Qualitative and temporal aggregation

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Abstract

Behavioral assumptions, rational or otherwise, are not solid enough to be eligible as first principles of theoretical economics. Hence all endeavors to lay the formal foundation on a new site and at a deeper level actually need no further vindication. The present paper suggests three non-behavioral axioms as groundwork and applies them to the analysis of qualitative and temporal aggregation in the pure consumption economy. It turns out that the structural axiom set is self-similar with regard to the differentiation of the household- and business sector as well as to the sequencing of time.

JEL D50, E10

Keywords New framework of concepts, Structure-centric, Axiom set, General equilibrium, Supersymmetry

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Each theory starts from a small set of foundational 'hypotheses or axioms or postulates or assumptions or even principles' (Schumpeter, 1994, p. 15). General equilibrium theory rests on a set of *behavioral* axioms (Arrow and Hahn, 1991, p. v). The standard set of behavioral axioms is in the present paper at first replaced by *structural* axioms. These are subsequently applied to the question of how qualitative and temporal aggregation can be consistently achieved for the pure consumption economy.

By choosing objective structural relationships as axioms behavioral hypotheses are not ruled out. On the contrary, the structural axiom set is open to *any* behavioral assumption and not restricted to the standard optimization calculus.

The case for structural axiomatization has been made at length elsewhere (2011a, 2011c, 2011d). With the basic understanding that an alternative formal foundation is reasonable as well as desirable the minimalistic structural frame that constitutes the pure consumption economy is set up in section 1. In section 2 the exemplary mapping of a differentiated microeconomic state onto the structural axiom set is carried out geometrically. The difference between the notion of a behavioral equilibrium and the notion of structural supersymmetry is discussed in section 3 and some good reasons are provided as to why the latter is preferable. In section 4 the exemplary mapping of a differentiated period sequence onto the structural axiom set is carried out geometrically. Section 5 concludes.

1 Axioms and definitions

The first three structural axioms relate to income, production, and expenditures in a period of arbitrary length. For the beginning the period length is assumed to be the calendar year. Simplicity demands that we have at first one world economy, one firm, and one product.

Total income of the household sector Y is the sum of wage income, i.e. the product of wage rate W and working hours L, and distributed profit, i.e. the product of dividend D and the number of shares N.

$$Y = WL + DN \quad |t \tag{1}$$

Output of the business sector O is the product of productivity R and working hours.

$$O = RL \quad |t \tag{2}$$

Consumption expenditures C of the household sector is the product of price P and quantity bought X.

$$C = PX \quad |t \tag{3}$$

The axioms represent the pure consumption economy, that is, no investment expenditures, no foreign trade, and no taxes or any other government activity.

The sales ratio is added for formal convenience as:

$$\rho_X \equiv \frac{X}{O} \quad |t \tag{4}$$

The expenditure ratio is defined as:

$$\rho_E \equiv \frac{C}{Y} \quad |t \tag{5}$$

As a point of departure one quite naturally takes the simplest case, i.e. market clearing $\rho_X = 1$ and budget balancing $\rho_E = 1$. It is of utmost importance, though, not to become fixated on this configuration and thereby confine the analysis to a case of practical impossibility. This fixation has rightly been criticized:

> But there is something scandalous in the spectacle of so many people refining the analysis of economic states which they give no reason to suppose will ever, or have ever, come about. (Hahn, 1984, p. 88)

