margin percentage to the total sales of each product and deduct the result from the total sales of each product to obtain the total costs that each product should bear; 3) deduct the separable costs of each product from the total cost (resulting from step two) to calculate the share of JCs for each final product. This method assumes that the relationship between cost and sales value (for each final output) is uniform.

On a different basis, the cost accounting literature has proposed methods to allocate JCs when one or more of the split products are by-products (Bhimani et. al, 2015; Blocker & Weltmer, 1954; Drury, 1996; Gordon, 1967; Horngren, 2011; Marshall & Drobrowski, 2003). As stated by Drury (1996), "by-products are products that have a minor sales value and that emerge incidentally from the production of major products" (p. 184). Although different variances are proposed in practice, the cost allocation method (called by-product method) consists of crediting a process with the sales value of the by-products either at the time of production or at the time of sale and dividing the residual among the main products. There are two basic methods of accounting for by-products: the production method (the by-product is recognized in the financial statement at the time production is completed) and the sales method (the by-product is recognized at the time of sale). With these two accounting approaches and the basic choice of whether to consider (in the income statement) the by-product revenues as a cost reduction of the main or joint products or as a separate item of revenue (or other income), different versions have been developed, in practice, for valuating by-product inventories on the corporate balance sheet. Considering that "in the joint-cost setting, it is not feasible to use the cause-and-effect criterion to guide individual product-cost allocation" (Bhimani et al., 2015, p. 155), a possible discussion concerning the effects of the application of the earlier methods can be proposed, considering the benefit-received criteria for cost-allocation. The physical measure-based method hypothesizes that a split product has no relationship to its revenue-producing ability: therefore, when using the benefit-received criterion sales-based methods are preferred (Horngren, 2011; Bhimani et al., 2015).

The search for neutral allocations has led other researchers to consider approaches based on economic principles and behavior axioms, in order to find allocation methods able to reflect the "true" relationship between a given indirect cost (JC) and its cost objective (JP). On this matter, Thomas (1969, 1974) argued that the principle of economics could be invoked in defense of an allocation method. The economic approach (Balachandran & Ramakrishnan, 1996) might be traced back to those studies in which the mathematical approach (with linear and nonlinear programming frameworks) and the duality theory for optimal allocation are used (see, Kaplan, 1982; Kaplan & Thomson, 1971; Kaplan & Welam, 1974; Manes, 1982) and to those which present a set of axioms or objectives that allocation methods and models should possess and provide models to achieve these objectives (Jensen, 1977; Louderback, 1976; Moriarity, 1975, 1976). Considering the two different approaches, several scholars later proposed models based on the game theory concept (Balachandran & Ramakrishnan, 1981; Hamlen, Hamlen Jr, & Tschirhart, 1980; Hughes & Scheiner, 1980), on the multiple agent setting, and the principal-agent framework (Balachandran & Ramakrishnan, 1996; Hemmer, 1996; Zimmerman, 1979), to name but a few. Among these models, Balachandran and Ramakrishnan (1981,1996) propose the two-phase model, which combines Moriarity's model (Moriarity, 1975; 1976) and Louderback's model (Louderback, 1976), overcoming the limitations of the two previous ones.

Moreover, in the accounting and economic literature, the activity-based costing (ABC) criteria may be used in allocating overheads to the production process activities (Cooper & Kaplan, 1988; Kaplan & Atkinson, 2015). Several scholars adopt the ABC perspective in order to determine the allocation drivers of JC to JPs (Dixon & Trenchard, 2001; Trenchard & Dixon, 2003; Tsai, 1996; Tsai et al., 2008). In this respect, Bromwich and Hong (1999) highlight significant criticisms about the application of ABC methodology on jointness situation. the authors, indeed, affirm that "Non-jointness is only one condition necessary to allow independent cost functions to be formed for each cost pool." (p. 46).

