SEPPO RUOHO

Essays on the Measurement of Economic Growth

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ACADEMIC DISSERTATION
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This dissertation is a byproduct of a long and laborious civil servant career at Lappeenranta University of Technology (LUT). It is a byproduct because for most of the time writing an academic dissertation was not a legitimate part of my job as a researcher of Eastern European economics and quantitative methods in economics.

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Tampere, December 2007

Seppo Ruoho

Preface

This is a study in economics. Its approach, nevertheless, is heterodox as well as both quantitative and qualitative. The theoretical review part of this study is standard main-stream theory about national accounting and index theory. The next standard step of an empirical study in economics would have been the statistical verification of the core hypotheses. Here we had to depart to the artifact of a qualitative research process. This was for three main reasons. Firstly, there was no opportunity of a fair probability sample of Soviet physical volume data. Secondly, there was no systematic data on quality adjustment in compiling growth statistics either in the USSR or in the OECD. Thus, we were driven partly to qualitative strategies of corroboration. Lastly, the institutional context of growth measurement, especially in the USSR, is a soft field in economic theory. The overall result is a scenario or a theoretical narrative.

The study grew in the fashion of grounded theory. The theoretical framework and the empirical part developed simultaneously. The empirical starting point was the conventional wisdom in economic Sovietology that there was hidden inflation in Soviet historical growth data. The first strategy was standard, too. One must construct one's own set of alternative indexes. Out of this fairly ordinary subject grew two independent reviews: one in the theory of national accounting and another in index theory. The third essay is an eclectic review of Soviet index theory in the context of Soviet economic theory. The fourth essay is an empirical case study on the measurement of economic growth. This is a qualitative study of Soviet growth measurements with well defined main-stream quantitative indicators. Apart from theory reviews and fragments of doctrine history, the empirical results are in the form of a well founded hypothesis model. The last part is a retrospective vision of the order and results of the research process.

ESSAYS ON THE MEASUREMENT OF ECONOMIC GROWTH

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ESSAYS ON THE MEASUREMENT OF ECONOMIC GROWTH

ESSAY no 1

From Theoretical Concepts to Operational Definitions and Procedures: Nominal Data and National Accounting

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Abstract

This essay analyses national accounting theory in retrospect. The aim is to create an interface to the inter-temporal and interspatial measurement of economic growth and size of economic systems. A formal system view is emphasized as it links up with the theory of economic indexes.

1. Theoretical Concepts and Operational Definitions

1.1 Economics and Science

Modern economics is a quantitative discipline. Its models and theories are formulated chiefly mathematically. Classical physics was the first paradigm of modern empirical science. Formally, classical physics was written in calculus. The main variables of early classical physics were often directly measurable in numerical terms. The concepts of length, distance, mass and velocity seem obvious. Operational rules for measurement were rather straightforward after the measurement of time was made mechanical. Even before the emergence of classical physics there was a long tradition of quantitative measurement, e.g. geometry was applied in astronomy and navigation. The research object is in a state of evolution in most empirical sciences. This is well exemplified by the gamma of cosmology and evolution theory proper. In contrast to most natural sciences, the structural evolution of studied systems in social sciences is very fast. The object of modern microeconomics has fully existed at most for a few centuries. The proper object of modern macroeconomics emerges even later. Because of its latter-day birth economics has often adopted formal ideals from classical natural sciences (see e.g. Porter in Mirowski, 1994, p. 153). Themes like constrained optimization, elasticity, stock and flow as well as simultaneous equation models and differential equations were first introduced in natural sciences. These models entail the idea of exact measurement and thus the ideal of precise measurement was inbuilt in the early concepts of theoretical economics.

In early classical physics measurement was related to both mathematical theory and empirical quantification (Porter in Mirowski1994, pp. 128-161). The first mathematical economists were the early neoclassical micro economists in 1820-1880: Cournot, Dupuis, Walras, and Jevons (Rima 1996, p. 200-201). Early microeconomics mostly lacked empirical quantification being a qualitative mathematical theory (Porter, ibid.). The fiercest opposition to the rising neoclassical school came from the German historical schools. These were not based on methodological individualism and advocated the use and collection of statistical data (ibid.). Despite the heavy thrust of empiricism e.g. in demand analysis, much of microeconomics remains formal and qualitative even today. Whereas the statistical approach advocated by such different standings as the German Historical Schools and the British representatives of inductive method e.g. William Whewell and Richard Jones, joined the great confluence of the emerging Keynesian macroeconomics and national accounting systems in 1920s and 1930s (Porter, ibid.; Vanoli 2005, pp. 16-20).

1. Theoretical and Operational Definitions

In social sciences, economics included, the transition from **theoretical** concepts to **operational, empirical** concepts is less straightforward than in natural sciences. Frequently theoretical concepts are characterized by a large number of attributes, the mutual logical and causal relations of which are not clearly elaborated. Another problem is the varying level of measurability. In the minimum case only qualitative distinctions can be made. Even if the theoretical dimension proper is assumed to be quantitative or formally well structured, the actual measurement may be a compromise with qualifications. To illustrate, there is no easy way to define empirically the concept of consumer utility (see Blaug 1985, pp. 353-355). The task is problematic even with the model of revealed preferences (Pålsson Syll 1998, pp. 288-291). Even such a central concept as the value of production has various operational definitions. Concepts related to economic accounting and records keeping have a long, down-to-earth history of evolution. This is well portrayed by the history the British Royal Statistical Society (Henderson in Rima 1995, pp. 31-62). Richard Jones above was one of the main initiators of the British Statistical Society (ibid.).

There are a number of schools for production and value measurement in the recent history of economics. A common, international standard for production and value measurement was established only some fifteen years ago in the nineties, after the collapse of the European planned economies. In the aftermath the SNA replaced the MPS-system of former planned economies. China joined the SNA convention in 1993. To measure economic growth we must first measure the nominal dynamics production. For measuring value and production we may differentiate three groups of theoretical and operational definitions: First, we have the **theoretical concepts** of **production**. The theoretical concepts relate to such questions as what is production and how to tell producers from final consumers. Shortly this is related to the boundary of production and value theories. Next, there are the **operational rules** for current national accounting systems**.** Here we have empirical definitions for aggregation of data in national accounting systems as well as the border between national and foreign systems. Further, we have the problems of capital formation and net versus gross production. The third group is the **measurement** of **real aggregates,** which is mainly related to the theory and methodology of economic price and volume indexes**.**

In order to find a common ground for international comparisons of growth and sizes of national economies, categories and indicators must be made compatible on the above levels.

2. Evolving Concepts of Value and Production

2.1 Where It All Started

To have concepts of aggregate production, we must solve the problem of variable-dimensionality. Since the clay and stone records of ancient civilizations of the Fertile Crescent and Egypt, production has been recorded in natural units (see e.g., Columbia … 1981, p.50). Natural units have their important place even in modern production statistics. Nevertheless, the necessary precondition for a general concept of production is that trade and production are accounted in **terms of money**. To aggregate production we have to decide whose production should be added up. **Aristotle** introduced the **household** as a subject of production and wealth. Yet this early concept for the subject of decision-making was multidimensional and the boundaries were not well defined (Rima1996, p. 9-13; Macve in Lee et al., 1996 p. 6). An early predecessor for the Aristotelian household concept was the numeric system of **Egyptian storage bookkeeping**, written in the hieratic script and numerals used in Pharaoh's court. The description of this system was contained in **Papyrus Bulaq 18**, dated to 1700 B.C. (Lumpkin 2002, pp. 20-22). This was a vector dimensional flow and stock system that recorded daily the incoming and outgoing flows **in kind.** The **system** also transferred the **daily surplus** into the balance of the next day. The conceptual threads extend even farther into the past. A synopsis of double entry records in prehistoric times is available by Mattessich (Mattessich 1995, pp. 26-33).

The conceptual prerequisites for modern perception of production, growth and accumulation were created with the introduction of **double-entry book keeping** in the medieval Mediterranean Merchant States. This system was first formally codified in public by Luca Pacioli in 1494 with his **Summa de Arithmetica, Geometria, Proportioni et Proportionalita** (Macve in Lee & et al., 1996 p. 4). Pacioli codified a tradition with historical references extending 200-300 years backwards. Technically Pacioli was a modernizer, for he used Arabic numerals and elements of algebra (Macve 1996, in Lee et al., pp.12-13). The methodological demarcations of Luca Pacioli help to determine the **subject** of **accounting,** e.g., **the legal person** involved, the **boundary** of **recording**, e.g., the legitimate inflows and outflows and, last but not least, the **rules** of **valuation** for nominal flows. Pacioli introduced the balance sheet. This may be seen as a predecessor of later stock and flow concepts in economics, although the depreciation issue yet remained unsolved. Book-keeping records commercial transactions. Thus, production value is something that may be measured with transactions. The Pacioli axioms formed the nucleus for later methodological thinking. The system had no clear rules for the accounting period (the time period principle) although Pacioli himself advocated annual accounts (ibid.). The subject of accounting was fuzzy as the joint stock company was yet to come and it was difficult to make a difference between a Merchant's whole property and the business activity related to the accounts held (Tsygankov 2001). The last complication relates to the so called **entity principle (**Macve 1996 in Lee et al., 1996, pp.4-7).

The dilemma of the **time value** of money, began to crystallize only after a few more centuries of inflation caused by sizeable imports of precious metals to Europe by the rising colonial powers the United Kingdom, France, the Netherlands, Portugal and Spain. The problem of fixed price value flows was not addressed until the eighteenth century by such pioneers of index theory as Fleetwood (1707), Dutot (1738), and Carli (1764). The first to introduce an adequate weighting to price indexes was Lowe in 1822 (Kendall 1969, pp. 2-7). Laspeyres initiated the present day index standard with his price index in 1871. The Paasche price and volume indexes followed in 1874.

2.2 Some Formal Elements of National Accounting

With Luca Pacioli as the norm-maker in elementary accounting and the proper production boundary *ceteris paribus*, we next turn to the aggregation of elementary value transactions into **total product**. In business accounting we have the concepts of **sales**, **turnover** and **revenue** on the one hand and the various categories of **profit** and the **additional value-added items** on the other. First, we have to define the spatial limits of national accounting. The entity is a **national economy**. Transactions are recorded according to the **legal persons** who carry them out. They are called **account holders**. The **turnover** is the sum of recorded transactions and depends on the chosen set of account holders. In a system of accounts the central events are sales and purchases of commodities. These are called **economic transactions**. Normally there are **financial transactions**, too. Financial transactions do not change the net worth of account holders. In line with bookkeepers we are interested in a definite period of current production. In economic transactions a title changes ownership. If a group of industrial enterprises is merged into a concern, then the border of ownership changes within an institutional environment. This may change the **primary recordings** in the reviewed set of accounts. If the account holders are grouped into sectors, but the property lines do not change, then the primary turnover is unchanged.

Formally a system of accounts may be understood as a **directed Euler graph**. (Dadaian, ed., 1973, pp. 294-299). In a directed graph the edges between vertices have a defined direction. The accounts are the **vertices** of the graph and the transactions are **weighted edges** in the graph. In a directed Euler graph the **degree** of ingoing and outgoing edges is the same. This is due to dual recording of every transaction in double-entry bookkeeping. Aggregating in this system means defining a homeomorphous mapping on accounts, whereby individual accounts are aggregated onto sectors and corresponding parallel edges may be added. Parallel edges relate to the same vertex pair. With grouped accounts the classification of primitive account holders into sectors is **exhaustive** and **exclusive**. To have a transaction recorded there must be two parties. A **cycle** is a circular edge on the vertex itself. Because aggregated groups consist of several account holders, cycles in the new graph must be accepted to keep unchanged the level of primary total product. This is based on the chosen concept of account holders. In primitive accounts there are no cycles, as account holders do not sell to or buy from themselves. A **visual graph** may be **equivalently** represented with a matrix, where the system of rows and columns is determined by the set of chosen vertices. This is the modern way of portraying a system of aggregated and integrated accounts. The associated structural matrix is called the **adjacency matrix** (Johnsonbaugh 2001, p. 297-98). Adjacency matrix is the structural plan for accounts. The graph of chosen accounts is **connected.** This is self-evident for the single account holder.

2.3 A Short Historical Survey of National Accounting

2.3.1 The Institutional Schools

The two modern systems of national accounting fit into the above general model. These are the institutional approach and the Walrasian system of multi-market equilibrium. The **institutional tradition** is older and is based on the accounts of functional, institutional sectors of an economy. The first pre-modern model based on this approach was the '**Tableau Économique**' of the French physiocrat **François Quesnay** (1699-1774). His value-theoretical predecessors were William Petty (1623-1687) and Richard Cantillon (1680-1734). Both thought that land and labor were the sources of value. Petty technically reduced land value to labor value, whereas for Cantillon labor is only an intermediate product and land the prime factor of production (Pålsson Syll 1998, p. 65-67; Negishi 1995, p. 67-68; Rima 1996, pp. 55-56)).

The economic table was published in two main versions in 1758 and 1766. The **Tableau Économique (TE)** is the first known, integrated precursor of national accounts and input-output thinking. It was in content a **linear economic model**, based on institutional sectors (Negishi, op. cit.). It was a complete system model. This model had the many constituents of later, modern models (see e.g. Blaug 1986, pp. 25-28). The model is a general circulation scheme, but the accounting concepts refer to physiocratic value theories. Thus, the model is an operational version of physiocratic value concepts, not a proof (ibid.).

The model defined three main sectors: **Farmers, industry** and **artisans** and lastly **landowners**. The production boundary was between agriculture, industry and artisans on the one hand and the landowners on the other hand. Quesnay introduced the concept of **net production**, but this was not **value added** in the modern sense. Modern thinking places wages into value added, but Quesnay put wages into the block of intermediate inputs. His net product is more like profit or surplus. Later in the terminology of classical political economy wages were seen as the **reproduction costs** of **labor power**. The class of artisans and industry did not produce net product. That is the sector did not generate value surplus. This sector produced intermediate inputs that were part of total product. There are two productive sectors with wages as intermediate inputs. There are two ways to see the role of landowners. The first way is to assume an **open Leontief model**. Here landowners are final consumers and their income is an income transfer in difference from a factor income. Another way is to see the **TE** as a **general closed Leontief-model** with an **absorbing sector**. An absorbing sector only receives inputs, but does not sell to other sectors (Grubbström 1997, p. 111). The modern interpretation of the **TE** is a **closed Leontief-model,** where the landowners are a proper **transaction sector**. This is the interpretation of Blaug and Philips (Blaug 1986, p. 27 and Philips 1956). In this version the implied net product is zero.

Some formal interpretations of Quesnay's 1766 TE are shown in the next table (Table 2.3.1.1). The data may be changed to represent a linear production system of simple, open Leontief type. It is seen below that the data is not fully compatible with the modern double entry approach. Among others income transfers must be generated. In modern systems wages are not in the inter-industry quadrant. Obviously, for modern value-added some imputations may be needed. However, a modern description of Quesnay's data may be presented with a closed Leontief model. We note that the amount of total product is different in the respective formal models. Modern concepts of national accounting differentiate between market valued transactions and income transfers. Quesnay and Marxists regarded the land rent received by landowners as an income transfer, whereas modern mainstream economists regard landowners as producers (see e.g. Dadaian 1973, pp. 21-31).

Table 2.3.1.1 Some Formal Interpretations of the Tableau Economique:

A **An open Leontief model on the basis of transactions data**

The recorded data of Tableau Économique 1766 by productive sectors

	XIJ Agriculture	**Industry**	**Y Final**	**X Total**
Agriculture	2	1	2	5
Industry	1	0	1	2

Y= Final product, X = Total product

Industry= Artisans and trade

Input-Output matrix **A**

0.4	0.5
0.2	0

A value vector derived by the logic of double entry book keeping
W

2	1

A derived full system with income transfers

Full Table

	Agric.	Industry	Final Consumption by sectors: Industry	Land owners	
Agriculture	2	1	1	1	
Industry	1	0	0	1	
Value W	2	1	-1	-2	← Income transfers

Source of version A: Dadaian 1973, pp. 22-24.

B **Tableau Économique as a closed Leontief Model**

	Agric.	Industry	Land owners	Total
Agriculture	2	1	2	5
Industry	1	1	0	2
Land owners	2	0	0	2
Total	5	2	2	9

***Source of version B*: Blaug 1986, pp. 25-27.**

We may differentiate between legitimate and productive incomes. The physiocrats did not think land owners as a productive sector, but considered their activities and income legitimate.

The physiocratic model of production circulation was further developed by **Karl Marx** (1818-1883) in the **Marxian models** of **reproduction**. These were elaborated mainly in volume two of the three volumes of *Das Kapital* in 1867, 1885 and 1894 (Blaug 1985, pp 250-253). The Marxian model of reproduction was based on aggregated sectors of consumer goods production and capital goods production. The basic Marxian equations portray the production process on the producer side or in the column direction of the standard I-O model. To get the standard view, the Marxian pair of reproduction equations must, however, be transposed. Marx's model was a conceptually and formally modern, aggregated input-output model (see e.g. Schneider 1962, pp. 22-44).

Even if one does not agree with Marx about the source of **surplus value**, the division of value formation into three components **constant capital**, **variable capital** or labor and **surplus value** is modern relative to the physiocratic ideas. Modern type of **value added** was introduced and every productive sector may produce profit or surplus. Marxian models deal with the conditions of balanced growth and the role of primary factors of production, too. Yet, as is well known from the debates of the last 150 years the **labor theory of value** and the Marxian concept of production boundary were not accepted by mainstream economics. Labor theory of value had strong roots in the antique and classical political economy. Only the emerging neoclassical school took a distinct departure from labor theory of value. The later Soviet input-output tables and the balances of national economy were refined and extended versions of Marxian reproduction models.

Two main approaches dominated in operational national accounting in the twentieth century. Combining the classical Marxian concept of production and the **method of**

balances, the Soviet Union introduced its first primitive MPS-system (material product system) in 1923/24 (Dadaian, ed., 1973, pp 113-114). The method of balances is an application of accounting where surplus and present production is equated with sales or deliveries. In developed market economies, where the production boundary was wider and included services, the standard system of national accounting took its conceptual shape between the two world wars through such pioneers as **A. Bowles, C. Clark**, **R. Frisch**, **J.R Hicks**, **R. Stone**, **S. Kuznets** and **E. Lindahl.** Formal accounting models were advanced in USA by **M. A. Copeland** and **R. F**. **Martin** in the 1930s. The Norwegian **Ragnar Frisch** and the German **Ferdinand Grüning** developed functional circulation models (Vanoli 2005, pp. 16-20)).

Early attempts to estimate national income were motivated either by purposes of taxation or measuring comparative economic power of states (Vanoli 2005, pp. 5-6). The classical concept of economic system was additive, atomistic and self-correcting, as well (Pålsson Syll 1998, pp. 306-307). The classical macroeconomic model lacked the concept of **system level steering**. Hence, there was no social agenda for state-level macroeconomic policy and an integrated system of national accounts. Early systematic work on national accounts coincided with the two world wars as well with the Great Depression. In this milieu the emerging Keynesian macroeconomics enhanced the social order for a comprehensive system of national accounting. The Keynesian macroeconomic variables found precise operational definitions in the emerging SNA concepts. The input-output technique was boosted by the Allied war efforts after the pioneering work of Wassily Leontief (Leontief 1941).

The **SNA** (System of National Accounts) was introduced as an international statistical convention by the UN in 1953 (Kurabayshi 1977, p 2). At the same time in the CMEA (also called COMECON), which was dominated by the Soviet Union, the MPS-system was adopted as an international standard. Since 1964 the MPS was established as an alternative standard system of national accounting in the UN. The main technical differences between these two systems were that the SNA was based on current market prices; whereas the MPS used planned prices, and that the production boundary excluded services in the MPS-standard. Historically all parties were for including the sectors of material production in the sphere of production. The physiocratic idea about industry and artisans as a kind of zero-surplus classes was a methodological hybrid (see e.g. Blaug 1986 pp. 24-28). The main dispute, however, concerned what in modern usage is called **services**. The demarcation line was between the neoclassical school and the classical school including the Marxists. **Adam Smith's** the *Wealth of Nations* published in 1776 followed the traditions of Antiquity. The latter rejected in the classic Greek spirit services from the sphere of production. This feature was later inbuilt into the methodology of the MPS system. An illustrative case is interest payments. Banking and consequently charging interest on loans is production in the modern SNA. The ancient Jews considered that charging interest of tribesmen for loans was usury. This Old Testament and antique Greek view on interest was carried on into Marxist thinking through classical political economy (Rima1996, pp. 13-19). A system specific difference was the **valuation** of **foreign trade balance**. This was because planned economies did not have a single meaningful exchange rate. The basic methodology of valuing foreign trade was represented in the CMEA methodological handbook (Sovet Ekonomicheskoi... 1986, pp. 42-47). There were considerable differences between market economies and planned economies in calculating the real production.

There were other minor questions such as imputations concerning non-market sectors as well as the treatment of depreciations. To define the concept of net production or value-added the production boundary must be determined. The MPS had two main aggregates: net value added and net final product and the total material product. After the World War II there was a debate between the proponents of planned and market economies on net and total product concepts. The Soviet value-added was a net concept, whereas the **GNP** was gross value-added. Much of the argument about double counting of production in the Soviet national accounting system was based on failure to make clear distinctions between various net production and turnover concepts (see e.g. Nove 1988, pp. 337-343). The main Soviet statistical indicator of production (*valovaia produktsiia*) was a turnover concept. The size of turnover is determined by the actual organization of accounting bodies, whereas the **value-added** or the **final product** depends only on the production boundary. If the structure of accounting/producing units is relatively stable and the medium term aggregate production function is of stable Leontief type, the two aggregates should grow at a similar pace. These two concepts of production may have different usefulness as target variables, but this is not directly related to the operational rules of production measurements. When **hard budget constraint** and **scarcity pricing** were lacking, using total production as a target variable seemed to lead to inefficient production (see e.g. Gregory-Stuart 1998, pp. 198-206). In other words, total product dominated as plan target. By contrast the GNP was also seen as a measure of welfare. This was due to individual optimization behavior in normal markets. It was the end use that was related to individual preferences.

2.3.2 The Walrasian Thread of National Accounting

The other main approach in national accounting was based on formal microeconomic modeling. The first mathematical neoclassical economists **Cournot**, **Dubois**, **Jevons**, **Walra**s and others introduced the **Cartesian** product space $\mathbf{P^n x Q^n}$ into economics (Blaug 1986, pp. 294-327). Profit and utility functions were defined in this dual product space. The total product concept in the $P^n x Q^n$ -space is simply the scalar product $\mathbf{P^n \bullet Q^n}$ of the price and volume vectors. Leon Walras' first **general equilibrium** model integrated the firm-level and sector-level microeconomic models into a macroeconomic system (see e.g. Blaug 1986, pp. 570-574). There were two sectors in the model: **firms** and **households**. Thus, we have commodities and institutional sectors in the same model. The later **Leontief input-output model** is a link between institutional accounting models and the Walrasian system of production.

The sectors in institutionally defined accounting systems are not **pure** in the sense that each sector produces a **single product**. This feature is not detrimental from the point of view of nominal national accounting in aggregate terms, but it is a complication if production is classified by commodities or commodity sectors. If sectors in institutional models are re-grouped into pure commodity sectors, we have the classical Leontief input-output model. This model combines the methodological roots of Quesnay, Marx and early neoclassical economists. Reich has used the division between microeconomic models and institutional models to put forward a value theory concept (Reich 2001, pp. 125-130). He calls value proportions emerging from linear macro production models macro values. We have been more interested in integrating model families. The modern price and volume index methodology is based on the conceptual infrastructure of the Walrasian micro-economic model. The space $P^n xQ^n$, where indexes are defined as positive functionals, is the same as the decision space in microeconomics.

The SNA and MPS may both be represented as input-output models. The First input-output models were published during World War II, 1941 in the USA and 1959 in the Soviet Union. The SNA methodology fitted national-accounting data closely together with input-output models. In standard Soviet models the precise fitting of data concerned only the final product. The total production concept of input-output models differed somewhat from the statistical category of total product (*valavoi produkt*, see. e.g. Narkhoz 1990, pp. 10, 296, 686). The basic problem was the same in both systems: the data is complete only on the firm level, but for constructing input-output tables data on the level of industrial/business establishments must be used. The human link between Eastern and Western traditions was the Russian emigrant economist **Wassily Leontief**, who published the study "*The Structure of American Economy* " in 1941 (Leontief 1941). Leontief began his career in Leningrad University in the early twenties and emigrated later via Germany to the USA. Quesnay's **TE** and Marxian models of reproduction were balance-equations models. Modern input-output analysis had two important elements: First, the aggregate production function was assumed to be linear. This feature made the system of national accounts and the input-output model formally equivalent. Secondly matrix algebra was systematically applied in the model.

Modern systems of national accounting are composed of three families of linear economic models: the double entry book-keeping models, functional models of economic circulation and input-output models. The formal models of the SNA and the MPS were very similar. The different theoretical inclinations were brought in through theories of production boundary and price formation. Planned prices were like the natural price of classical political economy based on average concepts, whereas market pricing was based on marginal price theory.

3. Natural Linear Systems of Production and National Accounting

3.1 Classifying Products

Production may be defined as follows: "The act of transforming the factors of production into goods and services that are desired for consumption and investment" (MIT 1991, p. 342). We may consider all relevant commodities and services as product flows. These flows may be seen from the point of view of their final destination e.g. **consumption** and **investment**. However, in order to build a **system model** for production it is more useful to start from the tradition initiated by **Carl Menger**, who classified products according to the stage of production. Menger and Walras are the originators of the present division of products into **primary**, **intermediate** and **final** (Grubbström 1997, p.76; Blaug 1986, pp. 570-580). Primary products and factors enter the system of production from without and are not produced within the system. Intermediate products are products produced and used within the production system or process. Final products and production are those goods that are destined for consumption and investment within or outside the system and do not enter into production processes as inputs during the current period. This classification is by purpose and not by the type of product. The three main categories are over lapping, as there may be products with multiple purposes. For instance, iron ore imported and excavated.

3.2 Production Systems and Production Processes

In abstract systems theory, systems may be thought of as structures formed by mutually **connected system elements** and the **system environment**. Production systems are systems in the more precise sense of Ashby (Ashby 1971, p. 40). Accordingly we may see production systems as **sets of variables connected by**

elements. Elements are physical processes that transform the incoming variables or **inputs** into outgoing variables or **outputs**. Variables are **quantitative product flows**. The transforming elements may or may not have an analytical mathematical description. Primary products that enter the system from the environment are **natural products**, **labor flows** and **imports**. A production system may be modeled as a mapping from the vector of total inputs, possibly including primary products, onto the vector of final products or it may modeled by subsystems with a special subsystem for consumption of materials. A **production system** is **linear** if the transformation function is linear. With linear systems this function is represented by a real matrix $\mathbf{S}_{mxn}$. The model for the linear system of production is **linear mapping**:

$$\mathbf{S: R^n \rightarrow R^m; Y_{mx1} = S_{mxn}X_{nx1}},$$

where X refers to inputs and Y to outputs. We have not yet a separate vector of intermediate products. The whole system is a single linear transformer and the concrete production activity is located within a **black box**.