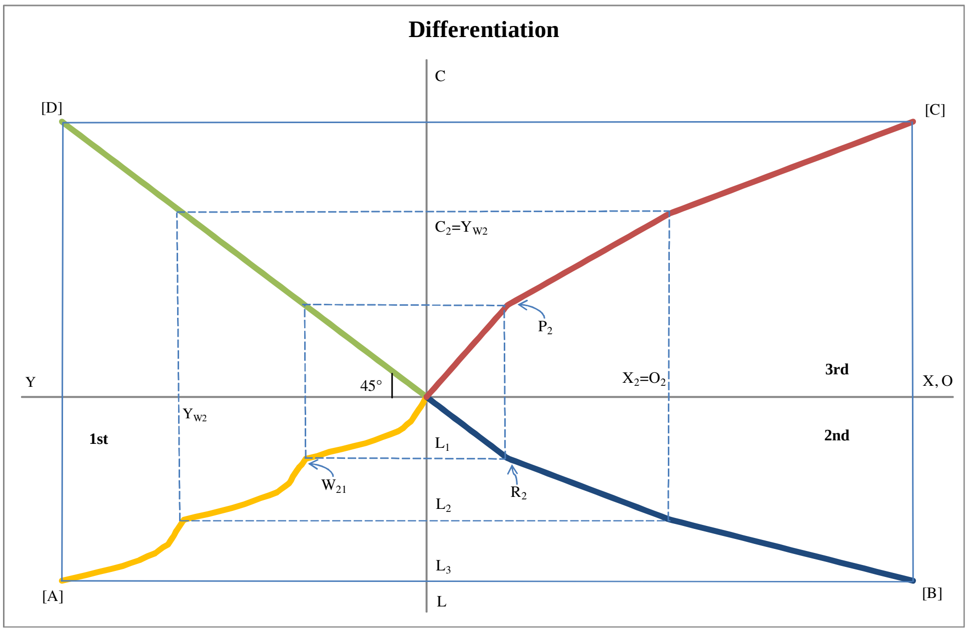
2 Qualitative aggregation

The axiom set refers to one single firm. Since the economy is composed of an indefinite number of firms differentiation is one of the first tasks. It is carried out geometrically in Figure 1a (for formal details see 2011d, pp. 20-21).

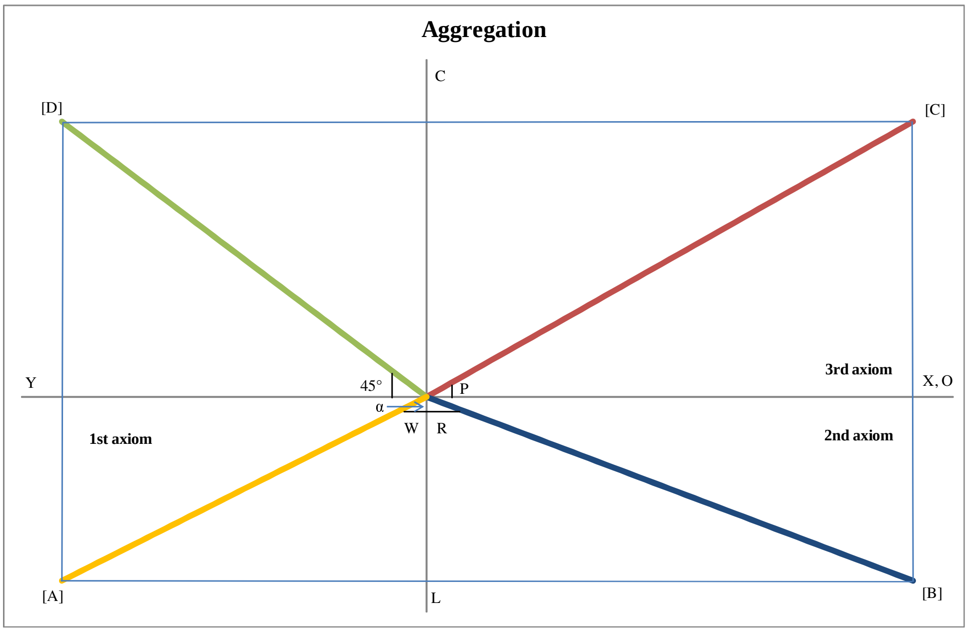
The diagram looks like the familiar Cartesian coordinates. It is, though, composed of the first quadrants of four distinct coordinate systems because there is no use for negative values. Thus, the four axes represent the positive values of the variables employment L, total income Y, consumption expenditures C, output O, and quantity bought X respectively. Accordingly the quadrants are not numbered clockwise from I to IV as usual but corresponding to the axioms they accommodate counterclockwise from 1 to 3. The bisecting line in the northwestern quadrant facilitates the comparison of the magnitudes of income and consumption expenditures.