3. Technical Overview of the Blood Manufacturing Process

Before describing the literature review process, a brief explanation of blood products as joint products is offered here. The blood components are prepared by centrifugation of one unit of whole blood or collected by apheresis procedure from blood donors. By centrifuging whole blood, one unit of red cells, one unit of fresh frozen plasma, and one unit of buffy coat (for platelet production) are obtained. By apheresis, a single component or multiple components are collected directly from the donor, and the rest of the blood components are returned to the donor (Basu & Kulkarni, 2014). With this technique (EU Recommendation No. R (95) 15; WHO, 2002), the most important components that can be collected are: a double unit of red cells, one unit of platelets and one of red cells, one unit of platelets and one of plasma, one unit of red cells and one unit of plasma, or a single unit of plasma). The blood products derived from whole blood collection are JPs because a single input (whole blood) yields three products simultaneously, after the centrifugation process. Each of these products (red cells, fresh frozen plasma, and buffy coat) can be produced by the same process; a chemical and technical formula fixes the proportion (see, for example, Recommendation E.U. R (95)15; WHO, 2002). The split-off point occurs at the end of the centrifugation. Therefore, donor recruitment, blood collection, processing, and (most often) laboratory tests are all steps of the joint production process to obtain JP (Toner et al., 2011). The blood products derived by apheresis procedures are also JPs, because the products (most commonly, two: plasma/platelets, red cells/platelets, or red cells/plasma) are collected from a single donor. The split-off point, in this case, is at the collecting phase and the joint production involves only donor recruitment and the first step of the collecting process. In this process, too, the apheresis collection respects specific proportions between the products (by formula) in compliance with the industry rules and regulations. Both methods aim to provide red cells, plasma, and platelets. Plasma can be either source or recovered; recovered plasma is produced by separating donated whole blood into cellular components and plasma, whereas source plasma is collected through apheresis (Laub, Baurin, Timmerman, Branckaert, & Strengers, 2010). The plasma (both source and recovered) is fractionated by pharmaceutical industries (De Angelis & Breda, 2013) to obtain plasma-derived medicinal products. One unit of platelets is obtained directly by apheresis procedures or is buffy-coat-derived, through a pooling process which works five-to-six buffy coats (Gulliksson, 2012). The techniques used to obtain buffy-coat-derived platelets were developed in the 1990s (Murphy, 2005). After the split-off point, the final processes for each of the blood products are storage and distribution for clinical use (Schotnitzer, 2005). Before being assigned for transfusion, blood products can be adapted or treated according to their intended therapeutic use; examples of subsequent manufacturing process are: leucodepletion irradiation, filtration (Basu & Kulkarni, 2014). The production process for blood components for clinical use follows a two-step process: one associated with the blood component preparation and one connected with transfusion services (Participants of the Charleston, 2005). The manufacturing process – characterized by joint production – is developed in the first step through the following main activities: donor recruitment, whole blood collection or collection by apheresis, blood processing, testing, tracking, blood destruction and associate notifications, inventory management, storage and (if required) transportation to the transfusion site (Participants of the Charleston, 2005; Schotnitzer, 2005). The activities related to transfusion services are linked to inventory management inside hospitals, pre-transfusion preparation, administration, short-term follow-up, and long-term outcome tracking (Participants of the Charleston, 2005). Both direct and indirect cost elements (for example, for personnel, screening, information system, equipment, materials, maintenance), are associated with each of these activities. Focusing the attention on the manufacturing phase, the costs associated with the activities before the split-off point (centrifugation of whole blood to obtain blood products; collection of blood products by apheresis) are JCs, regardless of whether the costs associated with the subsequent processing – including storage and distribution – are separable costs. Therefore, as stated by Cumming et al. (1974), "The costing problem would be confined to one of assigning all costs associated with bringing whole blood to the point of separation to various components produced: these costs are common to all final outputs" (p. 753).

4. Research Method

The following paragraphs discuss the methods used in gathering and analyzing the existing literature. In the accounting and economic research field, there are several different types of reviews (Cooper, 1998; Hopper & Powell, 1985; Webster & Watson, 2002). The present study proposes a descriptive review that is fundamentally concept-centric (Webster & Watson, 2002; p. xvi). Fink (2010) proposed four steps for a systematic review, enriching the structure proposed by Tranfield, Denyer, and Smart (2003). In the first step, the research questions are better defined: "What cost-allocation methods are used in defining blood product costs?" and "What is the understanding of blood products as joint products?"

Subsequently, the keywords "cost of blood", "joint costing of blood", "blood cost-allocation method", "jointness in transfusion" and "cost of production in blood sector", as phrases, were then defined. These keywords were selected in order to narrow the scope of the publications to those contributions strictly related to the JC discourse in the sphere of blood product costs. They were used to select which papers to examine. The databases searched were those provided by major publishers (Elsevier, Emerald, Springer, Witley) and, as suggested by Tranfield et al. (2003), not only bibliographic databases were considered. By including Google Scholar, it was possible to consider other journal publications, conference papers, and scientific reports. Using the search phrases mentioned above, the full text of the documents was extracted. In order to avoid a language bias or a preference for a specific language, only documents written in English were taken into consideration for the examination. The present literature review includes empirical publications as well as conceptual/theoretical publications (Atkinson et al., 1997). Moreover, in order to offer a complete picture of the state-of-the-art in this field, quality criteria (such as journal ranking) were not used for exclusion purposes. Publications which only mentioned the cost of the blood products, without discussing the cost-allocation methods applied, were excluded. In this group, the main research studies were framed in a social perspective or the payer's perspective.