The linear mapping above was from products onto products. In the case of general linear production systems we speak of **processes**. A process is also called an **activity** **(**Simon & Blume 1994, pp. 791-792; Grubbström 1997, pp. 80-83). One process may use multiple inputs or produce multiple outputs. In order to specify a linear system of production the inputs and outputs have to be fixed. A process is the **smallest modeled part** of production, which may use several inputs to produce several outputs. A process in a linear system of production is usually identified with a column in the transformation matrix. Linear means a fixed transformation between inputs and outputs. With input-output models a basic process usually portrays the costs of production. A production system may be modeled as a real flow system, where inputs precede outputs. The other view is a planning model, where the direction is from final product to input needs or more generally the feasibility of the production task. In a real flow system the process is modeled to measure costs e.g. by the columns of an input output model. In a reverse system a process generates total product from final product.

A system is **open** if its input vector contains primary inputs like labor or inputs from outside like imports. A system is also open if part of the product is transferred outside the system. Otherwise a system is **closed**.

General linear processes may have multiple inputs and outputs. A standard simplifying assumption is that the models used are **general Leontief systems.** Thus each process produces only one product, but there may be several processes producing the same product and $n \geq m$. General Leontief systems are mappings of **processes onto products** in the form $R^n \rightarrow R^m$ represented by a real matrix $S = (s_{ij})_{mxn}$. Obviously a necessary condition for a general Leontief system of production to be **consistent** with an output-vector $Y_{mx1} \geq 0$, is that the corresponding system of linear equations $Y = SX$ is **consistent**. What kind of planning tasks are solvable with the model depends on the characteristics of the matrix S. With general Leontief-systems we have $n \geq m$. In consistent systems the input product vector X can be calculated for the semi-positive final output vector Y. In real production only positive inputs are used. It follows that to solve a production plan for some $Y \geq 0$, $Y \in R^m$, the inverse image $S^{-1}(Y)$ should be in the semi-positive part of the definition manifold R^n. If this is true, then the vector Y is called **feasible.**

We may think of an enterprise as a general linear system of production. This is realistic at least for a single accounting year. The enterprise buys inputs and produces for markets one or more outputs. Sales outside and purchases from outside are recorded. The standard simplification of the general Leontief system is that every process produces only one product possibly with multiple inputs and that the number of products is the number of processes e.g. **m** = **n**. In this case the **system matrix** is **square**. If we have more processes than products, then we can aggregate over processes producing the same product. Technically these processes are coupled in parallel and can be added (Di Stefano & Stubberud, 1967, pp. 114-115). The above systems are called **simple Leontief systems** (Simon & Blume 1994, p. 796). Once we have aggregated parallel processes producing the same product we can no longer solve the production task backwards to the original individual processes. We recall that A is defined as A = (a_{ij}); a_{ij} = x_{ij} / X_j: j =1, …, n.

If the **law of one price** is valid, then the **value added account** for the production system is X_{1xn} - $\sum(x_{ij})_{nxn}$, sum over i; where X_{1xn} is horizontal total product vector and $(x_{ij})_{nxn}$ is the matrix of intermediate production. Labor inputs and other factors of income are not included in the total input vector X. That is why the profit account shows value added as total sales revenue minus material costs of production. We have reduced enterprises to the norms of simple Leontief systems. An economy may be described as a technological system of partially coupled, natural simple linear processes. The final aggregated model may then be represented with a natural input-output matrix A_{nxn}. The basic system description is Y = (I-A)X. The input-output matrix is the cost element and the matrix $(I-A)_{nxn}$ is the operator that transforms total inputs into net outputs. Every input-output system is an operational definition based on accounting data. The input-output model is an aggregated, consistency model and it does not have any spatial specifications necessary for detailed production planning. **Primary inputs** are labor and imports. **Final outputs** are domestic final demand and exports. If P_{nx1} is a price vector with market prices or other notional prices and P_D is the diagonal matrix presentation of the price vector, then we may ask when the final product vector and total product vector $P_D Y$ and $P_D X$ constitute a national accounting system.

3.3 Productive Linear Systems

Let us start from natural simple Leontief systems: **Y = (I-A) X.** With natural Leontief-models the elements of A = $(a_{ij})_{nxn}$ may be greater than unity.

Definition 1. The linear production system and the associated input-output matrix is called **productive** if there exists some $X \in R^n$ such that **X > 0** and **(I-A) X > 0** (Simon & Blume 1994, pp. 794)**.**

We list five theorems related to productive linear systems:

Theorem 1. Square matrix A is productive, if and only if the inverse matrix $(I - A)^{-1}$ exists and is nonnegative (ibid.).

Theorem 2. If A is productive, then for all $Y \in R^n$ and $Y \geq 0$, then the equation $(I - A) X = Y$ has a unique solution. In other words, all production tasks for semi-positive final vector are in principle feasible (ibid.).

Theorem 3. For the matrix A to be productive, it is necessary and sufficient that the modulus of the largest eigenvalue (characteristic value) of the matrix A is less than unity (Granberg 1978, p. 274).

Theorem 4. A sufficient condition for the semi-positive value input-output matrix A to be productive is that $\sum a_{ij} \leq 1$, $i \in I$ for all j (Dadaian 1973, p. 157).

Theorem 5. Let the input-output matrix A be **productive**, then for any positive value-added vector $W_n \geq 0$ there exists a semi-positive price-vector $P \geq 0$ such that $W_n' = P' (I-A)$ (Dadaian 1973, p. 157).

Definition 2. Two matrices A and B are called **simila**r if they are related by the transformation: $B = P^{-1}AP$, where P is an invertible square matrix. Similar matrices have **identical eigenvalues** (Lay 1998, p. 309).

With simple natural Leontief-systems, we may introduce value models by introducing a positive price vector $P > 0$. The price vector is **strictly positive** because we exclude free goods. If we span a diagonal matrix P with the price vector, then in value terms $X' = P_D X$ and $Y' = P_D Y$. The new value form input-output matrix is then defined $\mathbf{A^* = P^{-1}AP}$ (see. e.g. Dadaian, ed., 1973, p. 158). Natural simple Leontief production systems and their value transformations by price vector P are **similar** to each other and have the same characteristic values.

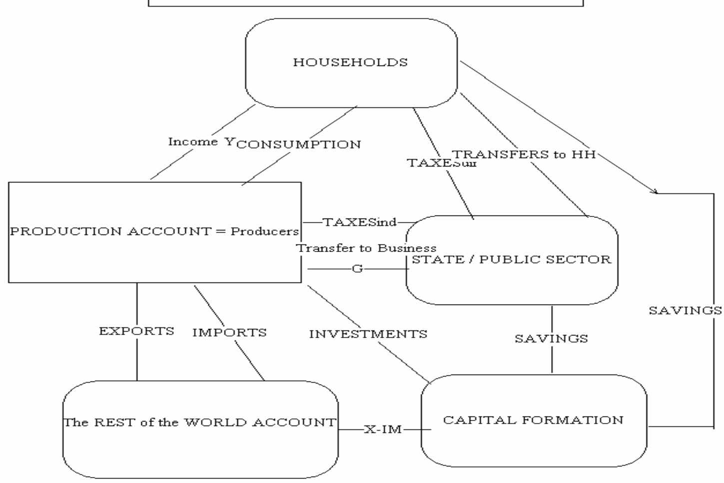
3.4 Input-output Models and National Accounting

In the general theory of national accounting, there are two main types of units: **institutional units** and **establishments**. Institutional units are legal persons entitled to own and use resources in legal sense and liable to profit and loss accounting for taxation**.** Establishments are units of physical production in one location, which produce one product or are classified based on main production (SNA 1993). An establishment belongs only to one institution, which may contain other establishments and units, too. We may without great loss of accuracy assume that simple linear production processes and establishments refer to the same items. Thus, a firm is operationally made of a simple Leontief processes.

In SNA the elementary production accounts are known as **BEPA**:s or Business Establishment Production Accounts (National Accounts … 2004, pp. 74, 96-97). The **border of recordings** is defined institutionally by income and profit statements of enterprises. BEPAs are a **synthetic breakdown** of this data onto the level of establishments. The total, intermediate and final production is defined by the accounts of enterprises. However, it is assumed that on the level of an establishment there is accounting data relating to principal inputs, revenues, salaries and wages. Some inaccuracy is generated when production data are presented by sector or commodity classifications, re-grouping the BEPAs. If we aggregate production sectors based on BEPAs, then the borders of accounting units do not change and thus total product and value added should not change. On the other hand combining linear processes physically may lead to increasing returns to scale (Grubbström 1997, pp. 128-130). Merging or breaking down legal entities, e.g. companies and concerns, changes primary records including such aggregates as total production or sales.

Let us assume a production boundary. Whether we have chosen SNA, MPS or even the physiocratic system does not greatly affect the general procedure. We adopted the operational convention that simple production processes and establishments refer to the same units. A national accounting system has three boundaries. First, the definition of legal persons determines valid transaction records. Secondly, the production boundary determines productive transactions. Finally, the third border defines territorial boundaries. In any economic system institutional groups carry out transactions within the system. **Economic transactions** change the net financial worth of trans-actors and **financial transactions** have no effect on the net financial worth of trans-actors. Elementary textbook models of national accounting have only two institutional sectors**:** **firms** or **producers** and **households**. A simple standard model of national accounting has three more accounts: the **government account**, **capital account** and the **rest** of **the world account**. A flow chart for these five accounts is shown below (Figure 3.4.1)

FIGURE 3.4.1 The System Structure of National Accounts



The way an input-out model is generated from national accounting data depends on institutional sectors as well as the commodity structure of production. Within the **SNA** system the exercise is done using so called **supply** and **use tables** (National Accounts … 2004, p.84). Our objectives are methodological and not related to immediate applications. Hence, we use a more general, formal transfer. We have defined establishments as simple linear production processes and based primary records on enterprise accounting. Conceptually we may arrange the enterprises by sectors. When needed, we may move those processes that are not sector specific to their proper sectors. Let the matrix A_{nxn} present our primitive simple Leontief system formed from one sector enterprises and processes (BEPAs). As it is n here is the number of separate production units. We aggregate over units with the same product. Formally the condition of unbiased aggregation is that **BA = A*B**, where B is a kxn aggregation matrix changing the original n-sector accounts into k-sector accounts and A* is the new production matrix of order k (Miller & Blair 1985, p. 179). The matrix B consists of zeros and ones in such a way that every existing sector is either unchanged or added once with some other sectors. If W is the weighting matrix, where the column element is the relative weight of a sub-sector in a sub-aggregate, then $A_{kxk}^* = B_{kxn}A_{nxn}W_{nxk}$. The above condition is operationally congruent with the postulate not changing legal persons. We have standard input output model:

$$\mathbf{Y_{kx1} = (I\text{-}A)X_{kxk}.}$$

If we add the **capital-account, the government account** and **the rest of the world** account, the final product vector is transformed into matrix **C + G + I + (EX-IM),** where **I** is gross investment, **G** is public outlays and **(EX-IM)** net exports. If I is gross investment, then the intermediate production quadrant does not contain depreciation. Introducing depreciation into national accounts is always a technical convention and may be realized in various ways. It customary to assume that the time derivatives of sector specific capital stock depreciation rates are constant, but not necessarily the same by sectors. Normally depreciation is a row in the **value-added quadrant**. Imports are usually embedded in the first quadrant by sectors or as a primary inputs row in the second quadrant. The third quadrant contains all value-added flows: **wages**, **profits**, other **proprietary income** as well as **depreciations**.

We ignore for the time being the **time value** of **money**. The only problem of measurement in our model is the rest of the world account. If trade and currency policy are actively used with strategic aims, then the official exchange rate may be an ambiguous measure of value. In planned economies this problem was even more severe. In what follows, we suppose that both the second and third quadrants are represented with aggregated vectors with $\mathbf{Y_F}$ for final product and $\mathbf{Y_W=D_{1xn}+W_{1xn}}$ for value-added (see below).

$\mathbf{AX_{nxn} = (x_{ij})}$	$\mathbf{Y_{Fnx1} = C+G+I+EX-IM}$
$\mathbf{D_{1xn}}$ $\mathbf{W_{1xn}}$	**Transfers**

We now come back to the issue of productivity. The definition of productivity is the same for natural as for value systems. With simple Leontief systems one of the equivalent productivity criteria is that the absolute value of the largest eigenvalue is less than unity (by the Theorem 3. above). As we know, the natural term production matrix is **similar** to its value-transform produced by the strictly positive diagonal price matrix P_D.

If we assume a taxing and income transferring government, then there are more solutions to the preceding planning problems naturally excluding the impossible. This may mean a multi-price system. We also know that in a productive system any semi-positive final product vector is feasible if we do not consider input constraints. We are mainly interested in final production and value-added items. These are equal when summed in aggregate due to the basic logic of input-output tables. In a market economy where enterprises are economically independent, value added components tend to be more uniform in structure than in planned economies. Thus, the relative structures of value added and final product may show more variation in planned economies than with markets.

We may conclude: If the production system is not productive but is working then it is consuming more of one or several final products than it produces. A non-productive system is not viable for long. There is a one-sided implication between the final vector Y and total output vector X in productive systems. There is always a semi-positive total output vector whenever the target vector Y is semi-positive. However, a semi-positive total output vector X may result in non semi-positive Y. If we allow that primary inputs, intermediate inputs and final outputs belong to the same nomenclature, then we may have a productive matrix with a negative final product item. This can be illustrated with the American 7-sector I-O table from 1977. Mining industries import more than they sell as final product while the matrix $(I-A)^{-1}$ is strictly positive (Miller & Blair 1985, p. 425). This is due to the procedure where primary factors are embedded in the first quadrant of the input-output matrix A.

If value added in some sector is negative, and the system is productive, then intermediate production or production costs are greater than total product. This implies that the respective column sum in the input-output matrix A is greater than unity. Because the condition in Theorem 4. above is sufficient but not necessary, the problem may be corrected by picking up a new price vector P following the Theorem 5. (Granberg 1978, p.274). The natural input-output system and the value form input-output system are by matrix theory **similar,** but operationally important is the uniqueness of the price system applied. A value based input-output matrix is always an operational definition, where the level of aggregation and sampling system must be chosen.

3.5 The True Value of Production

The institutional structure of an economy defines its accounting bodies. If the price system of an economy is such that parts of the accounting bodies are loss making in the long term, then the system will go bankrupt or will be supplemented with income transfers. If we adopt an *ex post* approach and fix the time path of physical production, then it is obvious that there are infinitely many price systems, congruent with a semi positive value-added vector. This is due to continuity and the Theorem 5 above. Some of these price-vectors may be clearly distinct. An input-output model is only a formal consistency model. It is in the realm of microeconomics to identify the working price systems. In market economies prices are determined by markets. In traditional economies and planned economies markets may not work. It is, however, possible to build linear models of production. If the price system is not a constant, then its dynamics has an effect on the nominal and real values of aggregated production. If we fix the binary physical endpoints of production in time, then there are **minimum** and **maximum values** for the growth record in the allowed set of productive prices. The famous **index number problem** is a sub-set of this variability. How do we know what prices or price path to use? This question is especially relevant in planned economies, where prices are key decision parameters as well as in international growth comparisons.

3.6 Market Prices versus Planned Prices

Perfectly competitive markets are thought to be a proper mechanism of valuation. If there are large monopolies or the resource distribution is very uneven at the outset, it may be thought that the adequacy of markets as a value setting mechanism is impaired from the point of view of satisfaction of individual actors. In the textbook-world the markets are based on perfect information. This, of course, is a rather crude abstraction. A good example of the shortsightedness of markets is the history of world energy prices. However, in the dire, administrative world of national and international statistical agencies, market prices are accepted for most aggregation tasks. Valuation in national accounts is always historical, nominal or real. Transactions recorded as production are assumed to be mutual, that is, generally market based. The production concept is, however wider than proper market transactions. Values of production flows that take place outside markets must be imputed. For example, standard SNA includes procedures for valuing public sector production or services due to owner occupied housing (National Accounts…, 2004, pp. 23-24). The **net present value** concept in business accounting has no counterpart in national accounting.

Planned economies were not bastions of consumer and producer sovereignty. The decision function was centered on the very top of the political power structure. From the beginning to the collapse of planned socialism, much of the target setting in planning was physical. There was a collective objective function mainly in natural terms. The formal constraint was that the aggregate system must be productive. Theoretically, several price systems may be combined with the same physical targets. Some requirements for the financial system may be set. For instance, it may be required that the main sectors are self-financing. There were no real, hard budget constraints on the enterprise or even ministry level. The last resort accounts were on the level the central economic decision-bodies (see e.g. Kornai 1992, pp. 140-145). This fact had implications for the measurement of production on the sector level. If the central decision-makers can transfer large surpluses and subsidies from one sector to another without uniform prices and costing principles, then it is possible to interpret the growth rate of production in a unique manner only on the level of aggregated total production. This is one of the reasons for the adoption of the famous adjusted factor costs (AFC) principles as advocated by Abram Bergson (Bergson 1961).

A practical consequence of the fifth theorem above is that in a productive linear economy, any positive value-added structure may be realized, but then the prices are determined by the model. This property has a connection with the famous **Marxian transformation problem**. In the first volume of the ***Capital*** Marx studied value from the production function point of view based on the **labor theory of value**. In the manuscript of the third volume he thought that profits not surplus value guided production and that prices were **cost based** so-called **production prices** (Rima 1996, pp. 221-223). The solution of the transformation problem presupposes that the so-called **organic composition of capital** C/(V+C) is the same in all branches (Blaug

1986, p. 229-233). Here C is constant capital and V variable capital[1]. However, it is possible to have prices that are proportional to labor consumption by each production process (Grubbström 1997, pp.102-104).We may therefore choose either side of the transformation problem, but not both sides simultaneously. Choosing the other side means starting from well defined production prices and calculating the value added. The Soviet thinking about planned prices started from the value aspect and turned to the side of production prices in the post-Stalin period.

In microeconomics prices are moved by costs and utility functions. Planned prices may have strategic motives, too. The Soviet industrialization debate or Stalinist technology policy determined by such tenets as the high investment share in heavy and especially machine-building industries and the agricultural sector as a forced source of accumulation illustrates this difference well (Gregory & Stuart 1998, p. 61). The normalization of income distribution for the agriculture lasted as long as the system itself. During the Soviet planned period planners used several theoretical pricing models. The earliest versions did not include capital costs, but were based on profit norms, labor costs and value of intermediate production. Later at the beginning of the 1960s, the basic Marxian scheme of production prices was introduced (Hanson 2003, pp. 100-108; Shirokorad, ed., 1992, pp. 192-204). Thus in former planned economies price reforms potentially had an effect on growth rates.

We have emphasized the productivity postulate as the prime factor. Formal preconditions of survival are however, not enough. The last Soviet input-output matrix from 1989 was productive (Narkhoz 1990, p. p. 296)[2]. Hence the system collapse of the Soviet economy was related to dynamic and not static conditions of productivity or viability (for similar reasoning see e.g. Rosefielde 2005, pp. 259-273). The economic system is not defined only by technology and labor power. The **social contract** is an unavoidable ingredient of a production system.

[1] Variable capital refers to labor costs and it is assumed that all constant capital is consumed during one production period (Rima 1996, p 206, Blaug 1986, pp. 225-226).

[2] Author's calculations

Historically three approaches were used to make the national growth records comparable. First, domestic prices, possibly with some modifications, may be used. Second, growth comparisons may be based on international comparisons of purchasing power parities (PPP). For the third model calculations may be used (see e.g., Havlik 1991). Excluding a thoroughly integrated international economic system we must choose someone's preferences or a combination of several sets of preferences in order to calculate numerical estimates for the sizes and growth rates of various national economies.

4. Conclusions

We have reviewed the measurement of production retrospectively. First, there are economic theories concerning the classification of productive activities and production boundary. Economic theories relate to valuing production, too. The main divisions in value theory such as market prices versus prices defined by an input-output model in Marxian or classic manner and the question about the labor theory of value were part of the international national accounting debate up to the beginning of the 1990s. The MPS-system has become a rarity that is used only in some planned and developing economies. Valuation in national accounts is always historical, nominal or real. This goes for imputations, too. The **net present value concept** in business accounting has no counterpart in national accounting (Bos 1997, pp. 177-178).

Secondly, we outlined a history of formal national accounting systems. We introduced linear economic systems as the background theory. This theory is the common denominator of production analysis in countries with different economic systems and development levels. The formal results concerning pricing and distributing value added in productive systems are important because they reveal the operational space for value distribution in similar as well as different physical systems. In market economies imperfections spring from the public sector or oligopolies and monopolies. In planned economies there was even more space for steering value distribution between sectors. *Ceteris paribus* the formal methodologies of the measurement of economic growth, the variability of value distribution in different economic systems calls for standards of measurement for economic growth.

Comparability of national data with other economies has two main factors: formal national accounting systems and principles value formation. There is a third pragmatic dimension. Increasing trade and international economic integration increase the comparability of economic measurement because they tend to decrease differences in relative prices and make the exchange rate systems of the participating countries more uniform. Thus, prices are under pressures of at least asymptotic convergence. Trade and integration standardizes **commodity nomenclature** and **technology**, too. The formal systems of national accounting are well developed by now. The scope and contents of these systems undergo continuous challenges. Global growth has e.g. created environmental pressures that have changed and will change among others the concepts of cost, capital and resource.

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II

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ESSAYS ON THE MEASUREMENT OF ECONOMIC GROWTH

ESSAY no 2

From Nominal to Real Aggregates: Does the Choice of Index Methodology Make A Difference?

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Faculty of Social Sciences
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From Nominal to Real Aggregates: Does the Choice of Index Methodology Make a Difference?

Table of Contents:

From Nominal to Real Aggregates: Does the Choice of Index Methodology Make a Difference

Abstract

In this essay the main features of modern inter-temporal indexes are reviewed. Axiomatic and economic indexes are discussed and put into the context of SNA index system developments. The essay is an independent survey as well a theoretical reference to put the related empirical studies into a theoretical context.

1. From Nominal to Real Aggregates

1.1 Approaches to Price and Volume indexes

Nominal aggregates are usually transformed into real or fixed price aggregates with price indexes. This is also the OECD practice. In the former planned economies volume indexes were the main instrument. Historically there have been three main approaches to index number construction. These are the **economic approach**, the **axiomatic** or **test theory approach** and the **stochastic approach**. In the economic approach index formulas are motivated by microeconomic theory. Maximizing and optimizing consumers and producers are the starting point. The behavior of an economic actor is guided by an **aggregator function,** that is to say e.g. utility and production functions. This aggregator function is used to fix the metrics of price or volume change. Since the procedures in the economic approach are based on individual aggregator functions, the **problem of aggregation** arises in the context. For this reason, we have first to determine the preconditions for using specific aggregator functions. The next task is to define the connection between theoretical and operational concepts and variables.

The **axiomatic** or test theory approach was pioneered by Irving Fisher (Fisher 1922). Price and volume indexes are positive functions defined in real spaces $Q^n x P^n x T$. In economic approach prices and volumes are causally related by optimization behavior. The axiomatic index theory makes no assumption about the covariance of prices and volumes. Rather the approach is indifferent on this. The rules that lead to desirable index formulas are not based on the behavioral axioms of economic actors, but on formal axioms of the index system.

The stochastic approach has remained the least popular approach. Originally introduced by Edgeworth and Jevons in the second stage of neoclassical revolution, the approach lost momentum in the twentieth century (Prasch in Rima 1995, pp. 176-178). The key idea is that there is some underlying, but unobservable price level, around which the prices of individual goods and services are randomly distributed (At What Price? 2002, p. 41). Each price ratio is interpreted as a linear function of the common inflation rate α and a random term ε, $P_1/P_0 = \alpha + \varepsilon$. The best linear unbiased estimate (**BLUE)** as well as maximum likelihood estimate (**ML**) is the **Carli price index**, defined as the mean of the individual price relatives (Selvanathan-Rao1994, pp. 49-51; p. 63). The theoretical foundation of the early stochastic approach was the quantity theory of money (Prasch op. cit.). The first inflation component was to change due to the quantity of money. The second part was due to changing relative prices. A modern introduction to the stochastic approach is by Selvanathan and Rao (Selvanathan & Rao1994). In the modern stochastic approach the index formulas are derived as parameters of regression equations and the statistical fit of the equation is the justification for the formula used. We will not go into the stochastic approach in more detail.

1.2 Value Functions in Linear Systems of Production

1.2.1 Some Definitions

Subsequently, we will assume that price and volume indexes are defined on time indexed, linear systems of productions. We use the term linear production system in the sense of a standard input-output model. In this model, accounts have been aggregated into pure-product sectors. Thus, the input-output presentation is closest to the pure index theory, where indexes are defined as real valued functions on $Q^n x P^n x T$. The accounting conventions including the boundary of production and aggregation level are inbuilt in the model. The model is $Y_F = (I\text{-}A)_{nxn}X$, where X_{nx1} is the vector of total production and the Y_F is the vector of final or net production. The value-added vector Y_{W1xn} is on the dual side of the above linear system. Standard indexes may be defined on total-product coordinates X, end product coordinates Y, on intermediate production or on their subsets. Usually price and volume indexes are simply defined in real manifolds R^n. Using the input-output framework, however, provides some clarity, when indexes are defined for value added categories.

Production is semi-positive. Commodities are either produced or not produced. Prices are strictly positive. **Aggregated total production** in value models is simply $\sum X_i$ and the **national** or **final product** is $\sum Y_{Fi}$, ; $i \in I$; $I = \{ 1, 2, 3, \ldots, n\}$. Intermediate production is presented by matrix $(x_{ij})_{nxn}$ and value-added is the vector $Y_{Wnx1.}$ The **law of one price** is assumed to hold in pure index theory. The final production is aggregated on the end user side. Due to the elementary properties of an input-output model, the user side final product is equal to the producer side value added. However, the individual components of value added may differ considerably from corresponding final product components. Having assumed the law of one price, we generally forget the problems of sampling.