The business sector is, in the 1st quadrant, split up into three firms with equal shares of the total working hours L. The number of firms and the distribution of the working hours L_1, L_2, L_3 between them is arbitrary. The different individual wage rates *within* each firm are given by the tangents to the income curve and they are here ordered from the lowest to the highest. The wage incomes Y_{W1}, Y_{W2}, Y_{W3} include the remuneration of all managers and executives of the respective firm. For the sake of simplicity the wage structure is assumed to be identical in all three firms. The individual incomes of the employees are cumulated and sum up to total period income Y. Distributed profits are set to zero for the time being.

The productivities that are given by the slopes of each line segment in the 2nd quadrant are different for each firm. Labor inputs and productivities yield the period outputs O_1, O_2, O_3 as shown on the horizontal axis. The outputs are qualitatively different. The magnitude of the different productivities and outputs depends on the unit of measurement, e.g. ounce, liter, piece, square meter, carat, and so on.



(a) Three firms produce and sell three diverse consumption goods under the condition of overall market clearing and budget balancing



(b) The identical mapping of the coordinates [A], [B], [C], [D], and the origin from Figure 1a to 1b amounts to the aggregation of the detailed structure of the business- and the household sector and yields the graphical representation of the axiom set

Figure 1

The 3rd quadrant depicts the price–quantity configurations for each product and the cumulated shares of total consumption expenditures. The prices are represented by the slopes of the respective line segments. The quantities bought from each firm are equal to the quantities produced.

The juxtaposition in the quadrant with the 45° line shows that consumption expenditures are here exactly equal to labor cost for each firm. By consequence there is neither profit nor loss.

The business sector's financial profit Q_{fi} in period t is defined with (6) as the difference between the sales revenues – for the economy as a whole identical with consumption expenditures C – and costs – here identical with wage income Y_W:

$$Q_{fi} \equiv C - Y_W \equiv PX - WL \quad \Leftarrow \quad Y_W \equiv WL \quad |t \tag{6}$$

This gives for firm$_1$ and analogous for the other firms:

$$Q_{fi1} \equiv C_1 - Y_{W1} \equiv P_1X_1 - W_1L_1 \quad \Leftarrow \quad Y_{W1} \equiv W_1L_1 \quad |t \tag{7}$$

The profits in Figure 1a are zero by construction. Therefore we have neither profits nor distributed profits for the time being.

The coordinates of point [A], [B], [C], [D] in Figure 1a and the origin are now mapped to Figure 1b. The rest is left behind. The straight lines that now connect the origin with the four identical coordinate points represent the axiom set. The mapping therefore amounts to the aggregation of the business sector and the household sector respectively. Aggregation leads formally back to the sole firm that has been the axiomatic point of departure.

The mapping that has been exemplarily carried out in Figure 1 can be generalized for an arbitrary number of firms and agents. For the economy as a whole one has $X{=}O$ and $C{=}Y$ or, what amounts to the same, $\rho_X{=}1$ and $\rho_E{=}1$, i.e. the product market is cleared and the household sector's budget is balanced. This configuration is referred to as supersymmetric outcome in the product market. Supersymmetry is a purely structural property and means not a whit more than that the household sector's consumption expenditure are exactly equal to the period income and the business sector's period output is exactly equal to the quantity bought by the household sector. This market outcome configuration is outstanding among all other possible market outcomes. Supersymmetry is fundamentally different from equilibrium as it does not refer to human behavior (see section 3).

What exactly does the mapping formally entail? The geometrical transformation of the kinked lines in Figure 1a to the straight lines in Figure 1b amounts to the calculation of the respective weighted averages. Thus the wage rate in the 1st quadrant, which is equal to the tangent function of the angle α, is given by:

$$W \equiv \frac{1}{L}\left(W_1L_1 + W_2L_2 + W_3L_3\right) \quad |t \tag{8}$$

W_1 is in turn the average wage rate of firm$_1$ and likewise for the other firms.

The productivity in the 2nd quadrant is given by:

$$R \equiv \frac{1}{L}\left(R_1L_1 + R_2L_2 + R_3L_3\right) \quad |t \tag{9}$$

The productivity R is a composite of productivities with diverse dimensions and it is not clear from the outset whether this average, which is geometrically at any time feasible, is economically meaningful.