In order to offer a comprehensive overview, the extracted elements of interest are classified into the following categories: context of the study, typology of the research, object of the study, cost-allocation methods. In particular, the context of the study guides the discussion underlining the differences between the blood services setting in different countries and the object of the study shows whether there is a jointness problem. The classification as theoretical studies versus empirical studies makes it possible to distinguish the studies based on frameworks that aim to explain the nature of the relationship between joint costs and cost-allocation methods (theoretical) from the studies that empirically test one cost-allocation method proposed in theoretical studies or studies that examine how blood providers approach joint costing in practice. Table 1 shows the results of the analysis.

Table 1. The analyzed literature on the JC of blood components

References	Context of the study	Typology of the research (on JPs)	Object of the study	Cost-allocation method
Cumming, P. D., Wallace, E. L., Surgenor, D. M., Mierzwa, B. D. & Smith, F. A. (1974). Public interest pricing of blood services. *Medical Care, 12*(9), 743-753.	United States	Theoretical research	Blood components	Red cells/market method Weighted cost-price method Patient unit method
Lowe, A. D. (1997). The role of accounting in the processes of health reform: providing a 'black box' in the costing of blood. *Management Accounting Research*, *8*(4), 439-458.	New Zealand	Empirical research	Blood components	"combination of physical volume measures and an arbitrary split of costs over the four 'main' products: whole blood; red cells; platelets, and plasma"
Dixon, R., & Trenchard, P. M. (2001). Bipolar value-driven joint product costing, *Omega. The international Journal of Management Science, 29*(6), 479-490.	United Kingdom	Theoretical research	Blood components	Quality-associated operations-based drivers, described within the activity-based costing method (ABC), and the net realizable value method (NRV)
Trenchard, P. M., & Dixon, R. (2003). The clinical allocation of joint blood product costs. *Management Accounting Research, 14*(2), 165-176.	United Kingdom	Theoretical research	Blood components	Outcome-driven cost allocations, based on the criterion of usefulness per unit of allocated cost per product
Fragoulakis, V., Stamoulis, K., Grouzi, E., & Maniadakis, N. (2014). The Cost of Blood Collection in Greece: An Economic Analysis. *Clinical Therapeutics, 36*(7), 1028-1036.	Greece	Empirical research	Red cells	Activity-based costing method
Eandi, M., Gandini, G., Povero, M., Zaniolo, O., Pradelli, L., & Aprili, G. (2015). Plasma for fractionation in a public setting: cost analysis from the perspective of the third-party payer. *Blood Transfusion, 13*(1), 37-45.	Italy	Empirical research	Plasma source and recovered	Tariffs method (value market method)
Mafirakureva, N., Nyoni, H., Nkomo, S. Z., Jacob, J. S., Chikwereti, R., Musekiwa, Z., … (2016), The costs of producing a unit of blood in Zimbabwe. *Transfusion, 56*(3), 628-636.	Zimbabwe	Empirical research	Blood components	Activity-based costing method

5. Findings and Discussion

An in-depth analysis of the articles included in the literature review underlines, firstly, that understanding blood product costs is useful for two main purposes or areas of application: (1) in price-setting and in reimbursement of healthcare providers; (2) in supporting public administration to increase efficiency, both in the use of blood resources and in providing health services to patients. Worldwide, in the blood services sector, providers may be public or private organizations that collect, process, and provide blood components (De Angelis & Breda, 2013). The different settings for blood supplying represent the starting point for a proper understanding of the instrumental role played by costing information for decision makers.