The minimum requirement for value aggregation is the existence of a numéraire. The **value function** defines the aggregated value of production (Vogt 1977 p. 77). The semi-positive value function is defined as **V:** $\mathbf{R}^{2n+1}+ \rightarrow \mathbf{R}+$. **V** (Q(t),P(t)) is called the value of production in (Q(t),P(t)) $\in Q^n x P^n x T$. The value function is the scalar product $Q^n(t) \bullet P^n(t)$. Since prices and quantities change over time, no calculation of size or growth of an economy can be made with the value function alone. Economic theory assumes that the value change of production is composed of two orthogonal dimensions: the price and quantity changes. If **no quality change** is assumed**,** then the volume dimensions are fixed. If product quality changes, then the character of the respective commodity dimensions changes, too. In index theory this change is interpreted as a change of coordinate metrics. Changing quality of commodities may lead to establishing new commodity dimensions.

1.2.2 Inter-Temporal Indexes and Dimensionality Problems

When calculating price and volume indexes the observable objects are price and quantity vectors. Excluding indexes for single commodities we pick up some sub-system defined by the three boundaries: production boundary, legal boundary (proper account holders) and territorial. The division into subsystems may be based on economic sectors or regions. To add things instead of counting, the elements must have the same dimensionality. In economic value data only value vectors with the same time index are dimensionally commensurate. The physical attributes of commodities change very slowly, but prices do change relatively fast. We escape the dimensionality problem only when adding subsystems with the same time-coordinate. Fixing the price dimension (or volume dimension) is the main preoccupation of index theory. The fixed measurement is based, as we will see, either on economic theory or axiomatic theory that has analogies in the dimensional theory of physical models.

1.3 The Axiomatic Approach to Price and Volume Indexes

1.3.1 Defining Price and Volume Indexes

The economic system here is a linear input-output system with n sectors[1]. Volume and price vectors are defined in the system. Between two points of time the system moves along an, in principle, continuous path. A point in R^{2n+1} corresponds to a unique value of production **V**(**P**(t),**Q**(t)). The classic question in index theory is**:**

If the economic system moves from the value point V_0 to the point V_1 along a continuous or discrete path, what is the real change of production?

In economic theory there is no unique definition for the real change of prices or volumes. In general form a price index is defined as follows (Balk 1995, p. 71): A price index $P(t_0,t_1)$ is a positive function such that $P(t_0,t_1)$: $R^{4n}+ \rightarrow R++$, in other words $P(P_0,Q_0,P_1,Q_1)$: $R^{4n}+ \rightarrow R++$**,** where prices are strictly positive and quantities semi-positive**.** There is no explicit time in the above definition. Price and volume indexes may be defined over space, too. To fit index functions into economic theory, the dimensionality requirements of mathematical models must be fulfilled. Some technical and economic restrictions or axioms are also imposed on the above index functions.

1.3.2 Axiomatic Index Systems

Traditionally there are two approaches to building axiomatic index systems. The first is to start from a set of intuitively reasonable axioms and to test how known

[1]We have chosen the input-output system as a reference, because we wish to identify commodities with sectors. Although standard national accounts do not have pure sectors or unique price vectors, this should not be a problem as our aggregation level is the same as in the pure index theory.

indexes like Laspeyres and Paasche indexes fit with these axioms. The other, modern approach is to start from abstract index functions and the basic axioms and to try to construct consistent index formulas. With this approach some standard indexes emerge as unique solutions to a set of functional equations of determination (see e.g. Balk 1995, p. 71). These two approaches have been respectively termed **constructive** and **deductive** (Lippe 2001, p. 52). A distinction is made between **binary indexes**, **chain-indexes** and **continuous indexes**. A binary index is defined for two discrete time points in $Q^n x P^n x T$. A binary index is also called a **direct index**. A binary index is defined with all the vectors P_0, P_1, Q_0, and Q_1, if the index is **two-sided.** If the index is **one-sided** like the Laspeyres index, only three vectors out of the four define the index. But, only two vectors necessarily relate to the end points, for the weight vector may be chosen otherwise. With chain indexes each sub-interval increases the set of arguments by a pair of price and quantity vectors. For continuous indexes the set $C \in R^{2n+1}$, defining the value of the index is a continuous curve. The standard axioms related to **binary price and quantity indexes** are listed below (Selvanathan & Rao 1994, pp. 41-44). P and Q refer respectively to price and volume or synonymously to quantity indexes.

Standard Index Axioms:

1. **Positiveness**: $P(P_0,P_1,Q_0,Q_1) > 0$.

2. **Continuity**: $P(P_0,P_1,Q_0,Q_1)$ is continuous in its arguments.

3. **Identity Test**: $P(P,P,Q_0,Q_1) = 1$. In other words, if the property being measured (prices or quantities) does not change, the value of the index is unity.

4. **Proportionality Test**: $P(P_0,cP_1,Q_0,Q_1) = cP(P_0,P_1,Q_0,Q_1)$ for all $c > 0$.

(Here, in effect, the index is a function of P_1 alone. The other arguments are parameters.)

5. **Commodity Reversal Test**: No permutation of the function arguments should alter the price (volume) index.

6. **Invariance to Units of Measurement:** The index value is to be invariant relative to a change in the units of measurement. (This property is called **dimensionality** in the case of prices).

7. **Time Reversal Test**: $P(P_0,P_1,Q_0,Q_1)P(P_1,P_0,Q_1,Q_0) = 1$.

8. **Factor Reversal Test**: $P(P_0,P_1,Q_0,Q_1)Q(Q_0,Q_1,P_0,P_1) = P_I \bullet Q_I/(P_0 \bullet P_0)= V_{01}$.

9. Mean Value Test: The price and quantity indexes should be bounded by the minimum and maximum of price and quantity relatives.

10. Circularity Test: For any three periods 0, 1, 2 the index should satisfy the equation $P(P_0,P_1,Q_0,Q_1)P(P_1,P_2,Q_1,Q_2) = P(P_0,P_2,Q_0,Q_2)$.

Two important results are related to these axioms (Ibid. pp. 43-44):

Result 1: For $n \geq 2$, there is no index number formula that satisfies the conditions 1), 3), 8) and 10) simultaneously.

Result 2: For $n \geq 2$, a price index satisfies 1), 3), 4), 6) and 10), if and only if it is the Cobb-Douglas formula.

We see that, if circularity and factor reversal axioms should be true simultaneously, then other important properties like identity may be lost. Indexes that fulfill the identity axiom are called **pure indexes**. The Result 1 is remarkable because the factor reversal property is central in actual index methodologies. The above version of the factor reversal test is the so-called **strong form** of the **product test**. In this form price indexes become volume indexes by a symmetric change of function arguments. The **weak product test** requires only that the product of price and volume indexes is equal to the nominal value index. The above axiomatic system is very similar to Irving Fisher's original system of axioms (Fisher, 1922).

Fisher's approach was constructive in spirit. Normally, two formal requirements are imposed on axiomatic systems: The system should be axiomatically **consistent** and **independent**. The Fisher system is inconsistent by the above results (Result 1). It may also be shown to be dependent, but there is no reason to do this if the axiom set is inconsistent (Lippe2001, p. 73). The consistency of Fisher's original system was for long an open issue. It was proved inconsistent by Eichhorn and Voeller (Eichhorn & Voeller 1976, cited in Lippe, 2001, p. 53.). This was preceded by contributions of among others Frisch (1930), Wald (1937), Swamy (1964) and Samuelson & Swamy (1974).

The modern strict axiomatic approach is based on the work of W. Eichhorn and J. Voeller (ibid.). Their system had two versions. The first consisted of four axioms and the second of five axioms. In the four axiom system, the axioms are **monotonicity, dimensionality, commensurability** and **proportionality**. The latter variant postulates the first three axioms above and additionally the **identity property** as well as **linear homogeneity**. Dimensionality is here the same as **homogeneity** of **degree zero**. Dimensionality relates to prices and makes the change of the monetary unit neutral. Commensurability means that that the index is invariant to changing quantity units. Linear homogeneity means that a proportional change in prices or quantities of comparison is "separable" in the system. That is, it produces an equal change in the index. In this sense price and volume changes are **pure**. The system with four axioms is implied by the system with five axioms. In operational definitions a choice must be made between the potentially contradictory elements of the original Fisher system of axioms. The Fisher index excludes circularity, but fulfills the rest. The continuous Divisia index fulfills circularity, but is not proportional and thus is inconsistent with the Eichhorn-Voeller systems (see e.g. Balk, 2005, pp. 128). We recall here that in order to place the continuous Divisia index into the context binary indexes, we also have to fix the continuous path. The Fisher index is **ideal**, because it passes all the axiomatic tests excluding circularity.

1.3.3 Additivity and Aggregative Consistency

Additivity is a concept that is related to a function and an algebraic or a set theoretic operation. A set function $f: S \rightarrow R$ is additive if $f(AUB) = f(A) + f(B)$; $A \cap B = ø$. The probability measure may serve as an example. A price index is **additive in prices**, if we have $P(P_0,P_x,Q_0,Q_1) = P(P_0, P_1,Q_0,Q_1) + P(P_0,P_2,Q_0,Q_1)$; $x = P_1 + P_2$ (Lippe 2001, p. 67). Obviously, Laspeyres and Paasche price indexes are linear in prices due to the basic properties of inner products. Preferably, the index system should be **consistent** in **aggregation** (Dalen, 1999, p.181; Lippe 2001, p. 83). Consistency in aggregation implies that, if we divide the definition set of an index into two or more **disjoint subsets**, then the weighted sum of index values defined on the subsets should be equal to the total index. The sum is weighted, if relative weights are used within the subsets. Indexes are relative numbers and they do not generally behave like **additive measures** (for measures see Vulikh 1976, p. 86-88).

Theoretically, consistency in aggregation or additive consistency is related to indexes having the structure of commutative semi-groups (Pursiainen 2005, p.11). Let us assume that we have a definition set and a value set. On both sets a commutative and associative binary operation has been defined. Such operations include the set theoretic union and addition of real numbers. We note here that the additivity property of indexes is over time indexed $Q^n x P^n$; $t_o, t_1 \in T$. In time dimension the corresponding property is circularity.

If the law of one price is valid, then Laspeyres and Paasche indexes are obviously consistent in aggregation, whereas the Fisher index is not. These three indexes are defined respectively as $L_P = P_1 \bullet Q_0/(P_0 \bullet Q_0)$, $P_P = P_1 \bullet Q_1/(P_0 \bullet Q_1)$, $F_P = (L_P * P_P)^{1/2}$. An additional property of price indexes related to **deflation** is **structural consistency**. Let $V = \{V_i, i = 1, 2, 3, \ldots, n\}$ be disjoint nominal value sets and $P = \{P_i, i = 1, 2, 3, \ldots, n\}$ the corresponding price indexes. The index is **structurally consistent**, if $\sum V_i/P_i = V/P$ (Lippe, 2001, pp. 89-90). Thus the Paasche price index is structurally consistent in **direct deflation**. Because the Paasche price index and the Laspeyres volume index lead to the same result, *ceteris paribus* the nominal volumes, there is an analogous property for Laspeyres volume indexes. However, in this case we multiply and do not divide as in direct deflation.

1.3.4 The Fixed Metrics of Axiomatic Indexes

The basic problem with inter-temporal indexes in pure index theory is that the price metrics is time dependent. The normal task is to compare two value function points using a common measure. With standard indexes like Laspeyres and Paasche, the measure is fixed by fixing either prices or volumes. For many standard price and volume indexes the procedures are symmetric.

The fixed weight structure may refer either to price or volume vectors at the end points of the time interval or it may be a function of these. We may differentiate **observable**, **real, synthetic** and **fictive** data. Observable data vector is a vector that is some time perceptible. A combination of data vectors is real, if all parts are observable and simultaneous. Fictive data is something not directly observable. It may, however, be calculated by some theoretical rule. The Laspeyres price index is a combination of observable and non-simultaneous vectors. This case may be called synthetic. In empirical statistical methodology, the time metrics problem becomes similar with commodity volume metrics. When the characteristics of physical commodities change, one has to select between introducing new commodity axes and making quality corrections for volumes.

1.4 Economic Approaches to Price and Quantity Indexes

1.4.1 The Cost of Living Index for the Individual Consumer

The axiomatic approach assumes that prices and quantities are independent. This does not exclude non-zero empirical covariance between volumes and prices. The early stochastic approach to price indexes, as advocated by F.Y. Edgeworth, assumed short-term independence of prices and quantities. This was duly criticized by J.M, Keynes (Prasch, in Rima 1995, p. 178). However, the problem in this approach seems to be that the units of observation are not weighted.

The economic approach to price and volume index numbers starts from individual utility, cost or production functions and strives to find indexes defined by these economic aggregator functions. The first concept for consumer indexes was the **true index.** The true index is a cost of living index (**COLI)** different from axiomatic **fixed basket** indexes known as cost of the goods indexes (**GOGI)**. The true index was introduced by A. A. Konüs (Konüs & Bushgens 1926)[2]. In order to

[2]Konüs worked then in the famous Koniunkturnii Institut in Moscow together with Bushgens, who was a Moscow university mathematician.

define a binary price or quantity index some factor must be fixed. In standard **fixed basket** indexes, such as Laspeyres or Paasche, value or volume weights are fixed[3]. The **Konüs-Laspeyres** and the **Konüs-Paasche** indexes take the respective utility levels at the ends of the time interval $[t_0, t_1]$, as a fixed factor. The consumer **cost** or **expenditure function** is defined **C(P,U)** = min[**P•Q:** U(**Q**) ≥ **u; Q** ≥ **0**]. This is the **dual problem** of the utility maximization problem. The **Konüs cost of living index** is generally defined (Selvanathan & Rao 1994, p. 31):

$$\mathbf{I_{01\ Kon\ddot{u}s} = C(P_1,U_r)/C(P_0,U_r),}$$

where $\mathbf{U_r}$ is the chosen Laspeyres, Paasche or some other level of **reference utility**. The consumer cost index is analogous to the **Hicksian demand function**. The Hicksian demand function h(p,u) is defined as min{P●Q: U(q) ≥ U_0} (Varian 1992, p. 105). The Laspeyres-Konüs price index is related to the concept of **compensating variation (CV)** in microeconomics (At What Prices …, pp. 80-81). Compensating variation is defined CV = C (P_1,U_0)-$C(P_0,U_0)$. The Paasche-Konüs price index is related to the concept of **equivalent variation (EV).** Equivalent variation is defined EV= $C(P_1,U_1)-C(P_0,U_1)$. Therefore CV and EV are difference equivalents for cost ratios (ibid.). With economic indexes we assume that there exists a utility function or some other aggregator function that spans the economic behavior. CV and EV may be represented as **consumer surpluses** related to the two Hicks's demand functions defined by the binary points of comparison on the **Marshallian demand function**. Given that there are n goods we have (Cowell 1986, pp. 82-83):

$$CV = C(P_1,U_0)-C(P_0,U_0) = \sum \int H_i(p,u_0)dp_i; \text{ integrated on } [P_1, P_0],$$

$$EV = C(P_1,U_1)-C(P_0,U_1) = \sum \int H_i(p,u_1)dp_i; \text{ integrated on } [P_1, P_0].$$

If the utility function is the **Leontief fixed coefficient function**, then Konüs-Laspeyres and Konüs-Paasche indexes are identical to the standard Laspeyres and Paasche indexes. If not, the Konüs-Paasche is bounded from below by the Paasche

[3] A fixed basket index uses a constant weight vector e.g. Laspeyres price index $P_1●Q_0/P_0●Q_0$.

index and the Konüs-Laspeyres is bounded from above by the Laspeyres index. If the utility function is **homothetic**, then both Konüs-indexes coincide (Selvanathan&Rao 1994, pp. 33-34). Thus, in this special case the **true index** is unique and independent on the reference utility**.** We cannot be sure to find upper and lower bounds at the same time. There is no a priori order for Laspeyres and Paasche indexes.

Economic COLI-indexes have utility functions as theoretical aggregator functions. These indexes include the Konüs price index, the **Allen** and **Malmquist quantity** indexes. The **Allen quantity index** is based on the principle of constant price comparisons. If the consumer expenditure function is C(P,U) and the initial and current utility level are U_0 and U_1, then the Allen quantity index is defined as $A_Q = C(P_r,U_1)/C(P_r,U_0)$ (Selvanathan & Rao 1994, p. 39). The U_r may or may not coincide with U_0 or U1. For the Malmquist quantity index we first define the **Malmquist distance** of two quantity vectors: $D(q_1,q)= \max \{ k: U(q_1/k) \geq U(q); k > 0 \}$. The Malmquist index for two vectors q_0, q_1 with q_r as a reference factor is then defined $M_Q = D(q_1,q_r)/D(q_0,q_r)$ (Selvanathan & Rao 1994, pp. 39-41). The economic consumer indexes fulfill only the weak product test. That is the adequate index pair consists of the index proper and its residual derived from the factor reversal test.

The uniqueness of the above economic consumer indexes depends on the utility function. Generally the true index is independent on reference utility only in the homothetic case. If the reference utility is chosen on the real time path, it is a function of time. We see that an arbitrary utility level reference point U_r, $r \in [t_0,t_1]$ may define an index that is clearly distinct from L_P, P_P and the F_P. When seeking observable proxies for unobservable economic indexes, we have to consider at least the type of aggregator functions, the selection of the reference point $r \in [t_0,t_1]$ and the effect of more frequent chaining of the reviewed indexes.

If the use of binary Laspeyres or Paasche indexes is thought to be biased, e.g. because of a long sample period, indexes that require more than binary point information, like the true index or some chain index, may be preferred. Hence, the information problem is normally solved with chain indexes or **superlative indexes** that approximate the true index. We will deal with superlative indexes later. From the point of view of statistical methodology the range of indexes is set by Laspeyres and Paasche binary indexes, the proxies of economic indexes and chain indexes.

1.4.2 The Optimizing Producer

The **COLI** or cost of living indexes focus on final production. From the point of view of a producer the situation is more complex. In the notation of the input-output model, final production is represented with the vector or matrix Y_F. The total production vector is X and intermediate production is represented by the vector AX_{nx1} or in matrix form $(x_{ij})_{nxn}$, where A is the input-output matrix. Value-added elements including wages, profits and other capital income are in the third quadrant of the I-O model. A consumer buys only end products, whereas a producer buys inputs and sells outputs. Formally, the nomenclature of final and intermediate production may be the same. Differences and changes in **technology** lead to different price dynamics of intermediate and final production.

Instead of utility based index types there are three producer indexes: **output indexes** for revenue or sales, **input indexes** for intermediate purchases and a profit or net revenue based indexes for the **value-added**. Value-added indexes must be calculated as residuals, for standard indexes use physical commodity flows and prices as arguments, but in the value added part of the accounts there are only value flows. Many analogies seem to exist between consumer and producer indexes. Some of these are presented in the table below (Table 1.4.2.1). Apparently, the dual problem, first order conditions, compensated demand properties as well as substitution effects are analogous. The basic microeconomic theory of producer price indexes was first formulated some 50 years after Konüs' true price index by Shell and Fisher in 1972 and R. Archibald in 1977. The main features of the following sketch are from IFM PPI manual (IFM 2005, chapters 17-18). The production function is based on technology sets that define the relation between net production and inputs including intermediate and primary inputs.

The **technically efficient technology set Y_e** is defined by: $Y_e = \{y: y \in Y, y^* \geq y \Rightarrow y^*$ is not in $Y\}$ (Cowell 1986, p 15). The technically efficient set is defined by the production function. In multi-product cases the efficient set is defined by the implicit production function $F(Q,Z) = 0$; where Q is the product vector and Z the vector of factor inputs (Grubbström 1997, p 152). Consuming inputs is signed negatively and production positively. In the case of **output indexes** it is assumed that the firm (or an establishment) maximizes its revenue under efficient technology constraint; $(Q, Z) \in Y_e$. Relative to the **input index,** the production level is assumed constant and optimal. The firm minimizes the cost function under these constraints. As for the **value added**, the function to be optimized is the net revenue function.

Table 1.4.2.1 Formal Aspects of Consumer and Producer Behavior

Item	Firm		Household
Dual Problem	$\min \sum w_i z_i$; $G(z) \geq Q_0$		$\min \sum p_i x_i$; $U(x) \geq u_0$
First-order conditions	$w_j/w_i = G_j/G_i = MRTS_{ij}$		$p_j/p_i = U_j/U_i = MRS_{ij}$
Cost Function	$C(w,Q_o)$, increasing in Q_0		$C(p,u_0)$, increasing in u_0
	concave in w		concave in p
Compensated Demand	$z_i^* = C_i(w,Q_0) \geq 0$		$x_i^* = C_i(p,u_0) \geq 0$
Substitution Effects	$\hat{D}_{ij} < 0$, $\hat{D}_{ji} = \hat{D}_{ij}$		$\hat{D}_{ij} < 0$, $\hat{D}_{ji} = \hat{D}_{ij}$
	Cowell 1986, p. 85		

Below we summarize the main results used for producer indexes. Producer price indexes follow **the theoretical COLI** relative to upper and lower limits for the theoretical index only in the case of the input price index. Both the input index and consumer indexes are based on minimization cases. With output indexes and the value added deflator the standard Paasche index dominates the economic Paasche type index $PPI(P_0,P_1,V_1)$. The situation is the opposite with Laspeyres variants. In the theory of economic indexes proxies for true indexes are sought with so-called **superlative indexes**.

There are two problems with the economic consumer indexes: first, one of the required volume vectors may be virtual and must be calculated and secondly it is often impossible to define operationally the required aggregator functions such as utility functions. The problem with producer price indexes is very similar. It is normally, however, possible to define operationally the aggregator functions. That is production functions.

Table 1.4.2.2 Main Features of Producer Price Indexes

	Output Index	**Input Index**	**Value-Added Deflator**
	MAX	MIN	MAX
Objective functions	**R(P,Z,V), revenue (Q,Z) in Y_e**	**C(Q,Z,V), cost (Q,Z) in Y_e**	**R(P,Z,V)-C(Q,Z,V) (Q,Z) in Y_e**
Index defined PPI(V)	**$R(P_1,Q,Z,V)/R(P_0,QZ,V)$**	**$C(P_1,Q,Z,V)/C(P_0,Q,Z,V)$**	**$R(P_1,Q,Z,V)-C(P_1,Q,Z,V)\}/\{R(P_0,Z,V)-C(P_0,Q,Z,V)\}$**
Laspeyres-Paasche Spread LPS	**$PPI(V_0) \geq Laspeyres_{PI}$** **$PPI(V_1) \leq Paasche_{PI}$**	**$PPI(V_0) \leq Laspeyres_{PI}$** **$PPI(V_1) \geq Paasche_{PI}$**	**$PPI(V_0) \geq Laspeyres_{PI}$** **$PPI(V_1) \leq Paasche_{PI}$**

LPS= Laspeyres/Paasche; V = the chosen technology

IFM PPI-manual, chapters 17-18,2005, pp. 440, 453.
Any technology V may be chosen, but V is in [Vt_0, Vt_1] normally

However, statistical agencies generally have no such detailed data. We return later to the superlative indexes. The individual microeconomic tendencies of consumer and producer price indexes influence the macro-economic consumer and producer indexes through many layers. First, there are the issues of aggregation of firms and consumers, secondly the pure theory results presuppose perfect competition and, last but not least, the calculated macro-economic indexes must be consistent with the national accounting data frame. Some further features relate to the technicalities of the statistical methodology.

1.5 Some Problems of Aggregation

1.5.1 The Representative Consumer

The cost of living index of a single consumer has to be generalized over a group of consumers in order to preserve the microeconomic rationale of the cost of living indexes. There have been two approaches. The first is the paradigm of the **representative consumer** and the second is to define representative indexes using **social welfare functions**, based on individual utilities. If a representative consumer or a social welfare function may not be postulated, then the somehow aggregated individual indexes must be put into the context of standard aggregated Laspeyres and Paasche indexes. The group behavior of consumers is represented with a **representative utility function**. In the first case the representative utility function is aggregated out of individual utility functions. The COLI index is closely related to the concepts of compensating and equivalent demand variation in the individual case. It is possible to aggregate the individual demand functions to a collective demand function. In order to have an analogous structure for COLI in collective and individual cases the aggregated utility function and atomistic utility optimization should lead to the same demand changes when prices change. This is a problem because individual demand is a function of all prices and individual incomes and the collective demand is a function all prices and total income. We therefore need a representative utility function that behaves under optimization like atomistic market.

The function v(p, m) that gives the maximum utility achievable at given prices and income is called the **indirect utility function** (Varian 1992, p. 99). If the individual indirect utility functions of consumers can be presented in the **Gorman form** (ibid., p. 153-154): $\mathbf{v_i(p,m_i) = a_i(p) + b(p)m_i}$, then the **indirect utility function** of the representative consumer may be presented in the form:

$$V(\mathbf{P},M)= \sum \mathbf{a_i(p)} + b(\mathbf{P})M = A(\mathbf{P}) + B(\mathbf{P})M\mathbf{;}\ \mathbf{M}= \sum m_i.$$

Above p is the price vector and m_i the individual budget constraint. The function a_i is consumer specific and the function b general for all consumers. The representation of indirect utility functions in the Gorman form is a **necessary** and **sufficient condition** for the existence of the representative consumer model (ibid.). No assumption is made about the distribution of wealth. Homothetic and quasi-linear indirect utility functions are a subgroup of Gorman form functions (ibid., p. 154).

If we know the individual, Gorman form indirect utility functions, then we may apply the normal reasoning related e.g. to Konüs true indexes and the representative utility function. If we use the model of the representative consumer under less binding restrictions for individual indirect utility functions, we make, in effect, an **approximate operational definition** and the biases relative to e.g. standard Laspeyres and Paasche indexes are difficult to estimate quantitatively. In microeconomics we need not worry about operational definitions. Index theory, however, is closer to empirical economics.

Concluding from the empirical data back towards theoretical concepts, we may verify statistically whether the data rationalizes some preference structure or utility function by the known **GARP**, **WARP** or **SARP** criteria (Varian 1992, pp. 132-133). A positive result neither contradicts nor corroborates the existence of utility functions or their aggregation properties, whereas a negative result is definite with stochastic qualifications.

1.5.2 Indexes Based on Social Welfare Functions

The theory of social **cost** of **living indexes** (**SOCOLI**) was pioneered by Pollak (Pollak 1989). The representative utility or cost function is replaced by a **social welfare function** of the **Bergson-Samuelson type** (**SWF**). Since the social welfare function is based on individual utility functions, it is a monotonously continuous function of individual utilities. Pollak's SWF is **Pareto-inclusive.** This means that a rise in each individual's utility leads to increased social welfare, when other utilities are unchanged (Pollak 1989, p. 128-132). SWF defines a preference ordering based on individual utility functions as arguments. A social expenditure function is defined for the social welfare level R or the corresponding indifference curve with the associated price vector P and the collective commodity vector X distributed among the set of consumers.

$E(\mathbf{P},\mathbf{X},\mathbf{R}) = \min \sum E(\mathbf{P},\mathbf{X_i},R_i)$; **i** is over consumers.