Finally, the price in the 3rd quadrant is given by:

$$P \equiv \frac{1}{X}\left(P_1X_1 + P_2X_2 + P_3X_3\right) \quad |t \tag{10}$$

The composite quantity X is made up of quantities with quite different dimensions, e.g. number of cars, liters of milk, and square meters of carpet:

$$X \equiv X_1 + X_2 + X_3 \quad |t \tag{11}$$

Recalling the saying that it makes no sense to count together apples and oranges the first thing to consider is that it is by no means self-evident that apples can be counted together in the first place:

> ... from a strict utilitarian point of view, there is no such thing as a generic commodity. To every individual qua individual, each apple is different ... the self-identity of the commodity, which is the necessary prerequisite of its basis as a cardinal number, is not at all psychologically present. (Mirowski, 1986, p. 205)

That apples may be counted together requires an abstraction with a more or less arbitrary bundling of physical characteristics. Thus, when we are not interested in apples and oranges as such but only in the category fruit there is no objection against lumping together a kilo of each and carrying home two kilos of fruit. In the same manner we can intelligibly speak of a zoo that is inhabited by nine mammals counting together four elephants, three dolphins and two bumblebee bats. Hence, when we introduce the abstract term *unit of output* we can sum up the heterogeneous specific units of X_1, X_2, and X_3. This abstraction makes it possible to calculate the price P of Figure 1b as a correspondence of the prices of Figure 1a. Care has to be taken, however, of what this operation entails.

In Figure 2 the line segment (X_1) is the result of a straightforward addition of output quantities with diverse dimensions as in (11). Let us assume now that an abstract unit of output has been defined as a unique measuring rod and that all output quantities are expressed in this new standard unit. Measured in this unit the composite output is now (X_2). In real terms nothing changes. The change in the unit of measurement, though, affects both productivity and price. The price goes up and the productivity goes down compared to the initial situation. The salient point, though, is that the these variations are geometrically related as follows:

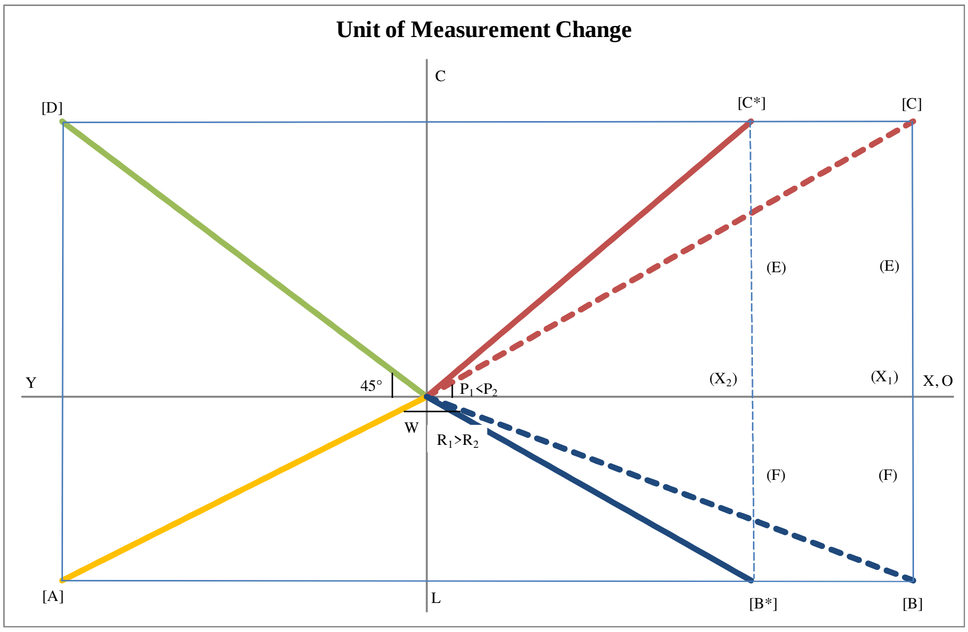


Figure 2: The product of price and productivity is invariant to changes of the unit of measurement

$$
\begin{aligned}
P_1 &= \frac{(E)}{(X_1)} \quad R_1 = \frac{(X_1)}{(F)} \quad \Rightarrow \quad P_1R_1 = \frac{(E)}{(F)} \\
P_2 &= \frac{(E)}{(X_2)} \quad R_2 = \frac{(X_2)}{(F)} \quad \Rightarrow \quad P_2R_2 = \frac{(E)}{(F)}
\end{aligned}
\tag{12}
$$