Cumming et al. (1974) were among the first to offer insights on blood costs. They developed an analysis of the effects of different cost accounting methods commonly used in pricing policies in the attempt to develop a rational pricing procedure which would maximize public and patient welfare in the U.S., where private blood bankers (both profit and non-profit organizations) supply blood components for transfusion procedures in hospitals. As affirmed by Cumming et al. (1974), in the U.S., blood bankers "must be ready to explain the economics of blood center operations to the public" (p. 743). Starting from the acknowledgement of blood costs as a joint cost issue, they affirmed "there cannot be a unique or "true" cost on which to base blood service prices. Every price, whether or not it is based on cost, is arbitrary and other consideration should enter into the choice of method" (p. 749) Using empirical data, they demonstrated that the most common pricing policy is based on the average cost of all units produced and the price is the same for every transfusable unit. However, these authors recognize that this method will "result in disproportionately large charges to the relatively small group of high volume or long-term users of blood services" (p. 753). In the attempt to offer a more equitable basis for price-setting in this area, they proposed three different cost-allocation methods of joint costs per single unit. The first, the red cells/market method, calculates the price of red cells (and whole blood) by subtracting the total price of the non-red cell products (based on commercial prices) from the expected revenue and then dividing the rest between red cells and whole blood. This method appears to follow the by-product method, where non-red cells are by-products and their value is recognized at the time of sale (thus having a market value). The second, the weighted cost-price method advocated by the American National Red Cross, is based on the existence of an ideal relationship among the prices of various products. This relationship should be reflected in selected weights, used as the basis for cost-allocation. The third, the patient unit method, estimates the number of patients expected to be served by a particular combination of products. The per-patient fee is determined by dividing the forecasted total operating costs by this number. The authors highlight that the red cells/market method provides an economic incentive to use components, the weighted cost-price method leads to higher component prices and does not satisfy the need to make products available at low prices to chronic dependents, while the patient unit methods provides no incentives for efficient use of limited community blood resources.

A similar purpose guides the studies of authors Trenchard and Dixon (2001; 2003) in the UK context, where a cost problem existed (at the time of their research) within the not-for-profit blood products manufacturing sector and was compounded by the legal requirement for cost-based transfer pricing (Trenchard & Dixon, 2003). The need to contribute to this field came in the wake of the introduction of a national blood product pricing policy for England by the National Blood Authority (NBA), a not-for-profit part of the NHS (National Health Service) internal market. In their first work (Dixon & Trenchard, 2001), the authors contributed to the debate surrounding the national cost-based joint blood product pricing policy which was built upon the ABC method and implemented by the NBA in 1999. Starting with the dysfunctional nature of this kind of approach, also discussed in the literature (Bromwich & Hong, 1999), Trenchard and Dixon proposed an optimal joint-cost allocation method based on a combination of quality associated operations-based drivers, used in both the ABC and the NVR methods. In particular, their work "evaluates joint product specification elements in terms of their external quality/benefit at the point of use, rather than their internal financial benefit at the split-off point and point of sale. This reinforces the concept that the benefits provided by products are the ultimate cost drivers and from an ABC-like perspective, REV is regarded as a value-based cost driver" (p. 489). The REV is the "realizable end value": a measurement referred to a value estimation which "must move from the split-off point to the point of product usage where the users will estimate value in terms of the relative importance of the various joint product outcomes" (p. 483). Trenchard and Dixon (2003) propose a second stage of the previous study, starting from the conceptual basis provided by model developed in Balachandran and Ramakrishnan (1981), which combines the advantageous properties of the Moriarity model and the Louderback model. The authors remanded to the two-phase model advocated by Balachandran and Ramakrishnan (1996). In both abovementioned cases, the ABC-like perspective is applied as a cost driver seeking methodology, but neither the former nor the latter strictly use the ABC methods as joint cost allocation method. Within their first study on this topic the authors, indeed, identify the REV as value-based cost driver; while in the second one they develop a combined common/joint cost model based on the product quality, which is proportional to its application usefulness.

In order to offer support in the efficient use of the Blood Centre's resources, Lowe (1997) proposes an application of a conventional costing technique to the costing of blood products. The empirical study (which constitutes a part of his work addressed to examining the role of accounting in health reforms) the apportionment of joint costs (related to collection and testing) are calculated by "using a combination of physical volume measures and an arbitrary split of costs over the four 'main' products: whole blood, red cells, platelets, and plasma. The split was agreed on following discussion between the manager of the blood center and the divisional accountant to reflect the resources expended in processing the primary products to this stage" (p. 448). Lowe (1997) also specified that the equivalent cost per unit of product does not consider the differences in volume.

In the aim of estimating plasma production costs, to allow for comparisons between Italian regions, Eandi et al.