The individual expenditure functions are on the right side, where X_i: s and R_i:s coincide with the SWF level R and the vectors X and P. The **social cost of living** index (**SOCOLI**) is defined as (ibid.):

$I(\mathbf{P_0},\mathbf{P_1},\mathbf{X},\mathbf{R}) = E(\mathbf{P_1},\mathbf{X},\mathbf{R}) / E(\mathbf{P_0},\mathbf{X},\mathbf{R})$.

To calculate the SOCOLI index, we must know the individual utility functions and define the function form of the SWF. In two special cases the SOCOLI index may be calculated directly with market demand functions. These are the case of the **maximizing society**, where society also redistributes the incomes in the maximizing task and the **independent society**, where the market demand functions are independent of the distribution of expenditure among households (ibid. pp. 133-139).

Pollak also introduced the so-called **Scitovsky-Laspeyres** cost of living index (**SLI**). Having fixed the social welfare level R and the related individual levels of utility, the sum of denominators of the individual COLI indexes is divided by the sum of the corresponding numerators (Pollak 1989. p. 139-142). The SLI index is a **plutocratic** index**,** for each household comes in with its own expenditure weight. A **democratic** index is un-weighted. Because the Laspeyres and Paasche indexes are consistent in aggregation, the upper and lower limits in terms of Laspeyres and Paasche indexes preserve their order in aggregation.

On the one hand, it is obvious that individual direct and indirect utility functions can be aggregated into a representative consumer only under very strict conditions. On the other hand a SOCOLI index depends generally on the chosen SWF-form. SOCOLI-values are independent on pre-selected function form only in the cases of maximizing and independent societies. The edge of the theoretical COLI index over axiomatic indexes and GOGI is qualitative; the COLI index acknowledges the existence of substitution as a model ingredient. The empirical result depends on how well the proxies fit the theoretical model.

1.5.3 Aggregating Economic Indexes

Theoretically aggregation is easier with production functions than utility functions. Production functions have by definition the same dimensionality. It is obvious, that although there is an aggregated production function, it is not usually possible to change the level of optimization. Therefore, the above listed limits of variation for individual producer price functions may be defined only for the sums of the individual producer price indexes of three types. In the aggregated case the COLI indexes and producer input price index behave similarly. While the output index and the value-added deflator have different upper and lower limits in terms of standard Laspeyres and Paasche indexes. The case for economic consumer price indexes is theoretically much weaker than for producer price indexes because production functions are easier to make instrumental than COLIs. In practice, both types are unobservable and serve only as conceptual limits. There are no numerical estimates for the deviance of theoretical economic indexes from Laspeyres and Paasche limits. We recall that the theoretical Laspeyres producer price index dominates the ordinary Laspeyres price index in the case of output, while with Paasche indexes the ordinary index dominates.

Diewert defined a **group** quantity index based on Allen's definition of the individual index by aggregating the individual indexes similarly to the Scitovsky-Laspeyres index (Diewert 2001, pp. 175-179). It can be shown that Diewert's **generalized Allen-Laspeyres** index is bounded from the above by the Laspyeres quantity index and from below by the Paasche quantity index in end-points. There exists a price vector P in $[P_0,P_1]$, such that the generalized Allen quantity index falls between the Paasche and Laspeyres quantity indexes (ibid.).

The **fixed basket indexes** like Laspeyres or Paasche ignore the substitution problem. Depending on our approach, we may consider the problem as a **cost of**

living substitution bias or as a **sample representativity bias.** In the case of the Konüs true index one or both volume vectors may be fictive. If the volume vectors are not **observable,** then they must be calculated directly or indirectly with the utility function, which is a theoretical construction. The Konüs-Laspeyres price index illustrates this. One commodity vector is observable and the other is generally non-observable. The axiomatic approach considers the bias of substitution as a sampling problem. The Fisher index may serve as a solution. It generally diminishes the representation bias accumulated during the sample period, but it requires more data.

1.6 Binary Indexes, Chain Indexes and Continuous Divisia Indexes

1.6.1 Defining Continuous Indexes

The value function, $\mathbf{V}(t) = \mathbf{P}(t)\bullet\mathbf{Q}(t)$, aggregates nominal production. Let $V(t_0)$ be the **value function**, $t \in t_0$. A **value index** with reference to t_0 may be defined as:

$\mathbf{V(t_0,t)} = V(t)/V(t_o) = \mathbf{P}(t)\bullet\mathbf{Q}(t)/\mathbf{P}(t_0)\bullet\mathbf{Q}(t_0)$.

The logarithmic derivative of $V(t)$ is defined as

$\mathbf{D_t}[\log(\mathbf{V}(t)] = \mathbf{D_t}[\mathbf{V}(t)]/\mathbf{V}(t)$, where

$\mathbf{D_t}[V(t)] = \mathbf{D_t}[\mathbf{P}(t)]\bullet\mathbf{Q}(t) + \mathbf{D_t}[\mathbf{Q}(t)]\bullet\mathbf{P}(t)$; (Vogt 1977, p. 77-79).[4]

Accordingly we have

$\mathbf{D_t}[V(t)]/V(t) = \{\mathbf{D_t}[\mathbf{P}(t)]\bullet\mathbf{Q}(t) + \mathbf{D_t}[\mathbf{Q}(t)]\bullet\mathbf{P}(t)\}[\mathbf{P}(t)\bullet\mathbf{Q}(t)]^{-1}$.

The above mapping is f**:** T → R and the equation is a standard differential equation defining the value function V(t) as a parametric family of exponential functions with an arbitrary, additive real constant:

$\mathbf{V}(t) = \exp \int \{\{ \mathbf{D_t}[\mathbf{P}(t)]\bullet\mathbf{Q}(t) + \mathbf{D_t}[\mathbf{Q}(t)]\bullet\mathbf{P}(t)\}/\mathbf{P}(t)\bullet\mathbf{Q}(t)\}$.

Following Vogt and Kaiser we may present the value index $V(t_0,t)$ as:

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[4] D_t denotes the differential operator relative to argument t. $V(t) \in R^n$.

$V(t_0,t) = \exp \int_T V(\tau)d\tau = \exp \int \{[\mathbf{D}\tau[\mathbf{P}(\tau)]\bullet\mathbf{Q}(\tau) + \mathbf{D}\tau[\mathbf{Q}(\tau)]\bullet\mathbf{P}(\tau)]/\mathbf{P}(\tau)\bullet\mathbf{Q}(\tau)\}$;

$T = [t_0, t]$; (Vogt 1977, p. 78, Kaiser 1974).

The first part on the right of $V(t_0,t)$ refers to instant price index and the second to the instant volume index (ibid.)[5]. To define a chain index as a line integral we must define a division for the interval T. The value of the definite integral on T may be presented as a product of exponential sub-integrals determined by the chosen division. Because of the additive properties of definite integrals and the product of exponential integrals the chain index has the same formal presentation as the above function $V(t_0,t)$. Each division of T defines a specific line integral (ibid.) A general line integral may or may not be path independent. If, however, the integral is **path independent**, as is the case with the value index, the result is the same along all closed paths (Ibid.). However, the price and volume index part taken separately are dependent on the path of integration (Vogt ibid.). If the time path in Q(t)xP(t) in defined by the curve C, when we define the **Divisia-**price index as:

$\mathbf{P}_{\mathbf{divC}} = \exp \int_C \{ \mathbf{D}_\tau[\mathbf{P}(\tau)]\bullet\mathbf{Q}(\tau)/(\mathbf{P}(\tau)\bullet\mathbf{Q}(\tau))\}$.

The **Divisia** volume index is defined as:

$\mathbf{Q}_{\mathbf{divC}} = \exp \int_C \{ \mathbf{D}_\tau[\mathbf{Q}(\tau)]\bullet\mathbf{P}(\tau)/(\mathbf{P}(\tau)\bullet\mathbf{Q}(\tau))\}$.

We have defined the **Divisia rule**: Quantity changes without price changes should not change the price index. The property is analogous in the case of a quantity index (Ibid.). It is easy to show that the Divisia price and quantity indexes are not generally path independent integrals (Vogt&Bartha, 1997, pp. 27-39; Adams 1999, pp. 900-902). With Divisia indexes, we may not know the path of the economy $\mathbf{C}(t_{0,}t)$ defined on the interval $[t_0,t]$. A. Vogt solved this problem by defining his **Natural Divisia** indexes as line integrals along the straight line between the binary end points of the path in $Q^n x P^n x T$. This approach uses more path-information than a binary index. He also defined many standard indexes as Divisia indexes over specific, **fictive** paths. The continuous Divisia-index for prices or volumes is the limit of chained Laspeyres and Paasche indexes, when the number of divisions of the time interval (t_0,t) approaches infinity and the max length of subintervals $\rightarrow 0$ (see e.g. Allen 1975 p. 178-180). The binary Laspeyres and Paasche indexes may

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[5] These were first defined by Divisia (Divisia 1925)

be presented as line integrals along corresponding coordinate axes intervals. A similar procedure is possible for the Edgeworth and Walsh indexes (Vogt ibid.) Using the so-called **Bortkiewicz** and **factor** quotients we may add the Fisher ideal index into the comparison (Köves 1983, pp. 145-146).

1.6.2 The Dynamics of the Laspeyres-Paasche Spread

The value of price and quantity indexes depends on the mathematical index formula as well as on the time interval. 0perational index formulas are usually: **Laspeyres**, **Paasche**, **Fisher**, **Walsh**, **Törnquist** or **Edgeworth indexes**. The Törnquist index is also called the Theil-Törnquist index. The Walsh price index is a fixed basket index. It is defined as follows in matrix notation[6] $[P_1\bullet(Q_1.\bullet Q_0)^{.(1/2)}]/[P_0\bullet(Q_1.\bullet Q_0)^{.(1/2)}]$, where prices are weighted with the square roots of the respective end-point volume components. The Edgeworth index has the arithmetic mean of end-points as weights. The Theil-Törnquist index is a weighted geometric mean. The weight vector is the mean of Laspeyres and Paasche weights. In the economic approach the choice of the proxy index formula as a rule leads to **superlative index formulas**.

Four statistical and mathematical laws are represented below. The first concerns the Laspeyres-Paasche spread (**LPS**)[7]. The first law in a price index version is:

Theorem 1. The Paasche price-index is greater than the Laspeyres price index if prices and quantities tend to move in the same direction between the base year and the end year; The Laspeyres price-index is greater than the Paasche price-index, if prices and quantities tend to go in opposite directions (Allen 1975 p. 64).

The covariance of prices and volumes is measured with the Laspeyres style weighted **Pearson's product moment correlation** of price and quantity relatives. The weights are the respective Laspeyres shares. The result is valid for price and

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[6] The pre-dotted exponents and products signify exponentiation and product by components (the notation is Matlab standard).

[7] Here the interval is [LP, PP] or [LQ,PQ] and the indicator in quotient form is LP/PP or LQ/PQ.

volume indexes. The second theorem concerns the **drifting effects** of chained Laspeyres price indexes. Drifting measures the deviation of a chain index from the binary index. To recall if a chain index is calculated with fixed binary Laspeyres weights, the product index is equal to the binary Laspeyres index.

Theorem 2. There is a positive (upward) drifting effect in chaining Laspeyres price indexes, if the terms $(p_{t+1})/(p_t)$ and q_t/q_0 correlate positively in the index data. If the weighted correlation is negative, then the drifting effect is negative or downward (Allen 1975, p. 187).

The overall effect depends on the product effect of individual sub intervals. The Laspeyres price index belongs together with the Paasche volume index and Paasche price indexes are related to Laspeyres volume indexes. We may define Laspeyres and Paasche indexes as continuous Divisia-indexes integrated on respective, fictive paths[8] (Vogt 1979, 51-52). This leads to the third theorem that concerns the difference between **Natural Divisia index** and the **continuous Divisia index**. The Divisia-index is path dependent. The value of the Divisia-index depends on both the end points of the reviewed interval and on the actual path between these ends.

Theorem 3. The logarithm of the quotient of the Natural Divisia index and the chained Divisia index (**piecewise linear path**) may be represented as a **closed** line integral along the real and natural path (See. Vogt, 1977, pp. 85-86).

Thus, the logarithm quotient is proportional to the area under the closed integral defined by natural Divisia path and a continuous path.

Thus, the logarithmic quotient is a measure of difference between the two Divisia indexes. We can calculate the Laspeyres-Paasche spread with line-integrals. The natural path is a straight line between the binary end points $[(Q_0,P_0), (Q_1,P_1)]$. The fourth theorem concerns the order the Fisher index and the Natural index. It is based on the Bortkiewicz and factor-quotient indexes (Köves, 1983, pp. 143-146).

[8] Vogt defines the potential domain of integration with the 4n-fold “rectangle” in $Q^n x P^n$, bounded by the boundary vectors (Q_0,Q_1,P_0,P_1). Laspeyres and Paasche indexes are defined as line integrals on the intervals $[Q_0,Q_1]$ or $[P_0,P_1]$.

Theorem 4. Let us define the Bortkiewicz-quotient as B = PQ/LQ and the factor quotient as R = LP/LQ. If B < 1 and R < 1, then it follows that NP < FP. If R = 1 then NP = FP. Otherwise if R> 1, then NP > FP. The inequalities are the opposite if B >1. (Köves, 1983, p.146).

If the Laspeyres index dominates and the inflation rate is lower than volume growth rate, then the Natural Divisia price index is less than the Fisher index. Although the Paasche index may be larger than the Laspeyres index, usually it is not. This is the standard micro theory view. The **LPS** is usually an increasing function of the length of the time interval. For technical reasons the actual Laspeyres price indexes are often **Lowe fixed basket indexes** with a weight structure that precedes the reference year. By the drifting law above, drifting increases in the long run the value of the chained Paasche index and decreases the value of the chained Laspeyres index. This is valid for growing economies with moderate oscillations. It is obvious that chain indexes may be effectively approximated with binary Fisher, Walsh and Törnquist indexes when the actual time path of the economy is close to the straight line defining **Vogt's Natural** index. By the fourth theorem, the value of the Fisher index moves around the value of the Natural Divisia index depending on the Bortkiewicz and factor quotients. If the growth has a strong trend concentrated in the beginning or in the end of the path, then binary superlative indexes tend to distance from chain indexes and move towards binary Laspeyres or Paasche indexes. A chain index with strong variation may or may not be close to the Natural Divisia index, depending on the test integral defined by the third theorem. Ultimately, index formulas and the length of the base sample-period make a difference numerically. This should be observed in long term international comparisons. The OECD members traditionally used Laspeyres price indexes with five-year or annual basis for inflation measurement and Paasche price indexes for deflating the GDP. By contrast, the former planned economies used Laspeyres quantity indexes with annual and five year base period.

1.7 Theoretical Indexes and Operational Indexes

1.7.1 Superlative Individual Indexes as Observable Indexes

The binary, standard indexes are fully defined, excluding sampling complications, using the four vectors P_0, P_1, Q_0, Q_1 or some of their functions. Economic indexes are based on **aggregator functions,** which are **theoretical constructs**. Utility functions are a parade case, but even in the case of technology it may be difficult to find empirical production functions. This is a problem, because with the theoretical economic price indexes, the quantity input vectors must be calculated from theoretical functions. The introduction of superlative **indexes** gives some formal guidance for choosing the operational indexes in the case of theoretical COLI or economic PPI indexes. For instance, the Laspeyres-Konüs and Paasche-Konüs-indexes collapse into a **unique** true index**,** when the utility function is **homothetic (**Selvanathan & Rao 1994, pp. 30-34). In this case the value of the true price index is independent of reference utility.

A twice, continuously differentiable function is called a **second order flexible form** relative to another function if the two functions coincide at the level of first and second order partial derivatives in some environment of the point x_0. An Index is **exact** relative to the aggregator function $f(\mathbf{X})$, if $I(\mathbf{X}_0,\mathbf{X}_1) = f(\mathbf{X}_1)/f(\mathbf{X}_0)$. Let $f(\mathbf{X})$ be a twice differentiable aggregator function. An index $I(\mathbf{X}_0,\mathbf{X}_1)$ is called **superlative** if the function $I(\mathbf{X}_0,\mathbf{X}_1)$ is **exact** for $f(\mathbf{X})$, which is a flexible form for the **linearly homogenous aggregator** function $F(\mathbf{X})$. In very small neighborhoods $N(\mathbf{X},\epsilon)$ the aggregator function $F(\mathbf{X})$ may now be approximated with the function $f(\mathbf{X})$ (see Diewert 1976). We recall that X is a function of time. The Konüs true index is **effectively** independent of the chosen utility level in $N(\mathbf{X},\epsilon)$. In the environment $N(\mathbf{X},\epsilon)$ superlative indexes like Fisher, Walsh and Törnquist closely approximate the respective true index. The well-known result by Diewert (1978) showed that all known superlative indexes approximate each other to the second order (cited in Hill 2002). However, this result concerns the above-defined **infinitesimal environments**. If ϵ is very small in $N(X(t),\epsilon)$, then the respective time interval is very short. Moreover, empirical limits for the minimum size of measurement intervals and the problems of seasonal variation are also brought in. Obviously, we have to consider how superlative indexes may be used operationally. R. J. Hill studied the superlative index family of **quadratic mean** of order-r aggregator functions $f_r(\mathbf{X})$,

$$f_r(\mathbf{X}) = (\sum\sum a_{ij} x_i^{r/2} x_j^{r/2})^{1/r}; \; i, j = 1,2,3, ...,N.$$

When r =1,2, we have respectively the Walsh and Fisher indexes. The **translog-aggregator function** related to the Törnquist index is the limit of $f_r(\mathbf{X})$, when $r \rightarrow 0$. Hill showed that if the length of $T= [t_0,t_1]$ grows, then only the quadratic mean of order-r indexes with $0 \leq r \leq 2$ fall within the Laspeyres-Paasche spread and approximate each other closely (Hill 2002, p. 17).

We may conclude that the superlative, quadratic order-r indexes are close to each other, either in small neighborhoods $N(\mathbf{X}(t),\varepsilon)$ or when $0 \leq r \leq 2$. Outside infinitesimal neighborhoods superlative indexes like the Fisher index may deviate from economic indexes as well as chain indexes. Outside the linear range of the original definition of the superlative index the economic index may not be independent of the reference utility level. For operational indexes it is useful to know that in the case of the COLI there exists a reference utility in $[U_0, U_1]$ such that the true index belongs to LPS (Konüs 1924)[9]. As for economic producer price indexes there exists a linear combination of end point technologies $[V_0,V_1]$; $V_a = aV_0+(1-a)V_1$; a in [0,1] such that the economic producer index belongs to the LPS-interval (IMF 2005,ch. 17-18).

1.7.2 The Convergence of Economic and Axiomatic Indexes

We use the term convergence here in a soft sense. The subject is too large and heterogeneous to apply a strict theory of convergence for function series, in norm or in probability measure. We wish to see when the four groups of indexes: the additive standard binary indexes; the superlative indexes: Fisher, Walsh and

[9] Translated into English in Konüs 1939. Original citation in At What Prices ..., p. 82.

Törnquist indexes; the economic indexes and chain indexes converge mathematically or empirically. There are two requirements: indexes should be based on microeconomic theory and the substitution problem should be reduced. Our point of view is statistical methodology. Therefore, all indexes should be observable. The traditional solution has been to replace the theoretical indexes with superlative indexes and increase the frequency of chaining either for standard additive or superlative indexes.

An axiomatic index preferably fulfills most of the classical and modern axioms (Fisher 1922, Balk 1995). The **circularity axiom** is not congruent with some other basic axioms such as the positiveness, identity and very importantly the **factor reversal test** (Selvanathan & Rao 1994, pp. 43-44). We consider here Laspeyres, Paasche, Fisher, Walsh, Törnquist and the continuous Divisia-indexes as standard axiomatic indexes. The Fisher Index is called the **ideal index**, because it satisfies all but the circularity axiom (ibid.). Despite its axiomatic properties, the Fisher index is not consistent in aggregation, whereas the Laspeyres, Paasche and Walsh indexes are. This is because they are simple fixed basket indexes.

The true price index is precise in operational sense only, when the utility function is linearly homogenous, exactly or approximately. Otherwise, the definition of the Konüs-true index leads to a parametric set of index functions. *Ceteris paribus* the sample period, the normal way to make the COLI indexes operational is to use superlative indexes such as the Fisher, Walsh and Törnquist indexes. The solution is the same with producer-type indexes. The economic approach with producer price indexes leads to finding theoretical limits in terms of standard Laspeyres and Paasche indexes.

The **substitution bias** with Laspeyres and Paasche indexes refers to two different concepts. The first is the normal requirement that the sample must be **representative** of the **population**. With economic indexes the substitution bias refers to the fact that the weights are fixed with Laspeyres or Paasche, whereas the true price index or economic producer price indexes presume **adapting quantities** when prices change. If we measure the **substitution bias** with the distance of Laspeyres or Paasche indexes from the Fisher index, we have to assume that the

Fisher index approximates the true index. If no very strict assumptions are made about individual utility or production functions, economic indexes do not necessarily solve the statistical representation problem because, as noted above, the economic indexes are generally a parametric set of functions. We recall that the standard superlative indexes belong to the LPS-interval spanned by Laspeyres and Paasche indexes. Above it was seen that the theoretical indexes may be outside the LPS on either side.

Within the UN-supported SNA and especially in the OECD and EU the development of deflator methodology has followed two lines: first following the economic approach the superlative indexes have been researched as well recommended as observable proxies for economic indexes. Secondly, chain indexes have become more popular and the basic sample period shorter, minimizing the LPS and statistical representation bias. The theory of economic indexes and Bortkiewicz's laws of the LPS as well as of the drifting of chain indexes are the background behind the changes. Bortkiewicz's laws for LPS may be extended for all additive indexes (Lippe, 2001, p. 74). Bortkiewicz's laws are statistical and they do not directly derive from microeconomics. The negative test correlation (Laspeyres dominance) between the Laspeyres weighted correlation of price relatives and volume relatives is customarily seen as an indicator of competitive markets and positive test correlation (Paasche dominance) as an indicator of seller controlled economies (see e.g. Allen 1975, p. 64). The negative correlation is seen as a tendency working due to microeconomic efficiency tenets, but in macroeconomic systems subject to exogenous disturbances, the Laspeyres dominance has the character of empirical statistical tendency. It is obvious that long term Paasche dominance will lead to stagnating growth. That is the prices of fastest growing commodity series rise fastest. Choosing a superlative index on any interval, helps to alleviate uncertainty due to the LPS. Nevertheless, this does not solve the problem of convergence for chain indexes.

The convergence of chain indexes relates to the two theorems presented before: the second theorem on the drifting Laspeyres and Paasche indexes and also the third theorem on the quotients of general chain index and the Natural Divisia index. It is obvious that chain indexes may exceed the upper binary index or go below the lower binary index only when part of the variation of chain indexes, in the integration space defined by $[t_0,t_1]$, is outside the hyper-cube limited by $[(Q(t_0), P(t_0)),(Q(t_1),P(t_1))]$. The drifting laws define the test correlation criteria for chain indexes to be outside the LPS. We recall that chain indexes are generally different from binary indexes because chain indexes have time dependent metrics. The tendency of chain indexes to fall into LPS most of the time is empirical. The **material explanation** for converging chain indexes, in other words the fact that the compounded LPS is smaller than the binary LPS, follows from microeconomic efficiency principles: the drifting test-correlation is negative, if commodities with strongly rising cumulative volume indexes have declining relative prices. Converging chain indexes also solve the problem of choosing among parametric economic indexes. Chained superlative indexes are within the converging compounded LPS. In practice there are distinct limits for chaining. We note here that we have not proved the empirical convergence of chain indexes or the general Laspeyres dominance. We have only tried to formulate a likely explanation. Establishing the empirical statistical tendencies in the world data is another research task.

The LPS is a case related measure. If we calculate the LPS based on five-year standard binary indexes with physical commodities, we will likely get a wider LPS than if we calculate a synthetic five year binary LPS, using volume measures based annual Fisher-type volume indexes. When aggregated indexes behave like real commodities in the sense exact aggregation is determined by the so called **composite product theorem** (Hicks, 1939, cited in The MIT .. 1991, p. 74). Chain indexes have the normal binary axiomatic properties only in each subinterval. For axiomatic comparison with the binary indexes the elements of the chain must be defined.

To summarize, there are two ways to follow the spirit of economic indexes. First we may keep the base period unchanged and use binary superlative indexes like the Fisher and Walsh indexes (see. e.g. National Accounts: … 2004, p. 106). We recall that the Walsh index is also additive. It is obvious that by the third theorem in 1.6.2 the substitution problem is only alleviated if the growth intensity is relatively evenly divided within the binary interval. Chaining indexes reduces the substitution and sample bias by definition. Empirically it is likely that, if chain indexes have no wide oscillations outside the binary end point levels, then the compounded subinterval-LPSs will decrease relative to the binary LPS. Mathematically the problem is that in practice chaining cannot be brought to infinitesimal level and the problem of seasonal cycles start to surface when the base period is shorter than one year. There is an alternative cost for chaining and it is the fact that the fixed measure becomes chained, too. This is related to then additivity requirement (Lippe 2001, p. 67). A common bureaucratic norm for additivity is the accounting year.

1.8 Indexes and Purposes

1.8.1 The National Accounting -Consistency of Indexes

The point of view of economic indexes is **agent-specific**. The true index is associated with the optimization of consumers and producers. The metrics of change is determined by the utility and technology levels. The national accounting point of view is, by contrast, based on **accounting consistency**. Accounts must balance in nominal as well as in real prices. This property was called **consistency in aggregation**. There is another, even more general rule for consistency. This is the **factor reversal** property. The product of price and volume indexes should be equal to the nominal volume change. It is desirable that price and quantity indexes play a symmetric role relative to each other. The **strong factor reversal test** expresses this requirement. If the chosen index fulfills the test, then either of the indexes will together with the nominal data give the same measure of real changes. If the product test is not fulfilled, then the remaining index pair may be calculated only as a **residual** or otherwise price and volume indexes are not congruent. If price and volume indexes are symmetric, then they may be checked against each other. The third consistency property concerns deflation. Above we called this structural **consistency** (Lippe, 2001, p. 89-90).

In standard input-output models total production, intermediate production and final product are observable regarding both prices and volumes. In contrast, the **third quadrant** that consists of value-added: wages, profits and other capital income is **unobservable** relative to **quantities**. The value added data consists only of nominal-value flows. This problem is typically solved either by applying the price index of total production for deflating the value-added production or the so-called **double deflation** is used**.** In double deflation the real value-added is the difference of real total production and the real intermediate production, both deflated with their own price- indexes. The first procedure is adequate when real and nominal dynamics are close in total and intermediate production.