Changes of the unit of measurement do not affect the *product* of price and productivity. The variable that gives rise to the question of proper measurement simply cancels out. Whenever both variables are used in conjunction it is of no import whether we add up heterogeneous or standardized output dimensions. As it happens this is mostly the case. As an example (7) can be rewritten as:

$$Q_{fi1} \equiv P_1X_1 - W_1L_1 \equiv P_1R_1L_1\left(1 - \frac{W_1}{P_1R_1}\right) \quad \text{if} \quad \rho_{X1} = 1 \quad |t \tag{13}$$

The profit of firm_1 in no way depends on the measurement of output units, despite the fact that both productivity and price vary with the chosen dimension of output. The crucial determinant of profit is the factor cost ratio $\rho_F{=}W/PR$ which is unit-free, i.e. a rational number. For each firm the factor cost ratio is unity, given the conditions enumerated in the foregoing. For the economy as a whole as given by the axioms the factor cost ratio is unity, too.

In sum: qualitative aggregation entails that for any microeconomic state in period t there exists a correspondence that is formally represented by the first three axioms.

3 Behavioral equilibrium as a limiting case

Equilibrium is the pivotal conception in standard economics. It means, though, quite different things to different people. Weintraub (1991, p. 99-112) explored its varying images and definitions as an instant of a Wittgensteinian language game.[1] Equilibrium may be regarded as a formal construct or a feature of the real world. The realists's critique of the mathematical conception is mostly in the spirit, if not always in the strong words, of Clower:

> An intellectually respectable answer should consist of something more than tired clichés; observable economic events derive ultimately not from unspecified coordinating mechanisms, whether invisible hands, price systems, or neowalrasian "auctioneers", but ... from definable actions of real people. (Clower, 1994, p. 806), see also (Chick and Dow, 2001)

The notion of equilibrium invokes a plethora of images: center of gravitation, natural state of rest, balance of opposing forces, best-of-all-worlds, mutual compatibility of individual plans, end of exchanges and readjustments, solution of a model, fixed point, attractor, entropy maximum, and, yes, justice[2] (Freeman, 2007). The crucial point, though, is the identification of equilibrium with reality:

> The partition of the nonnegative price-quantity space into equilibrium and disequilibrium points fosters a separation of interest, for nothing can really be said about most of the possible price–quantity configurations whatsoever, except that those pairs will not ever be wanted, desired, or observed. They stand outside analysis, outside economics, outside language. Equilibrium is real, for it is potentially observable. (Weintraub, 1991, p. 144)[3] [4]

[1] "The currently prevailing pattern of economic theorizing exhibits the following three characteristics: (1) a syncopated style of argument fluctuating back and forth between literary and symbolic modes of expression, (2) naive translation, or the loose paraphrasing of formulae into sentences, and (3) loose verbal reasoning for certain aspects of theoretical argumentation where explicit symbolic formulation is lacking." (Dennis, 1982, p. 698)

[2] "Commodities exchange ... in proportion to the quantities of labour which have been expended to produce them: this is the law of value which Ricardo formulated, a law of equilibrium and justice." (Halévy, 1960, p. 343)

[3] "So far as this limited sense of equilibrium is concerned it is true that we assume the economic system to be always in equilibrium. Nor is it unreasonable to do so. There is a sense in which current supplies and current demands are always equated in competitive conditions. Stocks may indeed be left in the shops unsold; but they are unsold because people prefer to take the chance of being able to sell them at a future date rather than cut prices in order to sell them now. ... In this (analytically important) sense the economic system. ... can be taken to be always in equilibrium." (Hicks, 1939, p. 131)

[4] "The second possibility is *to define* equilibrium in such a way that it is always present. Of course it is possible to do this; any outcome can be considered an equilibrium in the sense that agents do what they do instead of doing something else. But such a treatment does not get us very far; the study of what happens when the optimizing plans of different agents are not compatible simply gets renamed as a study of moving equilibria rather than of disequilibrium." (Fisher, 1983, p. 7), original emphasis