(2015) propose a joint cost-allocation method focused only on plasma, both source and recovered. In their empirical studies focused on the allocation of whole blood costs to recovered plasma, the authors identify a method which adopts the market-value method, recognized in accounting literature (Bhimani et. al, 2015; Drury, 1996; Gordon, 1967). In particular, they stated: "a final commercial value-based criterion was followed for the imputation; each component (RBC, platelets, and plasma) was attributed a share of the joint costs per unit corresponding to the ratio between its total value and the total value of the final products obtained from the unit (...) These proxy values should represent the willingness of the Italian NHS to pay for them (....)" (p. 39). While they followed the same logic, the authors distinguished between the allocation base of red cells and platelets and that of plasma. To allocate costs to red cells and platelets, the inter-regional compensation tariffs (determined by Italian NHS) were used. For plasma, the "final value was taken as the sum of the value of derivatives obtained and of the general tariff for plasma transformation accorded to the industry" (p. 39). It is pointed out that in the Italian NHS, public blood centers carry out all phases of blood product collection from the blood collection to the storage of blood components; instead, plasma fractionation is carried out by authorized manufacturers (Eandi et al., 2015).

In the empirical studies conducted by Fragoulakis et al. (2014) and Mafirakureva et al. (2016) the ABC method is applied in order to calculate blood component costs. Both studies referred to the method recommended by The Cost of Blood: Multidisciplinary Consensus Conference for a Standard Methodology (Participants of the Charleston, 2005). Fragoulakis et al. (2014) developed an in-depth analysis of all cost elements associated with the process flow of blood production, highlighting direct costs and indirect costs (mainly overhead) for each activity. They presented all the parameters needed to allocate indirect costs to blood activities (following the recommendations in Participants of the Charleston, 2005) and assert that "the main parameters that determined the variation in cost among hospitals were the number of staff employed in blood centers, the number of blood units produced, and the percentage of wastage of blood units" (p. 1035). At the end of their work, the authors reported the cost of one unit of whole blood. Thus, it was not possible to track the joint cost-allocation method to each component. In Mafirakureva et al. (2016), instead, the production costs of each component are reported. The authors declared that "The number of components produced for each component category was used to apportion the joint processing costs" (p. 633). It is worth of notice, however, that considering the number of components produced as the cost driver does not appear consistent with the cause and effect criterion in allocating the joint costs to the cost objects (Bhimani et al., 2015; Horngren, 2011). Although the ABC method, based on causality principle (Cooper, Kaplan, Maisel, Morrissey, & Oehm, 1992; Cooper & Kaplan, 1992), may be applied in calculating the amount of joint costs generated before the split-off point, as well as the separable costs beyond the split-off point, it is not feasible to apply the ABC methods in allocating joint costs to the split products.

6. Conclusion

The present paper searches to offer an in-depth review of cost-allocation methods used in different countries for price-setting or for determining the cost-effectiveness of blood products. Almost all of the studies examined consider joint costing issues that arise in determining the cost of production of blood components, derived from whole blood or apheresis procedures. At the same time, even if with different emphasis, accounting and economic scholars have recognized a certain degree of arbitrariness which could occur in defining the costs of split products (Biddle & Steinberg, 1984) wherever there is a joint production process. At the same time, the literature review shows that the cost of blood products or blood price-setting is clearly an issue in the numerous legislative proposals at the national and state levels and represents a matter of public interest and of public regulation. Despite this, the present work highlights that there are only a limited number of studies that examine blood product costs, with a focus on the joint-costing issues. In applying economic models rather than accounting methodology, some scholars have brought to light the problems arising from the continuous search for a neutral method for allocating joint costs in the blood production sector. As pointed out in the introduction of the present work, numerous studies have focused on the bottom line values of blood costs for the health system (see, for example, Surgenor et al., 1973; Toner et al., 2011; Varney & Guest, 2003). Nevertheless, the cost accounting and reimbursement system effectively underlying the acquisition, screening, and transfusion of blood appears, in practice, to be largely obscure. Finally, very little is known about the level of "relative importance" assigned to each product in the costing setting.

This study has taken a broad look at joint costing in blood production sector and the issues emerging in this field. It offers an overview of the current status in the economic and accounting literature, contributing in synthesizing and systematizing the discussion on the cost/price of blood products.

The present study suffers some limitations, typical of literature reviews. By only using the databases provided by major publishers (Elsevier, Emerald, Springer, Wiley) and Google Scholar, this work may not have achieved complete coverage of all empirical articles in the field. Moreover, only phrases and key words quoted in the research method are used in the searching step: not synonyms and related terms are considered. In addition, a complete review of the literature could be hampered by the fact that in the researching and selection of studies, documents not written in English are excluded. Finally, the paper is limited to researches on blood costing and blood pricing. There are potentially studies that investigate similar phenomena, but discuss it with different terms, and thus, were difficult to find.