To start with the national accounting consistency issue we first look at the pairs of economic indexes fulfilling the product test. Economic indexes based on theoretical aggregator functions are the Konüs price indexes, the production function based producer price indexes **PPI** and the Allen and Malmquist volume indexes. Excluding the case when the Konüs, Allen or Malmquist indexes coincide with the Fisher index, these economic indexes do not fulfill the strong product test. Thus the price and volume index pairs having the factor reversal property must be formed using the economic index and its product test residual. These functions have additive properties in operational form only if the Walsh index is the superlative operational index. In the theoretical case of producer price indexes there is no additivity concept that can be applied, because each element of national account output, input and value added have their own deflator index. These are solutions to different constrained optimization problems. However, when the law of one price holds, the real value added and final product can be shown to be equal in specific cases (IMF 2005, Chap. 17-18, p. 481). This is true for Laspeyres, Paasche and Fisher indexes. Thus they fulfill the basic law of consistency of input-output models. Considering the limits for economic indexes, in terms of the standard Laspeyres and Paasche indexes, and the operational solutions in terms of the Fisher, Törnquist and Walsh indexes, we see that the question of additivity reverts to the additivity properties of the standard axiomatic indexes.

The measurement of economic growth is based on national accounting systems. From the accounting point of view indexes that are consistent in aggregation are desirable. Laspeyres and Paasche are consistent, but they fail the factor reversal test and the time reversal test. Nevertheless, they form well behaving cross-pairs with the Laspeyres price index and the Paasche quantity index on the one hand and the Laspeyres quantity index with the Paasche price index on the other hand. Empirically the Laspeyres price index may be tested with the Paasche quantity index and the Laspeyres volume index with the Paasche price index in the sampling context. The Walsh price index is an example of an additive and superlative index. However, the symmetric Walsh price and quantity indexes do not fulfill the factor reversal test. The Walsh index is close to the Fisher index numerically, because it is exact to the quadratic mean aggregator function of order 1 (Hill 2002, pp. 17-18).

1.8.2 The Perspectives of the CPI and the PPI

CPIs are mainly used as compensation indexes, cost of living indexes, deflators as well as measures of general inflation (Diewert 2001,8 p. 167-168). A classical argument in methodological debate has been that medium and long run Laspeyres price indexes exaggerate the inflation rate. Thus, there is an obvious connection with the compensation aspect. On the conceptual level, the theory of economic indexes has played a major role. The COLI approach has figured at least in the USA, the Netherlands and Sweden (Triplett 2001, p. F311). The EU has opted for an inflation index with its harmonized consumer price index HICP.

The original motivation of the debate the **commodity substitution bias** has become increasingly outdated as the trend has been towards annual sampling systems. The Laspeyres-Paasche spread shrinks this way and annually chained Laspeyres and Paasche indexes move in the direction of the Fisher index, which is superlative and conceptually closer to the COLI than binary the Laspeyres and Paasche indexes. It is possible to interpret the USA COLI-CPI discussion in the nineties as an alternative approach to solve the problems caused by a slow moving sampling system. Consistency in aggregation is another issue that advocates chaining annual Laspeyres and Paasche indexes.

The point of view of **producer price indexes** PPIs is different from the CPI-COLI stand because all the profit, revenue and production functions are in principle **observable**. PPIs are important in conceptual double deflation of the value added element in national accounts. We may call nominal value added deflated by PPI price indexes, with V_0 and V_1 technologies, producer's Laspeyres and Paasche volumes respectively P_{LQ} and P_{PQ}. Because theoretical producer price indexes are derived through optimization, they are not generally additive on the domain. Using an observable additive index in double deflation will maintain the equality of the real value-added and the real final product *ceteris paribus* uniform prices.

When we move to the superlative indexes from the theoretical economic indexes the special economic approach view ceases to be valid. The standard indexes and the Walsh index are additive, but the Walsh index is not symmetric. What remains is choosing between the forward (Laspeyres) or retrospective (Paasche) perspective. The problem with the Fisher index is the slight deviance from additivity.

2. Commodities and Changing Quality

2.1 Introduction

The standard context of microeconomic theory is a fixed world of production, where the commodity nomenclature and the quality of commodities do not change. Pure index theory follows this view. In reality, however, quality changes. Dealing with changing quality is complicated (see, e.g., Shiratsuka 1999). If a commodity is no longer produced, then the corresponding coordinate axis is excluded from the model. If a new product is introduced, then a new coordinate axis is added to the model. Obviously, the problem is how to define a new product. If the new product is conceptually novel, then there is no problem. In most cases, however, new products are born from piecewise changes of existing commodities. Counting commodity quantities is fundamental in any price or volume index methodology. One has to set a standard for technical similarity. In index calculations, most product categories are aggregated. In other words the category label is **generic** not **specific**.

The changing quality of commodities must be dealt with by statistics agencies. Quality changes are imputed as quantitative effects into price or quantity vectors. This means that the metrics of the space $P^n x Q^n$ changes. The quantity and price dimensions are stretched or shrunk. Generally quality is improving and therefore the price dimensions are shrunk or equivalently the quantity dimensions are stretched. The choice depends on whether one has to do with price or volume indexes. The changes are auxiliary and conceptual and do not change the basic statistical data. The image is not symmetric relative to volumes and prices. The physical qualities of commodities change, but the technical character of the monetary unit does not. Money only becomes inflated. It is obvious that identical absolute quality imputations are reflected differently in different indexes.

2.2 Empirical Measures of Quality Change

Prices and volumes are objectively measurable, whereas quality often is not. Measuring quality is the most convention bound element of growth measurement. The way quality changes is linked to prices depends on the type of economic system and its internal structure. In market economies, if we exclude the case of absolute monopoly or cartel, price changes due to changing product characteristics will pass through the vote of consumer choices. A monopoly may enforce a quality feature. This is true of the central planner, too, who often has highly monopolistic supply logistics.

The technical methods used to quantify the quality changes are similar in all industrial countries. **Three basic methods** are used. **First** new products may be postulated. In this case there is no need to assess the quality changes. **Secondly** quality changes may be seen to be very slight and hence the new product variety is **comparable** to its predecessor. In the **third** case the price change is decomposed into a **pure inflation** component and a **pure quality** component. If the old and new commodity varieties exist simultaneously, then the simultaneous price difference may be interpreted as quality difference. This is called the **overlap method** (Moulton & Moses, 1997 pp. 322-330). If the products varieties do not overlap then the quality difference must be imputed. In the l**ink method** and the **class mean imputation method** the pure price inflation of the disappeared item is measured by some group average of similar product varieties. The difference between the price of the new product and the above estimated pure price inflation is regarded as a quality change (ibid.). An elaboration of the last two methods is the **MCR-**method (monthly chaining and re-sampling). The method was suggested by Ralph Turvey. In MCR the group overlap is guaranteed by advance sample planning. Samples rotate fast, e.g. monthly and the **group overlap** is between those similar varieties that belong to the both consecutive samples (Dalen, 1999, pp. 312-313). The fourth option is the **direct quality adjustment**. This may be done through cost functions or the product price may be regressed on various quality attributes using some hedonic model. Many of these attributes are quantitative or technical. Expert opinions may also be used (Moulton & Moses, 1997 pp. 322-330). A theoretical issue associated to introducing new products into price indexes is the concept of **virtual price** or **reservation price** (Varian 1992, p. 153). A new product appears on markets with a price and positive sales volume. The virtual price is the price with which the new product would break the zero demand level. By economic theory this is a case of positive consumer surplus. Demand functions are required and the virtual price must be econometrically estimated. The first three methods of quality managing are called **implicit quality adjustment** and the fourth **explicit quality adjustment**.

In the 1990s there was a lively debate in the OECD countries on measuring quality changes. The most famous debate concerned the USA-CPI (Baker, ed., 1998). The total effect of quality improvement in the BLS consumer price index was approaching the 2% annual limit (ibid.). Yet, the Boskin committee estimated that the quality contribution may be underestimated up to 0.6% annual percentage points in the CPI. A lot of comparative research on quality was done in the other OECD countries, too (see. e.g., Crawford 1993, Cunningham 1996, Dalen 1999, Rossiter 2005, Shiratsuka 1999). It would seem that the differences between the OECD countries are mainly due to different sampling systems and to the varying lengths of base periods in indexes. This is illustrated by the case of Sweden, where the quality bias in the late nineties was estimated to be 0.33% annually (Dalen, 1999, p. 314). The sampling system of Statistics Sweden is relatively fast changing with annual indexes (Dalen 1999, p. 187). A conservative sampling system with a long base-period neglects the fast improving varieties of new technology. The shorter the base periods the more representative the samples are for fast changing commodities and the less retrospective, *ad hoc* quality assessments, need to be made. In a number of studies the total quality understatement was estimated to be respectively 0.5% and 0.35-0.8% in Canada and the UK (Crawford 1993, Cunningham 1996, cited in ibid. p. 274-275).

The post war quality development in the former planned economies is an interesting problem. First the price changes due to improved quality were disproportionately concentrated in high priority sectors such as machine building. Secondly, bureaucratic procedures of quality assessment were based on hedonic and cost function models specific to an economic environment without hard budget constraints and effective end user feed back[10]. The underlying preferences were quite different in the two systems. To illustrate: the Soviet Gosplan had different preferences concerning trucks than private German logistics enterprises. The former wanted trucks that among other things tolerated bad road conditions and had defense relevance. The German enterprises most likely preferred their own profit function as a utility indicator.

[10] See the Essay no 3 of this study.

3. Methodological Conclusions

3.1 The Concepts of Index Theory as Conventions

With the introduction of continuous Divisia indexes, we saw that many standard indexes may be presented as exponential line integrals. Thus, indexes are integrals that have domains, a path of integration and a measure of integration. Accordingly, the general instrument is universal, but results are determined by institutions and technical conventions. The proper domain of an index function is the national accounting-sheet or its subset. This depends on the economic system and the system of national accounting. The historical trail of national accounting extends from Egyptian storehouse bookkeeping up to the modern SNA. The expansion and monetization of trade paved the way for the aggregate concepts of production. The advent of the Italian double-entry bookkeeping systems increased awareness about the border between production costs and producers' own consumption. The production border was an issue of moral, religious or ideological type before the modern SNA fully established its position finally in the nineties. The chosen statistical methodology, including the index system, is defined by the path of integration and the timing used. These are both conventions. There have been weighted aggregate indexes fulfilling the factor reversal test only for a hundred years or so. Quality adjustment is a coordinates transformation that is based on statistical conventions not directly derivable from economic theory or axiomatic theory. Thus, the statistical methodology of measurement went through a long conceptual development. The main threads were the axiomatic, physical approach and the aggregator function driven economic approach. When reading microeconomic theory one has the impression that the economic laws are as immutable as the laws of nature, whereas in our view the methodology of measurement economic growth is more like **path dependent technology.**

3.2 Preferences and Prices

Whenever borders are crossed, defining common prices for economic aggregates is a theoretical problem. We may aggregate individual utilities, calculate inter-temporal, interspatial or inter-system comparisons. A functioning market system is usually seen as a legitimate source for distributing value. However, in national accounting systems no corrections are made for imperfect competition.

The economic approach to index numbers chooses utility and other aggregator functions as instruments for measuring the real value of production. Above it was noted that the preconditions for aggregating utilities are restrictive and that constructing index concepts based on collective utility or welfare depended on the choice of the function type of the **SWF**. How should one proceed in constructing index numbers based on the microeconomic postulates when it is not known whether aggregator functions can be made operational or be aggregated? This leads to superlative indexes that closely approximate well behaving aggregator functions in relevant neighborhoods.

3.3 The Choice Between Economic and Axiomatic Indexes

The economic indexes of Konüs, Allen, Malmquist, Shell and Fisher or Archibaldi are theoretical concepts. Consumer and producer indexes have certain differences as to the problems of operational definition. The utility function is a highly reduced and ideal concept. Modeling production functions is an empirical problem. Observable standard indexes must be used as proxies for theoretical indexes. The candidates are usually the Fisher, Walsh and Törnquist indexes. Under some well-defined time path conditions, these superlative indexes may be close to neither the theoretical economic indexes nor the chain indexes. However, if chaining is made more frequent, then the index concepts and formulas have less effect on numerical results. Generally, the superlative indexes and chain indexes bring us back to axiomatic indexes. Economic indexes are only conceptual maps. Technical solutions must be found in the secular sphere of axiomatic indexes.

3.4 The Issue of Quality

The issue of quality arises, because quantity coordinates are assumed fixed in pure index theory. Empirically all quantity coordinates are operational definitions of commodities. Changing commodity quality shrinks or stretches commodity volume coordinates. To check the factor reversal test we should keep respective nominal prices intact and modify the comparison period quantities with the quality correction matrix or symmetrically keep the quantities and modify the comparison period prices. These changes concern only indexes, not statistical data. If we use the continuous Divisia index to formalize the case, then the domain of integration changes from $((P_0,Q_0),(Q_1,P_1))$ to $((P_0,Q_0),(C_{QD}Q_1,P_1))$, where C_{QD} is the diagonal matrix of quality correction. Because the Divisia index obeys the circularity postulate, ceteris paribus the path, we see that the quality effect is technically separable at least in the case of Laspeyres and Paasche indexes.

The differing quality concepts in the OECD and the former Eastern European countries were a problem. The same problem exists even within the OECD. According to the OECD price index manual, the member countries use a varying mixture of implicit and explicit quality adjustment methods (OECD 2002, pp. 51-52). It seems that, besides progress in the theory of economic indexes, many bureaucratic exercises are needed to achieve better international comparability. A benchmark for the size of present quality imputation is the USA figure of 1.7 % for the CPI in the mid 1990s (Baker 1998, p. 53). It is apparent that the role of imputed quality improvement is important. To avoid accumulating quality adjustment tasks sampling systems must be faster rotating than before. For a wider discussion about quality adjustment more data on country and sector level data on the established level of imputed quality is needed.

3.5 Sampling Issues

Sampling bias may be seen either as substitution bias related to COLI indexes or other economic indexes or it may be considered a statistical sampling bias. In sampling bias the **commodity substitution bias** and the **outlet bias** are usually separated. Sampling bias is managed through faster sampling systems, superlative indexes and chaining. If chain indexes are used, chaining tends to minimize the numerical differences because negative drifting tends to dominate. The main choices for index formulas have been Laspeyres and Paasche price or volume indexes.

Laspeyres indexes are usually larger than Paasche indexes (Allen 1975, pp. 64-65). Hence, the Laspeyres-Paasche spread accumulates when the base period of price indexes grows longer. The OECD experience illustrates this. The USA CPI (consumer price index) maintained by the Bureau of Labor Statistics (BLS) was based on the three strata of 44 geographical areas, 207 item groups and also on outlet groups. The slowest changing weight scheme was based on consumer expenditure surveys with 10-year interval. Item samples rotated by 5-year periods. Every year 20% of items were replaced (Moulton 1996, pp. 159-177). This system was a conservative example of the OECD 5-year system for Laspeyres price indexes. Because of the mixed stratification schemes of 10 and 5 years, the system acquired features of a Lowe index, which enhanced the Laspeyres-Paasche spread (see Diewert 2003, p. 39). The Boskin committee report measured the representation bias relative to monthly Fisher index. The combined sampling biases of the various strata in 1987-95 were 0.5% annually. That is, the CPI was too high (Baker 1998, pp. 2-3). In those OECD countries where the 5-year based system was faster moving, the various biases related to sampling were e.g. for Canada and the UK less than half of the USA measure (Crawford 1998, Cunningham 1996). A Swedish government committee report on the Swedish CPI found practically no sampling bias or about 0.1% annually (Dalen, J, 1999, p. 301). The changes instituted in the USA CPI in the late nineties moved the system in the same direction (see. e.g. Stewart and Reed, 1999, pp. 29-37).

In practice the sample bias and the drifting biases become intertwined. The drifting bias is generated by the de facto changing sample frame. The steadily increasing number of commodities and the accelerating product development and differentiation steer the national statistical offices towards faster rotating sampling systems. When the sample system is dated annually or more frequently, the substitution bias related to sampling period practically disappears and the burden of coping with changing quality moves from *ad-hoc* quality adjustment towards a better sampling of new goods as well as implicit quality adjustment.

3.6 Future Challenges to Measurement of Real Growth

Three issues may be noted here. These are related respectively to the **scope** of national accounting, the ever **faster change** of product quality and number of products as well as to the fact that when the **tertiary sector** grows there will be more value flows, which cannot be separated into prices and volumes. A lot of work has been done in developing national accounts based on **sustainable development**. This, however, is no longer our subject. The flood of new products mainly strains sampling systems and requires new procedures for defining new products as well as measuring the quality change of established commodities. The problem of pure, current value flows is analogical to the problem of measurement of the value-added.

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III

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ESSAYS ON THE MEASUREMENT OF ECONOMIC GROWTH

ESSAY no 3

Soviet Economic Theory and the Measurement of Economic Growth

Academic Dissertation
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Soviet Economic Theory and Measurement of Growth

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III

Soviet Economic Theory and Measurement of Growth

Abstract

This essay briefly surveys the general development of real growth measurement. Subsequently the emerging Soviet economic theory is put into the context. The main ideas of Soviet index theory are summarized. Lastly, a scenario of Soviet growth measurement is presented.

1. Introduction

The precise measurement of economic growth is a fairly new phenomenon. The development of the measurement of economic growth derives from **pure index theory** and the **theory of national accounting**. Italian double-entry book keeping is the methodological root of all national accounting. François Quésnay, the French physiocrat, constructed the first known integrated models of national accounting in 1758 and 1766. Classical political economy in the 19th century divided into two main streams: Neoclassical and Marxian.[1] These schools defined the concept of production differently. Following Aristotle, Marxian political economy adopted the material concept of production. Modern neoclassical schools defined production as marketable commodities and thus included services, too. These differences were later embodied in the SNA and MPS systems. Marxian economics did not have formalized microeconomics and its numerical value concepts were formalized in linear macroeconomic models. Marx's equations of extended reproduction were inspired by Quésnay and represented a forerunner of modern national accounting equations. Aside from value theories and formal systems of accounting, measured economic growth depends on price systems. Prices in market economies are based on demand and supply in more or less perfect markets. In planned economies, the logic of prices depends in the last analysis on input-output models on macro scale. If the input-output system is technically productive, the central planner can use income transfers between sectors on a much wider scale than even the most interventionist state in a market economy.

[1] A third important branch were the historical schools, especially the German historical schools (Rima 1996, pp. 2002-206)

2. A Brief History of Measuring Real Growth

2.1 Early Concepts of Index Numbers

Formalism of classical physics was an early model for mathematical economics. Mass, velocity, acceleration, space and time form a group of variables that are tied together by a system of definitional and behavioral equations. We cannot define acceleration without time and velocity. It took more than 200 years to achieve this type of closure in index theory after the introduction of early indexes. Early indexes measured changing prices or price levels without a clearly defined system of accounting and recordings. Among the first reported indexes were e.g. the price indexes of Fleetwood (1707), Dûtot (1738) and Jean Rinaldo Carli (1764). These indexes were various un-weighted arithmetic averages of base and comparison period prices (Kendall, 1969, pp. 1-2). The idea of un-weighted price indexes was later carried over to the twentieth century in the form of stochastic indexes. This was related to quantity theory of money. F. Edgeworth was an early advocate of stochastic indexes (Allen, 1975, pp. 5-6). W.S. Jevons was an advocate of simple geometric price indexes and even more importantly he was among the founders of modern consumer theory and utility functions (Landreth & Colander 1994, pp. 225-228).

The story of modern price and volume indexes starts from **fixed basket indexes** that are indexes with constant weights. The first known application of fixed basket indexes is attributed to the English economist Thomas Mun in 1609 (Kovalevskii 1988, p.13). The microeconomic manifold $Q^n x P^n$ was introduced by the representatives of the French marginalist school Cournot, Dupuis and Walras in the first half of the 19th century (Rima, 1996, pp. 232, 248). Indexes defined conceptually in this space are the origin of modern indexes. In 1812 A. Young introduced his index defined as a weighted arithmetic average of the price relatives. A few years later 1822 J. Lowe presented his fixed basket index defined with modern symbols (Kendall ibid.). His price index measures the proportionate change between periods 0 and t in the total value of a fixed basket of goods and services. The basket does not necessarily have to consist of the actual quantities in some period. Modern standard weighted price and volume indexes, with base and current year weight structure respectively, were introduced by Laspeyres (1871) and Paasche (1874) and they have dominated the scene since then. Other fixed weight indexes from the same period are e.g. the Drobish, Walsh and Edgeworth indexes (see e.g. Vogt 1977, p. 74). The Drobish index is a price index defined as the arithmetic average of the Laspeyres price index and the Paasche price index. In the Egdeworth index fixed weights are defined as the mean of binary endpoint values. In the case of Walsh index the rationale is similar but the mean is geometric. Although the names Laspeyres and Paasche index have become standard there has been some debate about the originators. Kendall claims that the originators of modern aggregate indexes are the works of d'Evelyn (1798), Young (1812) and Lowe (1822) (Kendall ibid.). There are other threads, too. E.g. the Russian statisticians F. G. Virst and V. Shchetkin have been documented for using standard, weighted aggregate indexes at the very beginning of 19th century (Kovalevskii 1988, pp. 16-17).

2.2 Creating Rules for Index Numbers

We may start with R. Frisch's rather modern definition of an index number: 'The index number problem arises whenever we want a quantitative expression for a complex that is made up of individual measurements for which no common physical unit exists' (Frisch, cited in Allen 1975, p.5). Thus the problem is to define to which aggregate a price or volume index refers. In pure index theory this is solved with references to $Q^n x P^n$ manifold. Aggregation is used in two senses: as **aggregation of commodities** and **aggregation of economic units** or subjects. Last, we have to ask what type of functions indexes should be. This is partly related to the dimensional properties of models and partly to the economic rationale of index systems. Pure index theory has two main branches: axiomatic index theory and the economic approach based on theories of optimal behavior. The economic approach was initiated by A.A. Konüs and S.S. Bushgens in Moscow in the 1920s. This school was regarded as non-Marxian and further development of ideas went over to the West. The main concept was the **true price index** based on individual utilities. The main aggregate indexes, the Laspeyres and Paasche price and volume indexes had been introduced in 1871 and 1874 respectively. Important results were produced by Divisia in the 1920s and R. Frisch in the 1930s (Allen 1975, ibid.; Divisia 1925). Divisia defined a line integral as a limit value for chain indexes. The axiomatic approach to economic indexes was pioneered by Irving Fisher (1922). Fisher's proposed system of axioms was shown to be inconsistent by e.g. Swamy in 1965 as well as Voeller and Eichhorn in 1976 (see e.g. Lippe 2001, pp. 53, 77). An important result was that transitivity or circularity property excluded the simultaneous occurrence of some other useful properties like the identity test, positiveness and the factor reversal test.

The theory of the **Laspeyres-Paasche spread** was developed by the Polish-Russian émigré economist L. von Bortkiewicz (1922, 1924). Dealing with the Laspeyres-Paasche spread became a key issue for both main systems, SNA and MPS. Axiomatic and economic approaches to index theory have a common interface in the form of superlative indexes. The concept of the superlative index was introduced by Diewert (Diewert 1976). Superlative indexes are observable standard indexes such as the Fisher index or the Walsh index that approximate the economic indexes in specified environments. The pure index theory assumes invariable physical attributes for commodity dimensions. In practice, the question is how to aggregate similar but in detail technically different commodities in Q^n. There is no comprehensive economic theory for adjusting commodity quality in indexes. In market economies, statistical authorities used **direct** and **indirect quality adjustment**. Hedonic methods and representative imputations were used in different degrees in individual OECD countries. In planned economies new commodities were priced and their quality adjusted by the State price committee or other planning bodies. Intrinsically, **asymmetric information** and **moral hazard** were problems as in any hierarchic bureaucratic system. Prices of new products influenced the incomes and success indicators of those decision-makers controlling new prices.

3. Soviet Theory of Growth Measurement

3.1 National Accounting: From Classical Economics to Soviet Marxism

Karl Marx adopted the classical concept of production. His equations of extended reproduction with two sectors of production formed the basis of early Soviet thinking in national accounting (Granberg 1978, pp. 20-22). Marx's model of extended reproduction was generalized to the case of several sectors by L. Kritzman in 1920 (Granberg 1978, p. 22). The theory of national accounting may be expressed in parallel form with pure sector input-output models. This is the Walrasian link to national accounting theory. The Russian émigré economist Wassily Leontief used the Walrasian general equilibrium model with linear structure as the basis for his input-output models. Russian input-output economics already had its first nuclei in Imperial Russia. Vladimir Dmitriev solved the technical problem of input-output coefficients in two publications in 1898 and 1904 (Granberg, 1978, pp. 11-12 and Pokidchenko & Chaplygina 2005, p. 184). Another theoretical predecessor to input-output models was Aleksander Bogdanov with his publications on organizational science in 1912-22. Bogdanov's contribution was related to the matrix form of economic input-output systems (ibid. p. 184).

The first Soviet material balance system (MPS) for the years 1923/1924 was constructed in this theoretical milieu under P.I. Popov (Granberg, ibid, p. 21). MPS went through several variants and was officially codified only in the 1950s in the framework of UN statistical cooperation. Before the forced collectivization campaign of the 1920s, the MPS was based partly on surveys and forecasts. After collectivization, a comprehensive census system for MPS was gradually built. M. Barengolts constructed the first input-output models for industry in the late 1920s, but the first systematic and public models were constructed for the year 1959 (Pokidchenko & Chaplygina 2005, p. 184). During the Soviet period, the main ideas of MPS such as production boundary, the basic accounting unit and the rest of the world account did not change.

The Soviet statistical administration was formally organized in 1918 (GKS 2004, p.1)[2]. There was a long tradition of Russian imperial statistics before the Soviet period, but before World War One, integrated systems of national accounting and modern aggregate price indexes were not yet on the agenda. In the 1920s the system was standard since sampling was widely used and data was relatively open. With forced collectivization statistical functions were transferred to the central planning office GOSPLAN in 1930 (GKS 2004, p.2). This transfer into the planning hierarchy meant the end of openness in Soviet statistics and discussion about statistical methodology. There was a blackout in empirical statistics and theoretical discussion up to the 1950s. The central statistical office (CSO or TsSU) regained its administrative independence only in 1948.