It deserves mention that no equilibrium has ever been observed. The comparison with the classical view provides a paradigmatic instance of the fact that formal progress is perfectly reconcilable with conceptual regress (Woo, 1986, pp. 79-96), (McCloskey, 1994, 133-145). The classical stance was distinctly evolutionary:

> One of the conditions oftenest dropped, when what would otherwise be a true proposition is employed as a premise for proving others, is the condition of time. It is a principle of political economy that prices, profits, wages &c. "always find their level;" but this is often interpreted as if it meant that they are always, or generally, *at* their level; while the truth is, as Coleridge epigrammatically expresses it, that they are always *finding* their level, "which might be taken as a paraphrase or ironical definition of a storm." (Mill, 2006, p. 807), original emphasis

Walras, to be sure, held roughly the same view with regard to general equilibrium:

> Walras was aware that economic equilibrium does not occur in reality and that in the latter the conditions of his model are insufficiently satisfied . . . . His proof of existence – at least the attempt to do so – is purely mathematical, namely, of a unique solution of his system of equations. (Klant, 1988, p. 93)

Equilibrium made its appearance in economics only in the mid-nineteenth century and has undergone extensive revisions in the twentieth century. In this process standard economics 'has lost any claim to having a unique and determinate notion of equilibrium' (Mirowski, 1981, p. 606). In sum: there is a conspicuous lack of good reasons for taking equilibrium as the 'central organizing idea' (Hahn) of theoretical economics.[5] To the contrary:

> It is erroneous to posit some equilibrium position – as if it were transcendental, self-subsistent, and commanding – and then consider certain phenomena as disturbances or deviations from it. (Samuels, 1997, p. 78)

The structural axiomatic approach is different from any partial or general equilibrium approach as it does neither refer to human behavior nor to imaginary market forces that move the economy toward a distinct state either simultaneously or in the undefined long run.

This all said, it is now assumed that, given their preferences, all agents are in their Pareto-optimal position with regard to the structure of wage rates and prices in Figure 1a. This marginalistic behavioral equilibrium has the following properties: overall market clearing, i.e. $\rho_X=1$, budget balancing, i.e. $\rho_E=1$, and zero profit in each firm.

[5] "The doctrine that there is as much science in a subject as there is mathematics in it, . . . , rests on a complete misunderstanding." (Popper 1983, quoted in Redman, 1993, p. 105)