The results of the literature review developed in various research areas (in accounting, economics, and medical science) offer relevant insights into a multitude of research streams. Investigations in this area are recommended to:

- Develop a conceptual model by using quantitative and qualitative mixed method in order to obtain less arbitrary results;
- Investigate the relationships between a national system of healthcare services and the cost-allocation methods used to determine the cost/price of blood components;
- Examine the effect of public regulation on blood costs;
- Evaluate the opportuneness of a neutral method that considers the benefit-value to patients.

Moreover, the proposed researches could offer relevant insights in identifying a cost-allocation method that may be used to determine the cost of plasma-derived medicinal products borne by pharmaceutical companies and the price-setting (cost-based) applied to users. In this further research field, the multiple spit-off points beyond the plasma-derived production must be considered (Burnouf, 2007): the first split-off point in the raw material production (plasma) discussed in the present study and other split-off points in the manufacturing process of plasma-derived products.

References

Abraham, I., & Sun, D. (2012). The cost of blood transfusion in Western Europe as estimated from six studies. *Transfusion, 52*, 1983-1988. https://doi.org/10.1111/j.1537-2995.2011.03532.x

Atkinson, A. A., Balakrishnan, R., Booth, P., Cote, J. M., Groot, T., Malmi, T., Roberts, H., Uliana, E., & Wu, A. (1997). New directions in management accounting research. *Journal of Management Accounting Research, 9*, 79-108. https://doi.org/10.1016/0305-0483(77)90100-1

Balachandran, B. V., & Ramakrishnan, R. T. (1981). Joint cost allocation: a unified approach. *Accounting Review*, 85-96. http://www.jstor.org/stable/246464

Balachandran, B.V., & Ramakrishnan, R.T.S. (1996). Joint cost allocation for multiple lots. *Management Science, 42*(2), 247-258. https://doi.org/10.1287/mnsc.42.2.247

Basu, D., & Kulkarni, R. (2014). Overview of blood components and their preparation. *Indian journal of anaesthesia, 58*(5), 529-537. https://doi.org/10.4103/0019-5049.144647

Bhimani, A., Horngren, C. T., Datar, S. M., & Rajan, M. (2015). *Management and Cost Accounting*. Edinburgh: Pearson.

Biddle, G. C., & Steinberg, R. (1984). Allocations of Joint and Common Costs. *Journal of Accounting Literature, 3*. Retrieved from https://ssrn.com/abstract=1797371

Blocker, J. G., & Weltmer, W. K. (1954). *Cost accounting*. New York: Mcgraw-Hill.

Bromwich, M., & Hong, C. (1999). Activity-based costing systems and incremental costs. *Management accounting research, 10*(1), 39-60. https://doi.org/10.1006/mare.1998.0102

Burnouf, T. (2007). Modern Plasma Fractionation. *Transfusion Medicine Reviews*, *21*(2), 101-117. https://doi.org/10.1016/j.tmrv.2006.11.001

Cooper, H. M. (1998). *Synthesizing research: A guide for literature reviews* (Vol. 2). Sage.

Cooper, R., & Kaplan, R. S. (1992). Activity-based systems: Measuring the costs of resource usage. *Accounting Horizons, 6*(3), 1-19.

Cooper, R., Kaplan, R. S., Maisel, L. S., Morrissey, E., & Oehm, R . M. (1992). *Implementing Activity - Based Cost Management: Moving from Analysis to Action*. Montvale: Institute of Management Accountants

Cumming, P. D., Wallace, E. L., Surgenor, D. M., Mierzwa, B. D. & Smith, F. A. (1974). Public interest pricing of blood services. *Medical Care, 12*(9), 743-753.

Custer, B., Agapova, M., & Martinez, R. H. (2010). The cost-effectiveness of pathogen reduction technology as assessed using a multiple risk reduction model. *Transfusion, 50*, 2461-2473. https://doi.org/10.1111/j.1537-2995.2010.02704.x

De Angelis, V., & Breda, A. (2013). Plasma-derived medicinal products self-sufficiency from national plasma: to what extent? *Blood Transfusion, 11*(Suppl 4), s132-s137. http://dx.doi.org/10.2450/2013.019s

Dixon, R., & Trenchard, P. M. (2001). Bipolar value-driven joint product costing, *Omega. The international Journal of Management Science, 29*(6), 479-490. https://doi.org/10.1016/S0305-0483(01)00038-X

Drury, C. (1996). *Management and cost accounting* (4 th ed.). London: Thomson Business Press.

Eandi, M., Gandini, G., Povero, M., Zaniolo, O., Pradelli, L., & Aprili, G. (2015). Plasma for fractionation in a public setting: cost analysis from the perspective of the third-party payer. *Blood Transfusion, 13*(1), 37-45. https://doi.org/10.2450/2014.0066-14

Fink, A. (2013). *Conducting research literature reviews: From the Internet to paper*. Sage Publications.