3.2 Soviet Index Theory

The older generation among the new Soviet economic profession was well aware of developments in Continental and American microeconomics. E.g. the Russian economist E. E. Slutsky pioneered in 1915 with ordinal utility in demand theory (The MIT…, 1991, pp. 389-390). Later in the 1920s, he worked in the new Koniunkturnii Institut (**KI**) in Moscow (IEU, 2003, p. 428). When introducing his aggregate index in 1871 Laspeyres had a position at the University of Tartu in Estonia, which at the time was part of Imperial Russia. Thus, many early Soviet economists worked with mainstream neoclassical paradigms in the 1920s. Soviet theoreticians launched the economic approach to index theory. A.A. Konüs and S.S. Bushgens, who worked in the KI in Moscow in the 1920s, introduced the concept of the **true price index** (Konüs and Bushgens 1924/1926). The KI was part of People's Commissariat for Finance (NARKOMFIN) then. However, later true price indexes were rejected in Soviet Russia as non-Marxian and the work of A.A. Konüs was continued in the West. In the 1920s when national statistical systems developed swiftly in Europe and Northern America, the **aggregate index approach** with weighted indexes took the upper hand. Interestingly, in the KI under N. D. Kondradtiev, M.B. Ignatev and N. S. Chetverikov experimented with weighted geometric index formulas (Komlev, 2003, p.9/31).

[2] The Soviet central statistical office CSO had several names in 1918-1990. Tsentral'noe statisticheskoe upravlenie TsSU was used in 1948-1988. Since then it was gosudarstvennyi komitet po statistike GOSKOMSTAT.

Irving Fisher published his basic work in the 1920s. Thus, the concept of the Ideal index and its relation to the Laspeyres-Paasche spread (LPS) was known (Fisher 1922, Komlev, op. cit.). At this time, there still was an exchange of ideas between A.A. Konüs and V. Bortkiewicz in Berlin (Komlev, 2003, p.16). Later, when most older generation economists in the KI related to West European neoclassical tradition were expelled from Soviet economics, Bortkiewicz disappeared from the Soviet statistical discussion. Much of Bortkiewicz's work was in statistics and applied mathematics. He was, however, the first to comment in writing about the Marxian transformation problem and pointed to its logical problems (cited in Blaug 1986, p. 233). The important decision in the twenties was the choice of the national accounting system MPS. What remained to be fixed was the index-methodology for the planned economy.

Mainly owing to Strumilin and Starovskii the aggregate index approach was chosen as a standard with Laspeyres volume index and the implied Paasche price index as its index pair (Kovalevskii 1989 p.78, Starovskii 1977, pp. 73, 109). Strumilin introduced his first weighted aggregate index in 1918 (Kovalevskii ibid. p. 24). Starovskii was one of the main spokesmen for the **teleological school** of planning. The representatives of this school became dominant in index theory, too. The main political proponent for the teleological school was J. Stalin. The school supported directive planning and rejected most neoclassical microeconomic elements from the emerging Soviet economic science. The economic index school of the Koniunkturnii Institut was outlawed from Soviet economics[3]. Within the KI economics, mathematics and statistics went together. After the Marxist conservatives gained the upper hand neoclassical tradition was excluded, mathematics became suspicious in economic theory and the Soviet view of statistics concentrated on national accounting and bureaucratic classifications (see e.g. Granberg 1978, p. 24; Pokidchenko & Chaplygina 2005, pp. 182-185). Soviet statistics became an administrative science in a period when Soviet probability theory was powerfully developed by such top mathematicians as A, N. Kolmogorov, A. Khinchin, B, V. Gnedenko and Iu, V. Prokhorov (Rybnikov 1994, pp. 379-394).

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[3] During the 1930s economic dissidence in the Soviet Union meant dismissal, internal exile, imprisonment or at worst capital punishment (see. e.g. IEU, 2003, pp. 458-461).

Fisher was well known as some of his works had been translated into Russian in the 1920s. However, Fisher's axiomatic approach was rejected as formalistic. According to Starovskii Marxist science must respect the fundamental operational definitions based on the essence of phenomena (Starovskii 1977, pp. 98-99). The Fisher index is numerically close to the Laspeyres and Paasche aggregate indexes, but the quadratic root solution seemed to defy direct operational definition. Despite the critical attitude towards I. Fisher's axiomatic approach, the new Soviet approach as advocated by Starovskii was based on a '**minimal axiomatic approach'**. He discussed the **factor reversal** and **time reversal tests**, Laspeyres-Paasche index pairs as well as the **circularity test** (ibid. pp. 91-96) [4]. We recall here that the inconsistency of Fisher's full axiomatic system was established only in the seventies. The circularity problem was solved in the Soviet Union traditionally by using the fixed base year weight within the base period. Under these conditions the chaining rule works. Therefore, the chosen logic of the Soviet index system was rather similar to developing index systems in Europe and Northern America.

The main index pair was the annual notional Laspeyres volume index and the implied Paasche price index. In practice the system was Lowe type. The difference from market economies was that the direct volume indexes dominated. Obviously, a near international standard was adopted easily in index theory because the system was independent on both value theory and national accounting theory. Sampling theory was accepted as a neutral element in statistics and economics, whereas generally the role of probability in statistics and economics was debated (Strarovskii 1977, p. 29). Surveys were used in the 1930s and during World War Two. It was thought that economists should decide about operational definitions and that there should not be unnecessary *ex ante* mathematical restrictions on economic analysis. After forced collectivization data gathering was increasingly based on comprehensive census.

When Bortkiewicz sank into oblivion in the early Soviet Union, there was no explicit theory for the dynamics of the LPS. We recall that Bortkiewicz was the first to formalize the theory of the Laspeyres-Paasche spread (Bortkiewicz 1922, 1924). This issue surfaced again at the beginning of the 1950s when the CSO had regained its

[4] Starovskii 1977 is a historical anthology. This part dates back to publications in the 1930s.

formal autonomy. From the beginning of the 1950s the CSO started to use comparative prices that followed the calendar of FYPs or five year-plans. The LPS was related to the so-called **substitution bias**. Thus in the Soviet case the price weight structure of the first planned base year, the year 1928 in 1926/27 prices, grew increasingly less representative until the system was rebased in 1951.

In order to discover the effect of a more frequent chaining on the original Soviet Laspeyres volume index LQ for 1928-1950, we calculated a synthetic, binary Paasche volume index PQ using Soviet sector indexes and the 1950 sector weights in 1956 prices. If the substitution bias is measured as a difference between the Soviet LQ and Soviet Fisher index FQ, it was about 1.9 % as an annual average for 1928-50. The Soviet official annual average growth rate by LQ was 9.4 % and the Soviet synthetic FQ was 7.5 % in 1928-1950. Bergson's first composite index was a chaining of the PQ for 1928-1937 and the LQ for 1937 -1950. Thus, it should not be too far from a virtual Bergson type Fisher volume index. The second composite Bergson index is the chained Laspeyres volume index LQ2837xLQ3750. Without adjusting the index type the difference between the Bergson composite LQ index and the Soviet LQ in 1926/27 prices is on average of 2.8 % for 1928-1950. If we assume that the correct pair to compare is the Bergson composite index BCMY and the Soviet synthetic FQ the average annual difference is 3.4 %. The difference contains the sampling error by Bergson, true quality adjustment and the hidden inflation component. Thus, using the Soviet Fisher volume index as a proxy for chained indexes diminished the estimated Soviet annual growth figure by 1.9 %.

Table 3.2.1 Heuristic Example: The Early Soviet Substitution Bias and the Revealed Residual (SOFLQ - Bergson's pure volume composite index)

	SOFYB SOFSYNT Cumulative Indexes			Subst. Bias	BERGSON			RESIDUAL Ann. % SOFLQ-BCLQCI
YEARS	**LQ**	**FQ**	**PQ**	**LQ-FQ %**	**BLQ28**	**BCMY**	**BCLQCI**	**BCLQCI**
1928	1	1	1		1	1	1	
1937					2,75	**1,6**		
1940	4,5	3,3	2,4	2,6		2,0	3,3	
1945	3,7	2,6	1,8	2,2				
1950	7,2	4,9	3,4	1,9		2,4	4,0	
28-50 %	9,4%	7,5%	5,7%	1,9%		4,1%	6,6%	**2,8**
annually						**SOFLQ-BCMY =**		**3,4**

Sources: Abouchar 1979, p. 35, Narkhoz SSSR za 60 let, 1977, p. 13, Narkhoz 1975, p. 47

***BCLQ** is a composite chain index **LQ2837xLQ3750** ,*
***BCMY** is a mixed chain index **PQ2837xLQ3750**; BCMY should be close to FQ*
Soviet PQ is calculated with Soviet official sector indexes, using 1950 weights in 1956 prices.
Bergson's index is not quality adjusted. Thus SOFLQ-BCLQ or SOFFQ-BCMY
is the residual containing sample error, quality contribution and hidden inflation.
LQ, FQ, and PQ =Laspeyres, Fisher and Paasche volume indexes

SOFYB= Soviet Statistical Yearbook

Table 3.2.2 Soviet Indexes
(Sources for synthetic calculations)

Year	**IND A**	**IND B**	**Const**	**Agriculture**	**Trans**	**Trade**
1928	100	100	100	100	100	100
1940	1000	420	750	130	410	230
1945	1120	247,8	645	78	315,7	103,5
1950	2050	516,6	1447,5	128,7	598,6	253
1960	6660	1369,2	4837,5	208	1586,7	749,8
W50	0,37	0,17	0,08	0,27	0,04	0,06
W60	0,45	0,17	0,11	0,16	0,04	0,07

Sources: Narkhoz SSSR za 60 let, Moskva 1977, p. 13, Narkhoz 1975, p. 47

***IND A** = Capital goods*
***IND B** = Consumer goods*
***W** = % weights*

The problem with Soviet historical data up until the 1960s is that there was not published structural nominal data. It is often impossible to calculate synthetic Fisher volume indexes, because there are no adequate weights. That is, the only data available is Laspeyres volume indexes in the comparative prices of the year 1928. The Soviet nominal structure data is available only from 1960 onwards.

3.3 Whose Preferences?

Irrespective of whether one is for economic or axiomatic indexes one is tied to $Q^n x P^n$ as the domain for index functions. The economic question with a planned economy is: what is the functional role of prices in planning? During the 1920s and 1930s, the issue in the Soviet economy was about the Marxian law of value. Marxists thought that prices regulated only the anarchy of capitalist production. Obviously, prices could not have a similar role in a planned economy where there was one collective planner (see e.g. Nove 1988, pp. 347-354). Marxian political economy had a clear profile concerning values. It was based on labor value, no opportunity cost or scarcity was considered, interest on capital was not a proper component in the planned context. For nearly a hundred years Marxist political economy had fought the evil of marginal thinking that was one of the main analytical instruments of the Neoclassical school. There is a formal equivalence with simple mathematical optimization and the Marginal school theory. Thus, the Soviet Marxist stand here conveyed a clear distrust against any formal optimization in economics. The Marxian leaning towards linear average prices and the victory of the teleological school postponed also the introduction of formal methodology into planning up to the late fifties (see e.g. Pokidchenko & Chaplygina 2005, pp. 182-186). However, prices continued to play the key role in the distribution of consumer goods through more or less rationed markets. The planning of production was based on comparative fixed prices. The physical planning process was not transparent enough and prices were needed for aggregating plan targets. Political economy was again codified only in 1954, when the new text book for political economy initiated by Stalin was published after his death (see e.g. PE, 1976, pp. 544-548)[5]. Only the demise of Stalin in 1953 step by step brought an end to the most passionate proletarian science in physics, biology, cybernetics and in economics and other social sciences, too (see Istoriia Rossii …, pp. 655-659).

The economic approach fixes the metrics of index calculation with preference structures. In market economies with the SNA system, it is assumed that market prices are adequate measures of preferences. How, then, should preferences be weighted in a planned economy? Bypassing the dilemma of how physical target vectors related to plans are chosen respecting individual preferences, there is a more practical problem. The necessary and sufficient formal precondition for a feasible linear system of production is that the physical system of production is productive. This implies only that the characteristic values of the input-output matrix have modulus values less than unity (Granberg 1978, p. 273). Having chosen the physical target vector for final production one may apply different price systems. Each price system implies different growth rates and distributions of income. The early Soviet price discussion concentrated on the Marxian transformation problem on the value added side. From the 1930s until the 1960s value models where the surplus is proportional to labor applied, dominated (Ocherki istorii… 1992, pp. 192-204). Linear mathematics tells us that this is possible but not necessary (Grubbström 1997, pp. 102-104). Later the discussion was extended to models where surplus value is proportional to zero profit cost of production or alternatively to all invested capital. Since the work of Kantorovich in linear programming and the revival of mathematical economics in the late 1950s and early 1960s, optimal shadow prices entered the discussion (see. e.g. Granberg 1978, pp. 256-258). Finally, the production price model was established in the 1960s. Obviously, this development modified the nominal structure of economy and growth rates as well, depending on the relative capital intensity by sectors.

A related, more heavily political issue was the Soviet industrialization debate between among others Bukharin and Preobrazhensky in the early 1920s about planned accumulation. Later V. A. Bazarov termed the two approaches respectively ***genetic*** and ***teleological schools*** (IEU, 2000, pp. 433-438). Generally the question was should one

[5] The preparations for this textbook had been initiated by the CPSU Central Committee in 1936 (ibid.)

rely on indicative or directive planning when moving towards a planned economy. S. G. Strumilin was an influential proponent of directive planning and the teleological approach. The line chosen by the communist party and Stalin led to forced collectivization. Exchange with the agricultural sector was planned to be non-equivalent. This was in accordance with Preobrazhensky‘s view of original accumulation. Investments were to be concentrated on heavy industries and planning was to be directive. Procuring prices in agriculture declined until the 1950s, while at the same the time wholesale prices of industrial production increased (Ocherki istorii… 1992, pp. 195-196). Physical production in agriculture grew very slowly in the 1930s. This fact and the subsequent return to a more normal income distribution between sectors, shaped the specific path of Soviet agriculture. The decision function of the Soviet economy was dominated by Stalin and the party elite. After Stalin's demise in 1953 the agricultural sector began to receive increasing transfers from the rest of the economy (Kudrov, 2006, p. 365).

3.4 The Post-Stalin Resurrection of Soviet Economics

In 1960s and 70s the leading economic institutes of the Soviet Academy of Sciences were the Institute of Economics (IE), the Central Economic-mathematical Institute (Tsemi) and the Institute of International Economic Relations (IMEMO) (Bartenev, 2001, p. 407). The universities in Leningrad and Novosibirsk must also be noted. The winners in the new Post-Stalin conditions were Soviet mathematical economics or economic cybernetics and a more realistic research of capitalist economies. The latter, however, was published only sparsely. The first Soviet I-O models were already presented in the 1920s. However, the first Soviet public input-output table was published only 1959. The growth theoretic contributions of Feldman and Nemchinov date back to the pre-war period (Granberg, 1978, pp. 22-26). In the late 1930s Kantorovich introduced linear programming (**LP**). Among other things, LP influenced the pricing of natural resources. Labor theory of value was not very expedient in pricing natural resources. Kantorovich showed that natural resources commanded positive shadow prices (Alexeev et. al.1992, p. 144). In the 1960s efficiency was emphasized. Novozhilov had formulated first the problems of comparing investment projects in planned economy. From simple planned optimization with linear models the genre continued by introducing the concept of optimal functioning of the economic system, **SOFE** (Sutela, 1984, p 103). This was related to Tsemi with N. Fedorenko and N. Petrakov (Bartenev, 2001, op. cit.). By the mid-1970s, the Soviet linear macroeconomic theory had crystallized into a fairly realistic macro-view (see e.g. Dadaian 1973, Granberg 1978). By realistic we specifically mean abstract limit models. It was possible to see the quantitative limits for planning growth, there was a developed set of linear models for price planning and it was possible in principle with sampling and I-O data to check flaws in census type statistical data. In the beginning of the 1960s the IMEMO had started the work in spatial economic indexes and international comparisons of economic size (Kudrov 1997 A&B). At the beginning of the 1960s the statistical yearbook Narkhoz SSSR started publishing international comparisons on the size of national economies.

After the beginning of the 1960s, several new tendencies emerged in price formation. The production price scheme became dominant as a theoretical base for planned prices. This affected especially those branches where capital intensity was high. The Kosygin reform of 1965 emphasized sales, the amount of profit and the level of profitability instead of total production (Hanson 2003. pp. 102-104). Only the main assortment of an enterprise was directive. The concept of a **scientific technical revolution** turned into a programmatic political device (EEPE 1979, p. 40-44). New directives for pricing new high technology commodities were issued in 1969 (Ocherki istorii… 1992, p. 200).

Moving from the 1960s to the 1970s, the labor influx from agriculture as well as fertility rates started to ebb. During later Soviet decades wages became real instruments for redistribution of labor that could move relatively freely. Tendencies for wage inflation grew (Gregory & Stuart 1998, pp.111-112)[6]. The investment process was mainly centralized even after the Kosygin reform. Substantial changes in the production functions of firms were unthinkable because inputs were rationed and standard technology components changed only slowly.

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[6] See also Essay 4, Figure 3.2.1.

Nevertheless, the index theory proper changed only little. Economic index theory was banned because neoclassical microeconomics still was taboo. Axiomatic index theory was being developed by Eichhorn, Voeller, Samuelson and Swamy in the sixties and seventies in the West. The new economic theory of producer price indexes by Archibaldi, F.M. Fisher and K. Shell did not really have time to enter into the Soviet index theoretical discussion. Even in the late 1980s, when axiomatic theory was presented in scope, the attitude was still cool (Kovalevskii, 1989, pp. 74-80). In 1980 Allen's *Index Numbers in Theory and Praxis* was translated into Russian. In the preface to the Russian translation one of the leading Soviet index theorists, V.V. Martynov focuses on Allen's view on splicing and chaining indexes and the Laspeyres-Paasche spread (Allen 1980, p. 7). In this roundabout way Bortkiewicz was back again in Russia.

An indicator for the willingness of the statistical administration and the state to discuss the state statistical methodology was the increasing suppression of statistics starting from the second half of the 1970s. The period 1960-1978 was relatively abundant with data containing among others sector specific yearbooks and three I-O tables. Series of moral statistics as well as such production series as trucks disappeared in the late seventies and early 1980s. A change to better moral and agricultural statistics took place in 1985 (see e.g. Treml, 1986). G. Khanin's and V. Seliunin's famous article in *Novyv Mir* in 1987: '*Lukavaia tsifra'* was the late turning point in Soviet statistical discussion (Khanin & Seliunin 1987). The article criticized very frankly Soviet official growth statistics. Since 1987 many vanished series reappeared and statistical yearbooks by main sectors were again published (see e.g. Treml, 1988).

During the last three years of *Perestroika* the discussion about statistics was open, critical and conspicuous. This, however, came too late to change the methodological profile of Soviet statistics. Nevertheless, the likely existence of hidden inflation was illustrated with empirical data in academic journals and the press. Among others, Faltsman, Valtukh and Lavrovskii produced data that suggested to the existence of hidden inflation (Faltsman 1984, Lavrovskii & Valtukh 1986). Rutgaizer, Sheviakhov and Zubova referred to a study by the research institute of the State Price Committee establishing 43% consumer price inflation for 1971-1983 (Rutgaizer et al., 1988, p. 33). Thus, the problem of hidden inflation was acknowledged, but it is not put into systematic methodological context concerning the quality adjustment of price or volume indexes. The system change in 1991 brought the standard international SNA methodology into Russia, too.

3.5 A Scenario for Soviet Growth Measurement

The Soviet statistical administration inherited the basic Marxian axioms on national accounting. In the 1920s, the Soviet economic theory was still influenced by pre-revolution mainstream economists e.g. those in the *Koniunkturnii Institut* (KI). The KI was founded in 1920, because `economic policy´ was needed (IEU, 2000, p. 428). Although Konüs and Bushgens were banned from the index debate in the 1930s, they and many of their colleagues in the KI e.g., S.P. Bobrov, had an important role in bringing the accumulated tradition of mathematical statistics and modern index theory into emerging Soviet economics by the beginning of the 1930s.

A standard system of aggregate indexes was chosen in the early 1930s. The major proponents of the winning side were Strumilin and Starovskii, who chose weighted aggregate indexes with a 'minimal axiomatic approach'. Forced collectivization was followed by a blackout in statistics and brutal repression of dissidence in economic science. This period was prolonged by the intervening World War Two. The Marxist system of national accounting had been adopted already in the 1920s. National accounting was based on 1926/1927 comparable or fixed prices. The problems were many. The census system became only gradually comprehensive. In all statistical systems, the problem of new products must somehow be coped with. In the Soviet system the task was handled by state planners, later the State Committee of Prices. It is obvious that controlling the quality of new products was muddled in the circumstances of the 1930s and 1940s. This opened up a space for inflation. The first comparative prices of 1926/27 were used in 1928-1950. Price formation was controlled by planners. However, the huge annual flow of new product or specifications led to practices where new products were given their nominal prices without proper checking whether or not the new product was only a refinement of some existing generic product (Kudrov 2006, p.356).

Apart from the aspect of hidden inflation, the period 1928-1950 was also rather long from the point of view of index theory. The index laws of V. Bortkiewicz suggest that the Laspeyres-Paasche spread was large and growing in 1928-1950. The default assumption in economics is that the Laspeyres index dominates the Paasche index statistically. This is apparent for the Soviet Union, too. On the basis of the author's calculations for 1960-1990, Laspeyres indexes clearly dominated. The Soviet real production index is conceptually a Lowe-Laspeyres index and therefore it mostly overstated the growth rate of production relative to binary Fisher indexes. A binary Fisher index is theoretically an approximate measure of chained indexes.

In the aftermath of Stalin's death, the Soviet statistical system was normalized by increasing controls and introducing normal five-year base-periods into the index system (Starovskii 1977, p. 232-246). The balance method grew more refined and input-output models were added to national accounting for the first time in 1959. Thus, assuming the established prices, indexes as well as accounting systems, one expects a move towards standard measurement of economic growth. The transfer of the CSO into the GOSPLAN had meant that statistics became part of operational planning. In the late 1950s, during the period in office of Nikita Khrushchev, the planning system based on industrial ministries was changed to a regional planning system in the so called *Sovnarkhoz-reform* (Hanson 2003, p.58). After the ousting of N. Khrushchev from leadership the planning system was revamped back to the industrial ministries. However, the control of statistics remained in the CSO. Many developments in the statistical system and methodology took place, but the emphasis was on automating the gathering of data as well as on developing the classifications of the NMP-system (Starovskii, 1977, pp. 281-284). Within the CMEA as well as in the context the UN, attempts were made to integrate the systems of classification into the norms of the MPS as well as with the SNA. The author's experimental PMI index for 1961-1990 showed the minimum difference from official figures in 1961-1965. Later the difference began to grow until it fell absolutely in 1986-1990 (Ruoho, 2001, p. 36)[7]. Thus, in the period 1961-1990 the Soviet product quality residual made a U-turn around 1980, as revealed by the difference in official and alternative pure volume growth rates. As for the 1950s, G. Khanin and the Joint Economic Committee JEC had different ideas about the figures

[7] See also Figure 5.4.1 in Essay 4.

(Harrison 1993, p. 146). Khanin’s estimate was between the American and the official estimates. The Soviet growth figures in the fifties suffer less than earlier from heavy LPS as there were two chained five-year-based LQs. The Soviet TMP average annual growth rate in 1951-1960 was 9.9%. The CIA GNP figure in 1960 prices had an average growth rate of 6% for the time 1951-1960. The adjusted NMP figure was 7.3% (JEC, 1982, p. 23-25). A Törnquist volume index calculated with the CIA main indicators yielded almost the same figure. According to a rough check there was hardly any difference in Soviet LQs and PQs in the fifties. Thus, the revealed difference for Soviet and the CIA estimates was 2.6%. The result is roughly the same if we use Khanin’s growth estimates for the fifties (Harrison ibid. p. 146).

In market economies, the period 1961-1990 was characterized by a steadily increasing product differentiation and improving product-quality. It is obvious that economic reforms, especially the 1965 reform and the methodological directives of 1969 for new, high technology products, modified the methodology of coping with the quality adjustment of new products. The relatively slow development of domestic technology and the worsening labor shortage made the Soviet economy move slower. Soviet methods for measuring improved product quality were cost-based and used narrow criteria of technical efficiency (Nazarov, ed., 1982, pp. 230-234). Therefore, aggregated productivity gains at macro-level were often smaller than assumed by production-specific technical norms.

Since the beginning of the 1960s, the main methodological choices of Soviet statistics affected growth accounting only little. The Laspeyres-Paasche spread had been under control since the early 1950s, for inflation was relatively low, whatever the true rate. The base year length in indexes was as a rule 5-10 years. This was enough to even out the effect of the Laspeyres-Paasche spread. Nevertheless, the way new products were introduced into the system was still based on the comprehensive census system with the expected problems of control. The choice between SNA and MPS had only a limited effect on growth rates, because in 1950-1987 the non-productive sector grew proportionally to material production. Soviet index theory was archaic almost to the end of the Soviet period. Soviet statisticians favored fundamental operational definitions and neglected the elaboration of the formal methodology. However, the main methodological choices of the classical Soviet system were mainstream. The shortage economy in the Soviet Union grew increasingly tense from the beginning of the 1970s. Economic reforms, labor shortage, declining capital productivity and increasing freedom of producers to use prices and the range of production as decision instruments exacerbated the difficulties. In a monopolistic economy, with weak end-user feed-back and information asymmetry, census type of price control led to a U-turn in revealed quality improvement.

The debate on the Soviet statistical system and growth record in the late 1980s and the early 1990s was often methodologically fuzzy. Political choices and methodological strains were not differentiated. Two main issues may be mentioned: First, was the Soviet comprehensive census system reliable? Secondly, was the Soviet quality accounting, based on comparative prices inflated? The reliability of the Soviet census system is not our concern here. Formal index methodology was mainstream, although the formal index theory was already rusty in the 1970s. The Soviet annual comprehensive census system and the small Laspeyres-Paasche spread implied that the growth rates were insensitive to changing methodologies or formulas. The lack of theoretical sophistication led to problems mostly in coping with quality improvement.

Multiple simultaneous changes such as reforming agricultural prices, coping with wage inflation, adopting new price methodology for high technology products as well as liberalization of assortment directives would have required coping with the problem of **open inflation** and various potential **rent seeking phenomena** under monopolistic production. This tool-box of economic theory was still taboo at that time. Soviet economic theory only revitalized during the late 1980s. The perfect world of neoclassical microeconomics had an even more value conservative cognate in the paradigm of unbounded rationality in Marxist political economy.

4. Conclusions

Indexes *ceteris paribus* MPS and SNA yield the same growth rates for an economic system, if the non-productive sector develops at the same pace as material production. The choice of the correct theoretical price system for index calculation was a disputed issue in comparative theory. Theoretically, equilibrium prices in market economies are based on individual aggregator functions and are *ceteris paribus* unique. In planned economies, the planners could relatively freely redistribute incomes and with a productive linear production system prices could vary depending on the chosen distribution constraints. There is no precise way to reconstruct the true market prices for planned economies in retrospect. However, the studies by the Joint Economic Committee of the US Congress, using the Soviet established as well as synthetic market prices showed little difference at macro-level (JEC 1982). As for the main problem, the existence of **hidden inflation,** the situation is very similar with the MPS and SNA. Albeit the inclusion of services in national accounts complicates the hidden inflation problem, because service flows often can be quantified only as value flows.