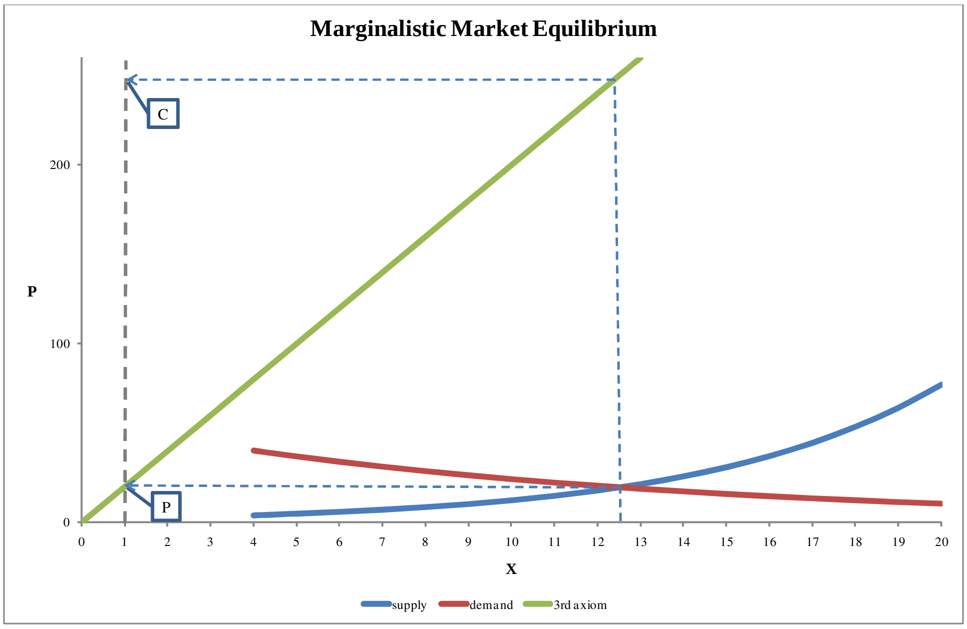


Figure 3: Relation between the demand–supply schedules and the 3rd axiom

The coordinates of the points [A], [B], [C], [D] in Figure 1b are identical with those in Figure 1a. This implies that the complex conditions of the marginalistic behavioral equilibrium can be mapped onto the geometrical representation of the first three axioms. There is a loss of detailed information but this is not necessarily a disadvantage because for many theoretical questions theses details are not of interest. In these cases the detailed structure of the marginalistic behavioral equilibrium is implicitly present in the structural axiom set and remains in the background. The geometric relation between the familiar demand–supply schedules of the product market and the 3rd axiom is visualized in detail in Figure 3.

The correspondence holds also when the agents are *not* in their marginalistic behavioral equilibrium given their preferences and the structure of wage rates and prices. *All* microeconomic states can be mapped onto the first three axioms. This has important consequences for the relation between the structure-centric axiomatic analysis and the behavior-centric standard analysis. The pairing of structural supersymmetry and marginalistic behavioral equilibrium demonstrates that the former is an objective conception that does not exclude the latter but, by the same token, is by no means restricted to it. Seen from the structural axiomatic perspective a marginalistic general equilibrium is a limiting case. Aggregation amounts to a surjection of the microeconomic details onto the axiom set that is perfectly neutral with regard behavioral assumptions which purportedly explain how the microeconomic state came to pass. This mapping is always feasible regardless of whether the explanation of the microeconomic state is true or false.

Now, marginalistic behavioral equilibrium comes in two temporal forms. Simultaneity is the standard form and it plainly has no counterpart in reality. However, simultaneous behavioral equilibrium may be reinterpreted as an one-period equilibrium with a conveniently chosen period length. The second temporal form has been originally developed by Hicks:

> By using the week, we become able to treat a process of change as consisting of a series of temporary equilibria; this enables us still to use equilibrium analysis in the dynamic field. (Hicks, 1939, p. 127)

Hicks's conception has a family resemblance with the structural axiomatic period analysis. It is clearly but one possible interpretation of general equilibrium and not the most popular anyway. The fundamental crux of any interpretation is, of course, the incongruity of the notion of simultaneity and the notion of a finite period length, that is, the conceptualization of time:

> The notion of time is so primitive and basic an element in man's experience that its neglect by much economic theory constitutes an incredible puzzle. This puzzle is attributable, perhaps, to the almost irresistible lure of formalism – particularly one that cannot adequately handle time. (Rizzo, 1979, p. 1)

4 Temporal aggregation

Aggregation is also about the formal relations between the values of the variables of the axiom set over an arbitrary number of periods and the resulting values for all periods taken together. Just in the same manner as in section 2 the differentiated geometrical representation of a given number of periods – instead of a given number of firms – can be mapped onto the elementary geometrical representation of the axioms that relate now to a longer period. Figure 4 shows the development over three periods (again without distributed profits).

The slopes of the respective line segments in the quadrants 1 to 3 represent the wage rate *W*, productivity *R* and price *P* for each period. In the first – innermost – period consumption expenditures *C* are greater than total income *Y* and the quantity bought *X* is greater than output *O*, i.e. the household and the business sector draw on existing stocks of money and products which have been here left out of the picture (for details see 2011b). Asymmetry prevails, just as in the real world. The differences of the flow magnitudes are represented by the line segments between the arrows on the horizontal and vertical axis. In period$_2$ total income exceeds consumption expenditures and output is greater than the quantity bought. In period$_3$ consumption expenditures are again greater than income but output and quantity bought are equal, i.e. $\rho_X=1$ and $\rho_E\neq 1$.