Forbes, J. M., Anderson, M. D., Anderson, G. F., Bleecker, G. C., Rossi, E. C., & Moss, G. S. (1991). Blood transfusion costs: a multicenter study. *Transfusion, 31,* 318-323. http://dx.doi.org/10.1046/j.1537-2995.1991.31491213295.x

Fragoulakis, V., Stamoulis, K., Grouzi, E., & Maniadakis, N. (2014). The Cost of Blood Collection in Greece: An Economic Analysis. *Clinical Therapeutics, 36*(7), 1028-1036. https://doi.org/10.1016/j.clinthera.2014.05.003

Glenngård, A. H., Persson, U., & Söderman, C. (2005). Costs associated with blood transfusions in Sweden – the societal cost of autologous, allogeneic and perioperative RBC transfusion. *Transfusion Medicine, 15*, 295-306. https://doi.org/10.1111/j.0958-7578.2005.00591.x

Gordon, S. (1967). *Cost accounting. analysis and control*, 2 ed., Irwin: Homewood.

Gulliksson, H. (2012). Platelets from platelet-rich-plasma versus buffy-coat-derived platelets: what is the difference?. *Revista brasileira de hematologia e hemoterapia, 34*(2), 76-76. https://doi.org/10.5581/1516-8484.20120024

Hamlen, S. S., Hamlen Jr, W. A., & Tschirhart, J. (1980). The use of the generalized Shapley allocation in joint cost allocation. *Accounting Review*, 269-287. http://www.jstor.org/stable/246344

Hemmer, T., (1996). Allocations of sunk capacity costs and joint costs in a linear principal-agent model. *The Accounting Review, 71*(3), 419-432. http://www.jstor.org/stable/248296

Hopper, T., & Powell, A. (1985). Making sense of research into the organizational and social aspects of management accounting: A review of its underlying assumptions [1]. *Journal of management Studies, 22*(5), 429-465. https://doi.org/10.1111/j.1467-6486.1985.tb00007.x

Horngren, C. T. (2011). *Cost accounting: a managerial emphasis*, 14th edition (hardcover), Prentice-Hall International Editions, Englewood Cliffs N.J.

Hughes, J. S., & Scheiner, J. H. (1980). Efficiency properties of mutually satisfactory cost allocations. *Accounting Review*, 85-95. http://www.jstor.org/stable/246173

Jensen, D. L. (1977). A class of mutually satisfactory allocations. *Accounting Review,* 842-856. http://www.jstor.org/stable/245583

Kaplan, R. (1982). *Advanced Management Accounting*. Englewood Cliffs, NJ: Prentice-Hall.

Kaplan, R. S., & Atkinson, A. A. (2015). Advanced management accounting. PHI Learning.

Kaplan, R. S., & Thompson, G. L. (1971). Overhead allocation via mathematical programming models. *The Accounting Review, 46*(2), 352-364. http://www.jstor.org/stable/244343

Kaplan, R. S., & Welam, U. P. (1974). Overhead allocation with imperfect markets and nonlinear technology. *The Accounting Review, 49*(3), 477-484. http://www.jstor.org/stable/244608

Laub, R., Baurin, S., Timmerman, D., Branckaert, T., & Strengers, P. (2010). Specific protein content of pools of plasma for fractionation from different sources: impact of frequency of donations. *Vox sanguinis, 99*(3), 220-231. https://doi.org/10.1111/j.1423-0410.2010.01345.x

Louderback, J. G. (1976). Another approach to allocating joint costs: A comment. *The Accounting Review, 51*(3), 683-685. http://www.jstor.org/stable/245485

Lowe, A. D. (1997). The role of accounting in the processes of health reform: providing a 'black box' in the costing of blood. *Management Accounting Research*, *8*(4), 439-458. https://doi.org/10.1006/mare.1996.0054

Mafirakureva, N., Nyoni, H., Nkomo, S. Z., Jacob, J. S., Chikwereti, R., & Musekiwa, Z. (2016). The costs of producing a unit of blood in Zimbabwe. Transfusion, 56(3), 628-636. https://doi.org/10.1111/trf.13405

Manes, E. G. (1982). A class of fuzzy theories. *Journal of Mathematical Analysis and Applications, 85*(2), 409-451. https://doi.org/10.1016/0022-247X(82)90010-5

Marshall, P. D., & Dombrowski, R. F. (2003). A small business review of accounting for primary products, byproducts and scrap. *National Public Accountant*, 10-13.