The Soviet basic index methodology was mainstream in profile. In the period 1928-1950 the substitution bias as measured by the difference of the 1928 prices Laspeyres volume index and a synthetic Soviet binary Fisher index was 1.9 % in annual average. This formal substitution problem was adjusted later. In the 1950s the Laspeyres and Paasche indexes were close to each other. After 1950 mainly five year based Laspeyres type chaining was used and the formal substitution problem was not noticeable.

Pure index theory assumes invariable physical attributes for commodity dimensions. The metrics of the volume manifold Q^n is to be fixed. In real life, statisticians must decide how to measure changing commodity quality. The question is how to aggregate similar, but in detail technically different commodities in Q^n. There is no comprehensive economic theory for adjusting commodity quality in indexes. Obviously, one of the problems in the Soviet Union was comprehensive gathering of data. In market economies controlling quality improvement was not associated with permitting new commodity varieties higher prices. The quality change assessment in the OECD was related in each base period to a limited sample of specific commodities with well defined generic product categories. With census type data gathering, the number of commodities controlled annually was tens of thousands. The price catalogues, *preiskuranty*, were based on technical and commercial product descriptions and thus controlling quality changes within these categories was a much greater effort than controlling product quality within at most few hundred generic product categories.

In market economies, statistical authorities used **direct** and **indirect quality adjustment**. Hedonic methods and representative imputations were used variably in individual OECD countries. This adjustment process was carried out *ex post*. In planned economies, new commodities were priced and their quality was adjusted by the State Price Committee. Intrinsically, **asymmetric information** and **moral hazard** were problems because prices of new products influenced incomes and success indicators. Quality in planned economies was seen in the light of the alleged, system-specific technical progress. The economic system was monopolistic with weak end-user feedback. The assessment of improved quality was **cost-based** and depended on complicated **technical indicators**. The SNA quality adjustment procedure was not fully comparable to quality assessment in planned economies. This was the background of the **hidden inflation** dispute. It is plausible that the methodology of quality adjustment was influenced by economic reforms in the Soviet Union. The Kosygin reform in the late 1960s launched a quality improvement boom that turned into decline during the Perestroika in the late 1980s.

The discussion in the 1990s about quality adjustment procedures in the statistics of the OECD countries showed that the statistical practice was far from standardized in the OECD. The SNA and neoclassical micro-theory outlived the MPS and Marxist economics. The axiomatic and economic approaches are vital even today. Coping with changing commodity quality in the times of rapid commodity differentiation has become the main theoretical problem. Ever faster rotating sampling systems have brought operational index solutions in both main approaches closer together.

In the OECD, where statistical methodology was based on sample systems, statistics establishments gained from the theoretical discussion related to superlative indexes and chain-indexes. Increased chaining and the use of superlative indexes alleviated the sample representativity problem. The effect of more frequent chaining can be seen when the in the 1990s estimated sampling biases of the USA and the other OECD members are compared. The USA with a rather slow moving sampling system and the forerunners of annually chained indexes e.g. Canada, Ireland, Norway, Sweden, and the United Kingdom showed clear differences in favor of the latter group. Moreover, faster rotating samples facilitated the monitoring of quality improvement.

In the Soviet Union there was no need to make data gathering more frequent as the system was annual with all major new products automatically registered in the year of introduction. As we recall the conclusions in the theory of indexes lead to the same operational solutions for axiomatic and economic approaches. The new developments of axiomatic theory mainly boosted sampling and the use of chain indexes. Thus in fact the operational systems of the two main traditions converged. For the Soviet minimally axiomatic index methodology dating back to the beginning of the 1930s, the true Achilles heel was the near absence of a critical theory for monitoring the quality improvement in a highly monopolistic system of production.

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IV

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ESSAYS ON THE MEASUREMENT OF ECONOMIC GROWTH

ESSAY no 4

THE DEBATE ON SOVIET ECONOMIC GROWTH IN RETROSPECT:

A Methodological Evaluation of the Debate on Soviet Economic Growth 1960-1990

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THE DEBATE ON SOVIET ECONOMIC GROWTH IN RETROSPECT:

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IV

THE DEBATE ON SOVIET ECONOMIC GROWTH IN RETROSPECT:
A Methodological Evaluation of the Debate on Soviet Economic Growth
1960-1990

Abstract: *This essay reviews the debate on Soviet economic growth in 1960-90. The approach is methodological emphasizing national accounting theory and index methodology. Various alternative and the official Soviet indexes were transformed into common methodological bases for analysis. Although the estimators compared are quantitative, much of the analysis is qualitative.*

1. Introduction

1.1 From the Early Soviet Period up to the Sixties

The Soviet official growth record was critically debated as long the Soviet planned economy existed. Most of the time the critique took place outside the Soviet Union. It is difficult to measure production in an economy that is undergoing intensive structural and political change. It may be assumed that the Soviet economic system gained structural stability only after the postwar reconstruction in the early 1950s. The basic index methodology of the Soviet statistical administration was defined in the early thirties.[1] The system of national accounting, the Marxian Material Product System (**MPS)** was derived from Marxian schemes of reproduction in the 1920s and early 1930s (Dadaian, 1973, pp. 82-83)[2]. After a dynamic theoretical development in the twenties and early thirties the Stalinist silence set in with forced collectivization and the Great Purges. This was to change only in the mid-fifties after the death of the party leader J. Stalin (see. e.g. M, Kaser in Treml, ed., 1972, p. 45-65).[3] Even though the basic national accounting and index systems were adopted in the early thirties, it is obvious that that putting into place an efficient system of statistical administration took much longer. The period 1928-1950 was shaped by the first five-year plans, forced collectivization and the exceptional circumstances of World War Two. The detailed methodology of growth measurement was not public and regular statistical data

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[1] The last official name of this organization was State Committee of Statistics (*Gosudartsvennii komitet SSSR po statistike* or in acronym **GOSKOMSTAT**). Goskomstat was created in 1987 to replace the post war Central Statistical Administration or *Tsentralnoe statisticheskoe upravlenie*, TsSU (http://en.wikipedia.org/wiki/Goskomstat).

[2] Russian transliteration follows in the main the system of the Library of the Congress.

[3] For official history see *http://www.gks.ru/wps/portal/english*.

were not published. Methodologically an important feature was the use of 1926/1927 constant prices in 1928-1950 for growth indexes. In 1928-1960, A. Becker, A. Bergson, C. A. Clark, S. Cohn, D Hodgman, N. Jasny, N, Kaplan, W. Nutter and F. Seton were perhaps the best known Western researchers of the Soviet economic growth (see e.g. Abouchar 1979, Kudrov 2006 and Treml 1972). The alternative estimates for Soviet economic growth 1928-1950 are not widely different and show e.g. according to Bergson hidden inflation rate being around 3.4 % (see Abouchar 1979, pp. 34-5; Essay 3 above, Table 3.2.1). In the fifties statistical administration was normalized and statistical yearbooks started to appear regularly after 1960. Also, input-output tables were published since 1959. There were important alternative contributions to Soviet economic growth in the sixties (see e.g. Becker 1969). Becker calculated alternative volume indexes for 1958-1964. In the West and especially in the USA the CIA continued the tradition of American and British Sovietological pioneers and had by the end of the 1960s established itself as the main publisher of quantitative, alternative Soviet economic data. We start from the year 1960, because regular Soviet statistical data started to appear then. Using the CIA estimates as the representative Western specimen is well founded, because starting from the sixties there exists a crystallized and mature statistical methodology for studying Soviet economic growth. In 1960-1990 the Soviet statistical system is methodologically and institutionally well established (see ‘History of Russia’s State ..’; Eidelman 2006, p. 55). Finally the crises and collapse of the Soviet system in the late eighties and the beginning of nineties made domestic, alternative Soviet growth estimates possible.

1.2 The Status Quo 1960-1990 and the Research Plan

The critique of Soviet economic statistics centered on four main arguments. Two of these concerned the behavior of planned socialist economies. The third dispute dealt with the statistical methodology used. The last issue concerned prices and national accounting systems. First, it was assumed that due to political convenience those parts of socioeconomic data having security implications or predictable negative publicity effects were not published or even compiled. Secondly using a phrase of modern institutional economics, various types of **principal-agent problems** were thought to interfere in the production of statistical data. The ideal planning process presumes perfect information about specific production functions and resources. In fact, this information was imperfect and often shared **asymmetrically** (see e.g. Gregory 1990, pp. 41-43). Using this information asymmetry producers could embellish their production data, hide part of their resources or manipulate the relevant success-indicators in their own interest. Both Western and Eastern economists believed in distortions of primary statistical data and existence of unrecorded stocks and their resources (see e.g. Treml 1972, JECC 1982, Åslund, in Rowen 1990, p. 13, Eidelman 1992). This problem was often bypassed by assuming that it was not getting worse. This was known as the **'law of equal cheating' (**Nove 1988, p.374). In contrast it was thought that physical production statistics were reasonably reliable (Nove 1988, p. 367, Ericson in Rowen 1990, p. 66). The third problem was the adjustment of improving product-quality in price and volume indexes. The reference period was one year or longer. During the reference period quality in some commodity categories inevitably changes and this has to be assessed. Either the change is negligible or its size must be specified. With profound changes, a new product category may be established. If binary Laspeyres sample indexes are used, then coping with this problem only through sampling design is not possible, because the sample is determined at the beginning of the period. In market economies the problem is similar, but it is more technical and professional related mainly to statistical methodology. In planned economies, producers and the industrial ministries supervising them had vested interests in quality assessment, because their success indicators were dependent on it, too (Gregory & Stuart 1998, pp. 124-126). In the Soviet Union the State Price Committee certified the price catalogues (preiskuranty) that were then used for setting the so called **comparative prices (**sopostavymie tseny**)**. Comparative prices were the fixed prices of the base year. The State Statistical Committee used these prices in the calculation of actual price and volume indexes (see e.g. Ivanov & Alekseev 2000).

The problem of quality became an issue in Western economic debate with the report of the Boskin Commission in the USA about the biases in the US consumer price index CPI in the nineties (Baker, ed. 1998, pp. 2-3). The report assumed that the statistical methodology used in the USA overestimated consumer inflation rates with 0.6-1.1 % in annual terms. Some 0.6 % of this was due to incorrect adjustment of product quality dynamics in price indexes. The remaining 0.5% was seen to be related to sampling biases on various levels of aggregation. The scope of the American CPI has been around 70 % of GDP. Thus the overall effect of biased measurement on annual GDP growth rates could be about 0.8 %. The quality improvement bias of capital goods must to be added to this figure to assess the bias on the GDP level. In the early nineties the realized quality imputation into the CPI was about 1.7-1.8 % annually (ibid., p.102). Thus the total effect of changing quality was plausibly more than two percentage points in the case of the USA. Technically the implicit GDP deflator is a Paasche type price index. Although the CPI is a Laspeyres index, the problem of quality adjustment is similar in all price and volume indexes. The quality adjustment issue was studied in other OECD countries, too (see e.g. Rossiter 2005, pp. 4-5; SOU 1999:124, pp.265-300).

Inflation was not regarded as a natural component of economy in the Soviet Union and prices established by the State Price Committee were considered non-inflationary. Inflation was in Marxian fashion seen to spring from the capitalist dynamics of production. In planned economies inflation was generated by such exogenous factors as wars and other catastrophes. A technical planning failure could be a source of inflation, too (see e.g. GSE vol. 10, pp. 273-274). The main changes in relative prices took place in planned price reforms. Hence, if there was distinct inflation, it could only be hidden inflation. Thus any **rent seeking** by economic actors related to adopting new prices could be a source of hidden inflation in the Soviet economy. Most of the time in 1960-1990 Soviet official nominal and real aggregates of total product moved closely together, as they should by the textbook rules. This correspondence was slightly disturbed by the 1965 price reform related to the famous **Kosygin-reform** and later by the structural changes in Soviet economy initiated by minor reforms in the seventies (Hanson 2003, pp. 101, 140). The final change was brought about by the **Perestroika** under Secretary General **Michael Gorbatchev** (Gregory & Stuart 1998, pp. 246-260). The official open inflation rate for **total material product** (TMP) in 1960-90 was around 0.9 % (Narkhoz 1960-1990). The difference between the Soviet fixed price NMP-series and e.g. the corresponding GNP series by the CIA was about 1.6 % annually in the same period (JEC 1982, JEC 1990)[4]. Thus, the ceiling for total annual inflation in the USSR in 1960-1990 could be as high as 2.5 %. The essential consensus among Western economists was that part of the numerically impressive Soviet growth record was a face-lift driven by hidden inflation (see. e.g. Treml 1972, JEC 1982, Åslund in Rowan 1990, pp. 49-50).

The last debate item was the role of prices and the system of national accounting (NA) in growth measurement. Production boundary was defined differently in the main modern national accounting systems the **SNA** and the **MPS**. These categories are commensurate in growth studies only if NMP and GDP change in constant proportion. The NMP always conveys less information than the GDP or GNP.

[4] NMP is the MPS-value added category, **net material product**.

Indexes are aggregated with prices. Soviet prices were not scarcity prices, which raised the issue of Soviet prices as legitimate welfare or cost indicators.

We limit our research task with some demarcations. First, we do not examine the reliability of Soviet statistics as to primary physical data. Secondly, we ignore the issue whether the Soviet price system was an adequate measure of production and welfare. This issue is relevant, for instance, in assessing the wear and tear of capital and capital resources in wide terms. The inclusion of foreign trade in the national accounting system depends on the price system, too. We analyze domestic growth dynamics and ignore the complexities of international comparisons due to the optional choices of exchange rates.

Our questions may be formulated as follows:

1) Would the Soviet official statistics and the alternative Western and Soviet growth statistics be congruent if the same national accounting system and index methodology were used?

2) If not, was there an alternative consensus about Soviet economic growth?

3) Was the Soviet method of quality imputation comparable to the common SNA practice in the OECD or did the Soviet quality adjustment procedure complicate international growth comparisons?

4) Were the alternative indexes seriously biased due to inadequate sampling?

2. The Choice of Standard Measures

2.1 Introduction

Standards of measurement usually refer to two things: the standard measures themselves and the acceptable variation between measurements of the same item with different standard measures (Stigler 1999, p. 361-366). Four main elements are involved in the measurement of economic growth: the system of national accounting, the operational indexes, the price system and the arrangement of data gathering. We only touch on the issue of price systems and take the measurement of economic growth as an exercise in index methodology. We attempt to control the effect of the three other basic elements on the measurement of Soviet economic growth. The emphasis on methodological unity as well as problems with availability of data in other than the Soviet MPS-category has led us to choose the MPS and Soviet index types as methodological tools.

2.2 The System of National Accounting and Real Production

We had to choose either the material product system MPS that was used in the CMEA or the standard **SNA**. The production boundary is narrower in MPS (see e.g. Becker in Treml et al., 1972, pp. 73; Comparisons of the System…). The MPS is Marxian and excludes services from the production. The Soviet national accounting data was comprehensive only in MPS categories, particularly for the total product **TMP category**[5]. Our own data, the **PMI model**, was based on Soviet official published data. Therefore, we chose to use total material product **TMP**, gross material product **GMP** and net material product **NMP,** which are the main MPS aggregates. The main Western producer of alternative estimates of Soviet economic growth, the CIA, published its main series in this category, too (JEC 1982, p. 25). However, most CIA series were of the SNA type. The **GOSKOMSTAT** published series

[5] Conceptually the **TMP** is equivalent to **total outputs** in I-O analysis. Hence it is a **turnover category**. The CMEA Statistical Yearbook used the English term **Gross Social Product**. The term gross usually includes depreciation and the term net excludes it. Therefore we prefer total to gross when referring to total outputs (valovoi obshchestvennyi produkt). We use the term gross in congruence with the SNA. Thus gross material product **GMP** is net material product plus depreciation.

for GNP/GDP in the late eighties and there are unofficial estimates of the GNP for 1970-1990, too (Zoteev 1991). In the Post-Soviet period we have the work of A. Ponomarenko on Russian national accounts and economic growth 1961-1990 (Ponomarenko 2002). There are data to compare both the nominal and fixed price divergences of NMP and GNP in the Soviet Union for 1960-1990.

The formal frame for calculating real product, growth and inflation is the same for both the SNA and the MPS. The economy and the index methodology *ceteris paribus*, the differences in the growth rates of GDP and NMP are due to production boundary and detailed operational accounting rules. The input-output form of national accounting is in principle equivalent to accounts in institutional form. Basically we have the group of matrix equations:

$$Y = (I-A)X;\ X = (I-A)^{-1}Y.$$

There are four quadrants in traditional input-out tables: The **intermediate production** matrix AX_{nxn} or $(x_{ij})_{nxn}$ is the first quadrant, the **final product** vector $\mathbf{Y_{nx1}}$ is in the second quadrant[6]. The final product vector Y may be presented as a matrix expansion of final product components including C +G+ I + (EX-IM)[7]. The investment concept is gross investments[8]. The **depreciation** row vector $\mathbf{D_{1xn}}$ and the **net value added** vector $\mathbf{W_{1xn}}$ belong to the third part. Conceptually the fourth quadrant is for income transfers. The value added and the final product are GMP or NMP categories.

$\mathbf{AX_{nxn}}$ or $\mathbf{(x_{ij})_{nxn}}$	$\mathbf{Y_{nx1}=C+G+I+(EX-IM)}$
$\mathbf{D_{1xn}}$ $\mathbf{W_{1xn}}$	

Imported inputs are embedded in AX_{nxn}. It is easy to calculate standard price or volume indexes for the total outputs X. The aggregates of interest are normally W or Y. If we choose to calculate the real W

[6] AX_{nxn} is not a matrix product.
[7] We denote exports and imports with EX and IM respectively, because we have reserved X for the I-O total product.
[8] The problem of taxation is ignored here.

the problem is that the value flows have no direct commodity representatives. There are two main solutions: the first is to assume that the relative structure of the input-output table remains stable and use the output vector X as commodity representative and the value structure of [D ; W] [9] or W as weights. This is the main procedure used e.g. by the CIA in their index models (see. JEC 1982, p. 42). If the proportions between the I-O table quadrants change, the final product or the value added dynamics will be biased. The second option is **double deflation**, where the output X_{nx1} and the intermediate production AX_{nxn} or (x_{ij}) are deflated with their own price indexes and the real value added is their difference. There is an analogous procedure for using a double system of volume indexes. This was the Soviet official procedure for calculating the real NMP produced (Nazarov, ed., 1985, p. 386). If we decide to calculate the real value of the final product Y= C+G+I+ (EX-IM) on the end use side, we have commodity representatives for most classes. Technically the final product is an open system because (EX –IM) is included. This brings in exchange rate changes and structural changes in exports and imports. The double deflation concept is applied here, too. The domestic production and imports are deflated with separate indexes and the real product is the difference of these two deflated aggregates (Studies in Methods, series F, No. 85, 2003, pp.104-112). Thus the GPD deflator is not a simple standard index. In the OECD short term inflation is monitored with Laspeyres price indexes and real growth of the GDP with Paasche price indexes. The GDP deflator is the so-called long term **constant volume measure** (**CVM**) that is chained annually.

2.3 The Price System

In economic theory free market prices are based on the optimizing behavior of consumers and producers. In the absence of monopoly or other forms of imperfect competition and the historical resource distribution ***ceteris paribus,*** market prices are a relevant measure for the value of production. All statistical categories are standards of measurement or classification and as such **bureaucratic social conventions**. In market economies, the SNA-system is based on actual market prices. In planned economies production decisions were based on collective objective functions expressed often in physical terms. Optimization by individual actors did not play a role in the planning process. The main

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[9] This is a Matlab notation. There are two row vectors.

target was to create **integrated plans** that were physically **feasible** and **financially congruent** with established prices and the prevailing distribution of income.

Planning was based on so called **material balances** as well as on **input-output models** (Gregory & Stuart 1998, pp.104-109 and Granberg 1978, pp. 242-243). A physically feasible plan was formally based on a **productive input-output matrix**. A linear system of production is **productive**, if there is a nonnegative solution for the inequality **(I-A)X > 0**. There are several technical tests to verify the productivity condition (Simon & Blume 1994, pp. 794-795). If a linear production system, represented by a square matrix **A** is productive, then any production task with a semi-positive target vector of **final production Y** can be solved formally. Which solutions are feasible depends on the prevailing constraints. Therefore a semi-positive **total product input vector** $\mathbf{X_n}$ is uniquely determined for any positive final product vector. The **dual task** in planning relates to the production or factor income side of the input-output model. Here productivity of input-output matrix implies that for any semi-positive vector of **value-added** a unique **price vector** can be calculated (Baranov in Dadaian 1973, pp. 155-157). If the column sum of a productive input-output matrix A is greater than unity in current prices, indicating a loss making sector, then it is formally possible to find a new price vector that changes all national income items in the input-output matrix to positive (Granberg 1978, p. 274). This has implications for planned economies. Enterprises in market economies have **hard budget constraints,** whereas in planned economies the **budget constraint** is **soft** for producing enterprises and even for branch ministries. The hard budget constraint is binding only on the level of national planning and accounting (Kornai, 1992, pp. 140-145). Hence, some branches and sectors in planned economies could be non-profitable or in a milder case not financially self-sufficient, necessitating a complex system of turnover- and profit taxes as well as subsidies. Due change of planned prices was often substituted with subsidies and skewed incidence of taxation. Profits as well as losses were planned and the distribution of these elements was a planning instrument that was substantially modified only by large-scale price reforms (Gregory & Stuart 1998, pp. 137-142).

Physical target setting dominated. This emphasized the final product approach at the cost of the producer side value-added approach. The equation was made even more difficult by ideological constraints derived from Marxist-Leninist political economy. The most salient of these was the legacy of the Stalinist **model** of **accumulation**, where the exchange with agriculture was planned to be nonequivalent from the start (see e.g. Gregory &Stuart 1998, pp. 62-69). The law about the superior growth rates of capital goods industries over consumer goods industries is another example. This law was regarded fundamentally valid until the late 1960s (see Nove 1988, pp. 357-361; EEPE vol. III 1979, pp. 167-169).

Because value added items in many sectors differed considerably from corresponding end use items due to income transfers, these net items had clear disadvantages as aggregating weights. This may explain the fact that the Soviet national accounting system was most detailed in TMP categories. The detailed NMP in Soviet statistics was from the producer side. Most alternative measures of Soviet economic growth used total product series as basic indexes, too. To bypass the problem of distorted value added shares, the CIA adopted Abram Bergson's **adjusted factor cost procedure (AFC).** This was based on standardized items of profit, removing turnover taxes and adding subsidies (JEC 1982, pp. 33-41). The AFC-based weights standardized the national accounting system towards the SNA, but they could not simulate markets. Some Soviet approaches used wage funds as value added weights (see e.g. Kholodilin 1997). This is a pragmatic device that had precedents in early Soviet price concepts (see, Shirokorad 1992, pp. 192-204). Yet, as for aggregated macro-data, the differences between the CIA GNP series using AFC weights and series using the Soviet established prices were rather small in the long run (JEC 1982, p. 40-41, Rosefielde 1991, p. 600). There is no retrospect remedy for the absence of markets in the Soviet Union. Due to lacking data, we adopted the **Soviet established prices** as weights. The bright side of this choice is that it improved the comparability of official and alternative growth figures.

The standard index methodology in the OECD countries in the period 1960-1990 was to calculate Laspeyres and Paasche price indexes with the five-year sample period. Conservative countries used five-year base periods with price indexes. Modernizers like the United Kingdom, France and Sweden changed rather early to annually modified price indexes (Forsyth & Fowler 1981, p. 224-225). However, the GDP deflators were calculated annually.

The alternative index systems of Soviet economic growth were methodologically **heterogeneous.** This goes for sampling, the length of the base period as well as index types used. The CIA’s and Ponomarenko’s data were in the SNA and the rest of the indexes in MPS. We made various growth indexes commensurable by transforming them into **synthetic indexes** of the same type. That is, we transformed them into the Soviet form. The Soviet input-output tables were useful in this transformation (Narkhoz 1960-1990; Baranov in Dadaian 1973, pp. 138-142). Soviet input-output tables were used to interpolate and extrapolate sub-sector value weights of the 13 main sectors. Our synthetic transformations were not precise. The modified indexes are not numerically identical with their methodologically correct large sample counterparts. However, their behavior should be very similar to these both in qualitative and quantitative terms. The Soviet sector-specific volume indexes were chain indexes, chained and spliced between different references of comparative prices. Because the primitive indexes were of Lowe-Laspeyres type, it is likely that the Laspeyres-Paasche spread (**LPS**) of the derived synthetic indexes is too small. The bias should be highest in the Paasche end of the scale. The alternative primitive indexes have a weight structure bending to the Paasche end. This, too, is a source of bias.

2.4 The Choice of Standard Indexes

2.4.1 The Index Formulas

The Soviet State Committee of Statistics used growth indexes that may be interpreted as chained **Lowe-Laspeyres** volume indexes based on almost comprehensive data[10]. The Soviet Lowe volume indexes had fixed prices for 5-10 year periods, but new commodities were introduced annually, because the system was comprehensive. When measuring the real growth of the GDP or GNP the price index is the Paasche type deflator. The so-called **factor reversal test** requires that the value index is the product of the price and volume indexes. Thus Laspeyres price and Paasche volume index is a pair, likewise Paasche price and Laspeyres volume indexes. The exact factor reversal criterion applies only for theoretical or comprehensive population indexes (Balk 1995, pp. 71-75). The OECD GDP-volume index is Laspeyres. Formally the situation is slightly more complex as in obtaining the real value added so called double deflation is used. Double deflation is also applied to (EX-IM) on the end use side. The GDP deflator is always a chain index. The long term constant volume measures were in the USSR of Lowe-Laspeyres type. Conceptually the residual Soviet implicit price indexes were proximate

[10] A Lowe index is a **fixed basket index**, where prices may refer to other points in time than the first and last point of

Paasche indexes. Both the Soviet and the OECD long term volume measures were proximate Laspeyres volume indexes, but the Soviets calculated them directly and the OECD countries through composite Paasche price indexes.