The coordinates of the points [A], [B], [C], [D] are the endpoints of the development over three periods. Since for each period the new origin is given by the

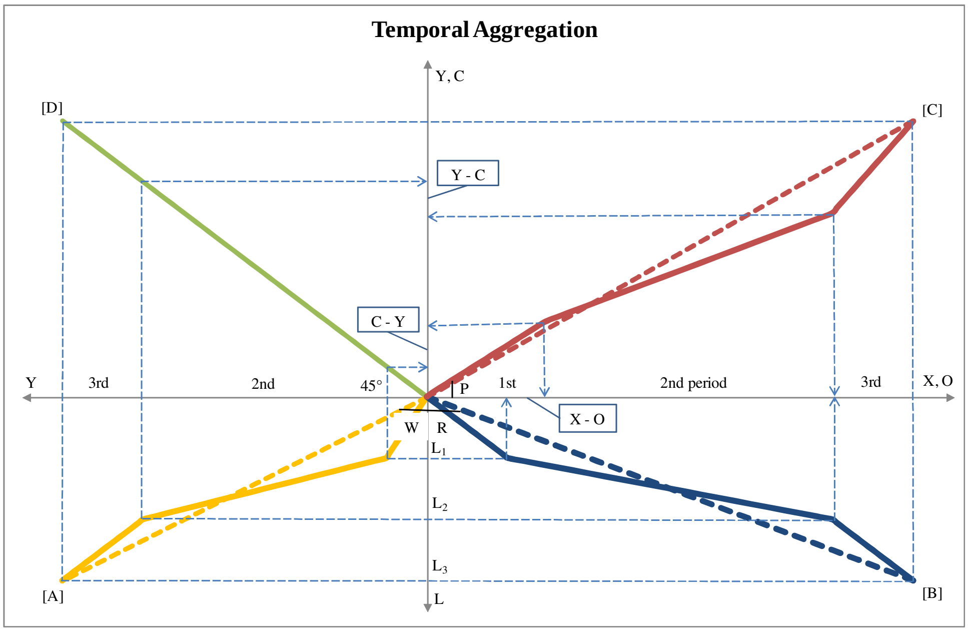


Figure 4: Aggregation of three asymmetric periods with supersymmetry for all periods taken together

endpoint of the previous period the three periods t_1, t_2, t_3 can be geometrically added up to one longer period t with identical end coordinates [A], [B], [C], [D]. The diverse line segments in each quadrant lead to the same end points as the respective straight lines. This implies that the actual conditions in each period can be mapped onto the geometrical representation of the first three axioms that now refer to the longer period t. The geometrical summation over three periods results in this special case in supersymmetry for the longer period. Hence saving and dissaving as well as the increase and decrease of the stock of products cancel out over the longer time span. The question of how this outcome comes about is left open here.

The equations that perform the mapping are the same as in section 2 with the difference that the output is here taken as homogeneous over all periods. So when we start with the Hicksean week as shortest meaningful period length we can map the 52 detailed weekly representations onto the axiom set that relates to a year and then map ten of them onto that of a decennium. The graphics always look the same but for the scales on the axes. This holds for each discrete period length. There is, again, a loss of detailed information about each single period but this is not a disadvantage when a bird's eye view is needed. There is a consistent sequence of periods between the short and the long run that is summed up by mapping.

By their respective endpoints the shorter periods are truly preserved as these endpoints are the starting points for the next step in the development of the economy. The first property to emphasize is that the geometrical representation of the axiom set is self-similar over time. If we could draw an analogue to Figure 4 from the beginning to the end of the economy it would inevitably turn out to be supersymmetric. The second important property is that it is possible to employ Figure 1a in each period of Figure 4. That means that temporal aggregation implies qualitative aggregation.

It is, in principle, possible to shrink the period to an infinitesimal length and thus to perform the formal transition to a continuous analysis. This, indeed, is a quite separate line of inquiry that is not pursued further here.

Temporal aggregation is about the formal relations between the values of the variables of the axiom set for an arbitrary number of periods and the resulting values for all periods taken together. The axiom set has the property that its geometric representation is self-similar over time, and that means, that it is independent of the chosen period length. Qualitative and temporal aggregation entails that the elementary axiom set is applicable independently of the underlying microeconomic details and independently of the chosen period length.

5 Conclusions

The two main results of the structural axiomatic analysis are:

- Qualitative aggregation entails that for any microeconomic state in period t there exists a correspondence that is formally represented by the first three structural axioms.
- Temporal aggregation entails that the structural axiom set is applicable independently of the underlying microeconomic details and independently of the chosen period length.

The structural axiom set is self-similar with regard to the differentiation of the household- and business sector as well as to the sequencing of time.

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