Moriarity, S. (1975). Another approach to allocating joint costs. *The Accounting Review, 50*(4), 791-795. Retrieved from http://www.jstor.org/stable/245242

Moriarity, S. (1976). Another Approach to Allocating Joint Costs: A Reply. *The Accounting Review, 51*(3), 686-687. http://www.jstor.org/stable/245486

Murphy, S. (2005). Platelets from pooled buffy coats: an update. *Transfusion, 45*(4), 634-639. https://doi.org/10.1111/j.0041-1132.2005.04467.x

Participants of the Charleston. (2003). The Cost of Blood: Multidisciplinary Consensus Conference for a Standard Methodology, *Transfusion Medicine Reviews, 19*(1), 66-78, https://doi.org/10.1016/j.tmrv.2004.09.005.

Schneider, A. (1986). Simultaneous Determination of Cost Allocations and Cost-Plus Prices For Joint Products. *Journal of Business Finance & Accounting, 13*, 187-195. https://doi.org/10.1111/j.1468-5957.1986.tb00089.x

Schönitzer, D. (2005). Overview of Transfusion Medicine in Europe: general data on blood organisations and activities. *Blood Transfusion, 3*, 240-247.

Shander, A., Hofmann, A., Ozawa, S., Theusinger, O. M., Gombotz, H. & Spahn, D. R. (2010). Activity-based costs of blood transfusions in surgical patients at four hospitals. *Transfusion, 50*, 753-765. https://doi.org/10.1111/j.1537-2995.2009.02518.x

Sullivan, M. T., & Wallace, E. L. (2005). Blood collection and transfusion in the United States in 1999. *Transfusion, 45,* 141-148. https://doi.org/10.1111/j.1537-2995.2004.03288.x

Surgenor, D. M., Wallace, E. L., Cumming, P. D., Mierzwa, B. D., & Smith, F. A. (1973). Blood services: prices and public policy. *Science, 180*(4084), 384-389. https://doi.org/10.1126/science.180.4084.384

Thomas, A. L. (1969). The allocation problem in financial accounting theory. In: Studies in Accounting Research, vol. 3. American Accounting Association, Sarasota, FL, 1-122

Thomas, A. L. (1974). The allocation problem: part two. In: Studies in Accounting Research, vol. 9. American Accounting Association, Sarasota, FL, 1-194.

Toner, R. W., Pizzi, L., Leas, B., Ballas, S. K., Quigley, A., & Goldfarb, N. I. (2011). Costs to hospitals of acquiring and processing blood in the US: a survey of hospital-based blood banks and transfusion services. *Applied Health Economics and Health Policy, 9*(1), 29-37. https://doi.org/10.2165/11530740-000000000-00000

Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing evidence‐informed management knowledge by means of systematic review. *British journal of management*, *14*(3), 207-222. https://doi.org/10.1111/1467-8551.00375

Trenchard, P. M., & Dixon, R. (2003). The clinical allocation of joint blood product costs. *Management Accounting Research, 14*(2), 165-176. https://doi.org/10.1016/S1044-5005(03)00021-0

Tsai, W. H. (1996). Activity-based costing model for joint products. *Computers & Industrial Engineering, 31*(3-4), 725-729. https://doi.org/10.1016/S0360-8352(96)00246-X

Tsai, W. H., Lai, C. W., Tseng, L. J., & Chou, W. C. (2008). Embedding management discretionary power into an ABC model for a joint products mix decision. *International Journal of Production Economics, 115*(1), 210-220. https://doi.org/10.1016/j.ijpe.2008.05.013.

Varney, S. J., & Guest, J. F. (2003). The annual cost of blood transfusion in the UK. *Transfusion Medicine, 13*, 205-218. https://doi.org/10.1046/j.1365-3148.2003.00443.x

Webster, J., & Watson, R. (2002). Analyzing the Past to Prepare for the Future: Writing a Literature Review. *MIS Quarterly, 26*(2), Xiii-Xxiii. http://www.jstor.org/stable/4132319

World Health Organization [WHO] (2016). *Blood safety and availability*. http://www.who.int/mediacentre/factsheets/fs279/en/

World Health Organization [WHO], Blood Transfusion Safety (2002). *The Clinical Use of Blood. Handbook*. http://www.who.int/bloodsafety/clinical_use/en/Handbook_EN.pdf

Zimmerman, J. (1979). 1978 Competitive Manuscript Award: The Costs and Benefits of Cost Allocations. *The Accounting Review, 54*(3), 504-521. http://www.jstor.org/stable/245977