The basic Soviet index system was based on so-called **comparative prices** (sopostavimye tseny). A comparative price was taken from the official price list (preiskurant, see GSE vol. 20, p. 531). Prices in the price lists were based on expert opinions and standard directives. The State Price Committee set the most important new prices. In the Soviet system the **adjustment of improved product quality** relative to a new price took place when the new list price was established. The comparative price production for a given year was $\sum p_{ic}q_i$, where p_{ic} is a comparative price. Enterprises reported the comparative price data themselves to the GOSKOMSTAT (Narkhoz SSSR 1990, p. 698). The length of the comparative price base period varied. It could be a 5 or 10-year Laspeyres-system or a **Lowe-type index,** where the price base year preceded the first index year. In most five-year periods the price reference was earlier than in Laspeyres indexes, for instance 1955 prices for industry in 1961-1965. The Soviet base price year system was stratified. On the level of NMP/TMP the basing differed by sectors in such important sub-sectors as industry and agriculture (Table 2.4.1). There was no new goods problem in sampling, because all commodities entered the index. The problem was how to establish the correct comparative price from an adequate price list (Eidelman, 1992, p. 19).

Soviet statistical thinking was based on volume indexes, comprehensive sampling and the system of comparative prices. The system was a hybrid one, as is already apparent in the base year price system. Most of the time in 1960-1990 comprehensive price indexes could be calculated only as residuals according to factor reversal test. In the 1960s and the late eighties some sample based price indexes were also compiled. It is difficult to strictly define the correct Soviet price index that fulfills the factor reversal test. This is due to the hybrid nature of Soviet volume indexes. Factor reversal test always refers to binary indexes. In the Soviet Lowe-Laspeyres indexes the base year for prices usually preceded the Laspeyres base year. In 1966-70 the Soviet index is closest to standard Laspeyres references for NMP/TMP. The comparative prices did not change in the reference period. Within the reference periods the annual chain indexes fulfill the circularity test because of unchanged prices. This

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the reference period. Lowe/Laspeyres indexes have a price or volume reference that precedes the sample period.

Table 2.4.1 The Comparative Price Reference Years of Soviet Volume Indexes
by Five-Year Plans 1960-1990

FYPS[1]	1961-65	1966-70	1966-70	1971-75	1976-80	1981-85	1986-90	1986-90
Sub-period of the FYP		1966	1967-70				1986-88	1989-90
TMP and NMP	1958	1965	1965	1965	1973	1973	1983	Annual
Industry	1955	1955	1967	1967	1975	1982	1982	1982
Agriculture	1958		1965	1965	1973	1973	1983	1983

Source: Narkhoz SSSR 1960-1990

[1] Five-Year Plans

is also true for the OECD standard indexes with base periods longer than one year. The difference from the OECD was that the valid system comparative prices used in the USSR followed nominal prices more closely.

Adjacent indexes were chained through splicing (Nazarov 1985, p. 386). Because a Lowe index with the price reference year preceding the first index year usually dominates over the corresponding Laspeyres index, the five-year Laspeyres system should give slightly smaller growth figures than the Lowe (Basic Index …, pp.399-400). It is obvious that the bulk of the Laspeyres-Paasche spread in Soviet indexes was due to changing comparative prices at the nodal points where the base years of comparative prices changed. The Soviet base year system was slow moving. Thus it may be expected that chaining synthetic volume indexes below the basic periods of official comparative prices has fast declining drifting effects on the LPS. The potential bias in the Soviet system was related to the fixed prices used. The volume sample was always representative. With slow moving comparative prices the problem was to set correct temporary fixed prices for the new goods.

We transformed both the Soviet and the alternative indexes into Laspeyres-volume indexes in annual, five-year and binary forms. Index formulas are many (see e.g. Vogt, 1997, pp. 9-36). Two indexes are especially theoretically recommendable in addition to the standard Laspeyres and Paasche-indexes. They are the **Fisher ideal index** and the **continuous Divisia-index** (Rao & Selvanathan 1994, pp. 111-120). Technically the latter index formula is a path dependent line-integral. In order to evaluate this integral the continuous path in $Q^n x P^n$ must be known. Often the required data is lacking. The Swiss statistician Vogt therefore introduced his **Natural Divisia** index, which is calculated along a linear path connecting the binary endpoints in $P^n x Q^n$ (Vogt 1977, pp. 76-79). The Natural Divisia index can be calculated approximately having only binary price and volume data. We also calculated the **Törnquist** and **Walsh** indexes.[11] We compared the relevant growth indicators in all the six forms above listed. We studied the effects of chaining and formula types within our synthetic model indexes.

[11] The formulas of all the above indexes are given in Appendix IV.

2.4.2 The Choice of Index Type and Economic Theory

In index theory two main approaches dominate: the **economic approach** and the **axiomatic approach**. The economic approach assumes that well-behaving aggregator functions underlie the consumer and producer choices. The concept of the **true price index** uses utility levels to standardize the measurement of price changes (Selvanathan & Rao 1994, p. 31). Producer price indexes are based on production functions. Indexes explicitly referring to utility levels are not observable or operational. Although production functions are empirical, it is difficult to aggregate them in a meaningful way. Thus the economic approach leads to upper and lower limits for theoretical indexes in terms of the standard Laspeyres and Paasche indexes. This explains the desirability of the so-called **superlative indexes.** These closely approximate the economic index numbers in small, time neighborhoods, *ceteris paribus* the assumptions about the aggregator functions, namely utility, cost and production function (ibid. p. 57). The Fisher ideal index and the Törnquist index are examples of superlative index numbers[12]. The axiomatic approach assumes that prices and volumes behave independently. This means that their covariance is logically free in the model frame (see e.g. Balk 1995). There are two main concerns: First, index numbers should satisfy as many axioms as possible. Second, as no utility functions, collective or individual, are assumed, the required operational criteria are related to **dynamic sampling properties**. An index number should utilize the maximal amount of information about the realized path of an economy in $Q^n x P^n$. This leads to considerations about **chain** and **integral indexes** (Vogt 1977, pp. 84-86). The ideal solution is the continuous Divisia index. With some approximations both theoretical index approaches lead to the same operational formulas. We have to establish the level at which standard indexes become interchangeable.

We have fixed the most relevant parameters in our comparisons; hence the differences revealed between the index numbers should mainly be due to the fact that the alternative growth indexes were not adjusted to changing product quality, whereas the Soviet official indexes were quality adjusted. The difference may also be due to sampling bias in the alternative indexes.

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[12] This index is also called the Theil-Törnquist or the Törnquist-Theil index.

2.4.3 The Sampling Problem

The Soviet statistical primary data was **census-type** or comprehensive. Producers were liable to record their production details for the **State Statistical Committee (GOSKOMSTAT)**. It was an offence not to report or to report false data (see e.g. History of Russia's State …). All alternative indexes of Soviet economic growth were based on sample data. We had some problems. First the **adequate sample frame** was not known and secondly the data published was so limited that practically all-main indicators of the Soviet statistical yearbooks (Narkhoz SSSR, 1960-90) had to be used. This type of sample may well closely represent the structure of production, but it is not a **probability sample**. The gravity of the problem varies by branches and sectors of the Soviet economy. Some sectors of production were well covered by published indicators on a high level of physical aggregation. This was true e.g. for **agriculture** and **transport**. Here the non-random sampling resembles **cut-off sampling.** Some sectors of industry were well represented by highly aggregated product categories, e.g. electricity, fuels, metallurgy, construction materials, forest industries and a part of the light and food industries, too. Here the 'virtual representativity' was due to the nature of the technological process. The main problem with these sectors was the loss of accuracy due to quality neglect. The lack of details was most acute in the machine building and chemical industries. The sample of commodities in Narkhoz SSSR was not systematic relative to the formal nomenclature. Nominal sub-sector weights were difficult to obtain from Soviet data. These shares had to be interpolated and extrapolated from annual fixed price value-structures and from input-output tables for 1959, 1966, 1972 and 1987-89. The TMP data in input-output models deviates from the corresponding MPS data. The input-output data exaggerates the total production in some sectors, diminishes it in some other sectors and it is on the aggregate level about 10% larger than the statistical yearbook concept (Granberg 1978, pp. 250). The Soviet national-accounting data was in purchaser prices for total material product and net material product. For industry the wholesale prices of industry or enterprises were used. The input-output data was in the prices of end users. A crude test of aggregation is to recombine the Soviet official volume indexes by sectors into a TMP index and compare this with the official TMP[13]. For the TMP/NMP structure purchaser's prices were used.

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[13] In Soviet terminology this was called ***valovoi obshchestvennii produkt*** or **VOP**.

In line with Aristotle and the classical economists, Soviet Marxists placed the service sector outside the production boundary. The most similar sector to services was trade, including domestic retail and wholesale trade as well as foreign trade. The product of the trade sector was seen to be delivering the material production of industry and agriculture to domestic and foreign users. The product was a mark-up on industry and agriculture sales. In Soviet input-output models the pure trade-sector delivers only **intermediate production** (Dadaian, ed., 1973, p.138**)**. There was no final product. This reflects the MPS product concept. Products are material commodities or services related to material production. Serving producers is material, whereas serving consumers is not. The total product of trade can be derived from input-output tables as an intermediate sales vector if all the other total product indexes are known. We calculated the total product of Soviet trade in our PMI index this way, because in Soviet statistics there was no commodity data related to wholesale trade. In the column direction of an input-output table trade also creates value-added. The total product in construction is also calculated from an input-out table. The construction sector sold only **final product items** (see e.g. ibid.**)**. If the input index of construction is correct, it should be the same as the final product index. The data on final products were scarce, hence the TMP of construction is estimated using intermediate inputs of production. When we estimate total product by intermediate inputs, we must ensure that the ratio of intermediate inputs to total product remains unchanged in the period reviewed. The volume bias in trade and construction is derived from the biases in the used 11 input sectors. Soviet statistics showed the TMP aggregate for all production, industry and agriculture. The proxy for fixed TMP dynamics in the transport sector was the total freight turnover in Narkhoz. Within the Soviet I-O model the transport sector had mainly intermediate sales. In 1959 there were no final sales and in 1989 the share of the final product was about 5% (Dadaian, 1973, p. 138, Narkhoz 1990, pp. 296-297). In the SOF model NMP of transports was used as a proxy for fixed TMP in transports. This is slightly higher than the total physical freight turnover in tons. Fixed Soviet TMP in trade was assumed to follow the official NMP trade index. The official NMP and TMP for construction indexes were shown by Eidelman (Eidelman 1993, p. 16). There was no precise series for real valued Soviet construction TMP in Narkhoz.

When studying the bias in the CPIs, it is customary to speak of the **upper level** substitution bias and the **lower level** substitution bias (see Rossiter 2005, p. 5; Baker, ed., 1998, pp. 50-54). Sampling systems for CPIs are always stratified. First the shares for broad product strata must be determined, regional sampling strategies must be chosen and lastly the actual sample commodities must be selected. The upper level bias refers to changes in the upper layers of stratification, e.g. when the shares in national accounting data change annually or regional quotas or the retail trade logistics change. E.g. the market shares of various types of retail outlet change. The lower level bias refers to the elementary level of stratification, where the actual sample goods are. Because of the census type data the Soviet official indexes had only a minor sampling bias, excluding the opportunity of false reporting and losses. In the alternative indexes compared the upper level bias is limited, because up to the 13 main sectors and some subdivisions the weights were based on the Soviet nominal national accounting data ex post. Because of non-random sampling and problems in identifying the true sample frame, there were likely more problems in the middle and lower levels. There were hardly any physical commodity statistics for some modern sectors of the machine building industry. From the Soviet official point of view the problem was adjusting the quality and prices of new goods. This is an important field, as in the Boskin report for example, the upper and lower level substitution bias was estimated to be around 0.5 % annually in the USA (Baker, ed., 1998, p. 53). In 1995 the imputed quality in the USA CPI was about 1.7%. The phantom that the alternative indexes tried to capture was the **unbiased pure volume growth**. This way the quality imputation problem and the sample bias problem could in principle be separated.

It is obvious that we cannot use **strict probability arguments** to **validate interval estimates** for the alternative indexes. Therefore we used **triangulation** as a method of **corroboration**. The probability argument fails due to non-random sampling from the Soviet published data. It was not known whether the sample frame in the Soviet statistical yearbooks was unbiased. **Falsification,** however**,** can be used in reverse. If the alternative indexes are good, they should correlate positively with their Soviet co-indexes. The other stochastic point of view is the **time series view**. Here the problem is the small sample size of 30 years. This allows in practice one or two explanatory variables. However, a stable trend between the Soviet official series and the alternative series, although corroborating the robust sampling validity, does not without further assumptions allow to separate the effects of biased sampling from changes in quality imputation by the state price planners. The limitations on stochastic testing are not as bad as it may seem. The Soviet raw data used in official indexes were comprehensive and the time variation in these series should be qualitatively adequate. Secondly, we could use

behavioral congruence within alternative and official indexes as well as the **technological invariance** of production to study the sample issue. The methodological maxim was: *the scheme of analysis should be qualitatively and conceptually strict and robust in volume terms.*

3. Methodology and Data

3.1 Triangulation in Data Analysis

We intend to study the congruence of Soviet official data with alternative indexes. Therefore we have to assess the reliability of our own and other alternative indexes[14]. Instead of the high level bias our problem was the low level bias. Because we did not have a random sample of Soviet production data, we or other outsiders could not use standard confidence interval estimates for growth rates[15]. Another problem was the fact that the alternative estimates were pure **volume estimates**, whereas the Soviet figures were **quality adjusted**. We had to compare qualitatively different figures and were uncertain about sample quality. Hence we needed **triangulation** as a method of **corroboration**[16.] Triangulation implies that similar, but not strictly commensurate methods are used to establish a broad consensus on the issues under study. This consensus may be quantitative or qualitative. First we calculated the standard growth record by pure volume indexes. After this we calculated the residual differences of the official Soviet growth figures and the alternative pure volume growth rates. These differences may be attributed to hidden inflation, true quality adjustment relative to new prices or sampling biases in alternative indexes. We chose three criteria for sample quality:

1) First if a **value indicator** of some sector in the sample covers the bulk of the nominal production in that sector; we may assume that the indicator is **robustly representative**. This applies mainly to agriculture, transport sector, electricity and fuels.

2) Secondly if there is a **general production indicator** in natural units for the whole branch e.g. rolled steel in ferrous metallurgy, we may conclude that this gives a reasonable, even if conservative, picture of the general dynamics although the ruble value of the indicator is far from covering all the production.

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[14] Validity is not a serious problem because standard measures were used. Quality imputation, however, is related to validity, too.
[15] The essential data for the PMI was gathered in 1991.
[16] Corroboration refers to accumulating and increasing the existing evidence material. We are indebted here to Francis Bacon for our methodological approach. He had the methods of agreement, difference and concomitant variation (*http://en.wikipedia.org/wiki/Corroborating_evidence*).

3) It is possible to measure the statistical proximity of sector specific growth rates of official and alternative indexes from a **time-series perspective**. Statistical properties of estimators may also be used for corroboration by applying **the principle of falsification**. A bad sample should display a low correlation between the alternative indicator and its official covariant. This is so, because methodologies for assessing product quality change slowly and it may be assumed that quality improvement by sectors is a linear trend. In order to test this various time-series methods may be used.

We applied official value-weights and we compared three alternative growth estimators to the official Soviet figures. Two of these are by outsiders: the figures of the CIA and the figures of PMI-index compiled by the author. The third alternative series are the recalculations of Soviet industrial production and construction by M. Eidelman, who worked for the Russian GOSKOMSTAT at that time (Eidelman 1992 , 1993). The first two indexes may be biased due to non-random sampling and small sample. Eidelman's study had a robust sampling strategy. His alternative calculations comprise 80% of all industrial production. Sector and sub-sector sample indexes cover 40-80% of the sample frame production. The sample consists of over 200 sectors and 2500 commodities. According to the published references his index is much like a pure volume index (Eidelman 1992, pp. 21-26). Eidelman's data are very similar to the CIA or PMI series. The fourth systematic reference is the study by A. Ponomarenko (Ponomarenko 2002). Ponomarenko's subject was Russia. Nevertheless, his ideas about quality adjustment in Russian indexes should be interesting for assessing the whole Soviet data. Historically the Soviet and Russian growth series were close to each other in most sectors.

Although we dealt with only a few alternative indexes, we do not believe that other alternative indexes were not good. Many of them had great merits. E.g. Kholodilin and Suhara used labor costs as weights for volume indexes (Kholodilin 1997, Ponomarenko 2000). The best-known domestic alternative indexes for Soviet economic growth were those by the Russian economist Grigorii Khanin (Khanin 1991). He gained great international publicity with his article *´Lukavaia tsifra'*, the *Cunning Figure* in the periodical Novyi Mir 2/1987 (Khanin & Seliunin 1987). The article changed the perception of the Soviet growth record radically downwards. Khanin's work applied resourceful model technologies and it was done under the harsh information constraints of the Soviet Union. Alas, Khanin's approach was methodologically too eclectic to fit into our standard index approach. In addition to standard volume indexes, Khanin used indexes based on various types of technological invariance (Khanin 1991). In line with Suhara and Kholodilin he also used wage funds as weights (see e.g. Ericson in Rowen 1990, pp. 63-92). He then used the averages of these heterogeneous indexes as final indexes. His study was a paragon of qualitative triangulation. His long-term estimate for the Soviet economy 1950-1990, however, is in line with other alternative estimates (ibid. pp. 73-74). Khanin's early work illustrates well the overwhelming distrust that many Soviet economists and statisticians felt about the official Soviet statistics. Subsequently, Russian research on the theme has produced a more varied, even if similar picture of Soviet statistics (Kudrov 1996A, pp. 84-88). The Russian GOSKOMSTAT continued to study the Soviet economic growth after the transition. The research work of Eidelman and Ponomarenko belongs there. The prevalence of pure volume growth measurement in their studies makes their data commensurable with Western alternative studies.

We chose a fairly conservative approach based on standard methodology to utilize formal index theory. In this type of narrow, economic and statistical approach not many important institutional developments can be analyzed in detail. Although we used eclectic methods in triangulation of the empirical results, the PMI model itself is a standard estimator. With group comparisons we used various **screening rules**:

1) If the figures of all index groups are very close to each other, we may assume that the chosen alternative volume indexes are robust and that in these sectors the Soviet official indexes are insensitive to quality changes.

2) If the differences in alternative volume indexes relative to the Soviet official indexes are very similar, we assume that in these lines of production the Soviet indexes are sensitive to quality changes, there is hidden inflation in the Soviet data or there are sampling problems in the alternative indexes.

3) As for the differences between the alternative volume indexes, this may be due to different weight types, e.g. value added versus total production or this may be due to biased samples in the CIA or PMI indexes relative to Eidelman's comparatively large sample.

3.2 The Soviet Price System and the Standard Index Methodology

Price or volume indexes are calculated to discover the rates of real growth and inflation. In a market economy the prices are current market prices. Consumers and producers are sovereign. The actual atomistic selling and buying contracts aggregate to national product or income. **Inflation** and **real production** are ***ex post*** and **synthetic.** The planned economy was divided into two departments: on the one hand the **producer sector** and on the other the **retail** and **household** sector. Money flows in the producer sector took place in the form of **book money** in the accounts of the state banks. No major contract was made without administrative permission (Nove 1988, p. 28). Money was not a universal means of payment. The everyday money, e.g. in the form of banknotes, played a role when wages and salaries were paid and purchases made in the retail sector. Individual optimizing behavior in the sense of standard micro theory took place only in private consumption, where consumers were price takers, *ceteris paribus* incomes. Consumers were price takers not due to perfect markets but to regulation. Consumers were price takers, but they could also not to buy if they did not accept the planned supply.

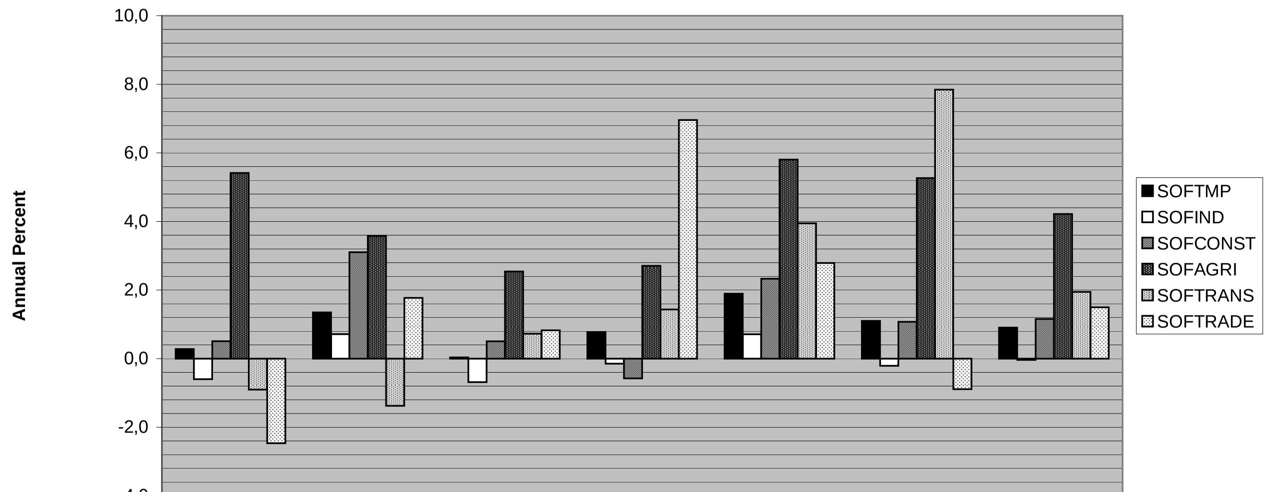
All main prices were administrative. The main commodities had a current administrative price and a fixed price called **comparative prices** (sopastavimye tseny). The comparative price was an expert-determined administrative price. In market economies the changing product quality is adjusted for indexes *ex post* when price indexes are calculated. In a planned economy for a new or modified product the price was adjusted to the changed product quality when the administrative list price was established. Fixed price production was the current physical product calculated in comparative prices. Prices were relatively free only in some limited consumer markets and in informal economy. Because consumption in detail was not planned, the state retail prices should clear the markets based on autonomous demand.

In the long run production technology developed and planners' preferences changed. There was a tendency starting from the late fifties to enhance the decision competence of enterprises (Gregory & Stuart 1998, pp. 245-264). Starting from the late sixties the nominal profits of enterprises doubled. They returned to the original level only in the eighties (Narkhoz 1960-1990). Consequently prices had to be adjusted. Prices were adapted in recurring new price lists and in major **price reforms**. Since the planners strove to keep the fixed price and nominal price aggregates close together, price reforms led to immediate **relative income transfers** between various sectors and sub-sectors. Because inflation was to be avoided on practical and ideological grounds, price reforms often led to deflationary tendencies in certain sectors.

Figure 3.2.1 is a summary picture of Soviet official price dynamics as measured by implicit Paasche price indexes derived from Soviet nominal sector-data as well as the official volume indexes for respective sectors. Total inflation was very low, about 0.9 % annually. A faster, open inflation is observed first in connection with Kosygin reform of the late sixties and later systematically in the eighties. Total product TMP and net material product NMP showed occasional deflationary tendencies up to 1975 and later in the mid-eighties. Deflationary tendencies in some branches of industry continued even in the early 1980s. Some sectors, such as the machine building industry, were deflationary throughout the period 1960-1990. Open inflation was highest in agriculture, which was the outcome of the gradual abandoning of Stalinist agricultural policies since the beginning of the sixties. Relative fast price dynamics took place in trade and construction, too. The open inflation in the Soviet Union in 1960-1990 originated mainly from agriculture, construction, transports and trade. Within some sectors of industry the changes caused by price reforms were non-smooth. Deflationary trends are important because they have an effect on the Laspeyres-Paasche spread (LPS). Owing to deflationary trends, the Soviet planned economy behaved normally in index terms. In other words, Laspeyres volume indexes usually dominated Paasche indexes.

All alternative calculations of Soviet inflation and economic growth were based on Soviet nominal data. Alternative volume indexes generated price indexes that were noticeably deviant from the Soviet price indexes. We started from nominal value structure and used the sample volume indexes to span the real production dynamics. *We assumed that the factor reversal test always holds.* The synthetic index models of the Soviet national accounting (SOF) system were based on operational definitions of the axiomatic index theory. In our synthetic models we used the fixed price volume indexes of sectors as if they were *composite physical commodities.*

Figure 3.2.1 Soviet Official Open Inflation by FYPS in 1961-1990



	61-65	66-70	71-75	76-80	81-85	86-90	61-90
SOFTMP	0,3	1,4	0,0	0,8	1,9	1,1	0,9
SOFIND	-0,6	0,7	-0,7	-0,1	0,7	-0,2	0,0
SOFCONST	0,5	3,1	0,5	-0,6	2,3	1,1	1,2
SOFAGRI	5,4	3,6	2,5	2,7	5,8	5,3	4,2
SOFTRANS	-0,9	-1,4	0,7	1,4	3,9	7,8	1,9
SOFTRADE	-2,5	1,8	0,8	7,0	2,8	-0,9	1,5

FYPS 1961-90 (Five Year Plans)

There is a theorem by J.R. Hicks stating that if the relative prices within a commodity sample do not change, this sample may be seen as a composite commodity (the MIT 1991, p. 74). That is, sector indexes are physical goods in the sense of basic index theory. This is an operational choice for an empirical model and depends on many conditions. The composite primitives that we used were based on Fisher volume indexes for the PMI model. The Soviet official volume indexes are not technically Fisher indexes, but they are close to binary Fisher indexes under five- year time span. The standard indexes fulfill the factor reversal test and they are independent of the volume units used. Using the nominal value structure of the aggregated Soviet national accounting TMP model and the chosen physical composite goods indexes, we derived the actual model prices. These prices are **fictive**, but they should by index theory behave very similarly to real prices. Prices in axiomatic index models are homogenous of degree zero (see. e.g. Balk, 1995).

4. Index Theory in Model Building

4.1 The Synthetic Index Systems

The setting was made by the official indexes and the chosen alternative indexes. The PMI and the CIA indexes are complete models in the Soviet TMP context. There was a lack of detailed value data and there were great problems with the volume-data sample. The Soviet data consisted of a 13-sector TMP model for 1960-1990. Most sectors were divided into sub-sectors to calculate the 13 main indexes in the PMI model. In addition to volume indexes we had annual nominal data for five sectors and input-output data for the years 1959, 1966, 1972, 1987-89. Missing value weights had to be estimated from fixed price structural data or estimated separately with input-output tables. The Soviet fixed price base years were not based on standard five-year systems and the reference years were not the same in all main sectors of the economy. The nominal weights for the 9 branches of industry at five year intervals were approximated in the prices of the nearest fixed price weights. For instance 1967 for 1965, the geometric mean of 1967 and 1975 for 1970, 1982 for 1980, 1983 for 1985. The end point weights for 1960 and 1990 were extrapolated by transforming the fixed price weights for 1960 and 1990 with Soviet price indexes. The nominal weights for the main 13 sectors were only by five-year periods and the annual nominal 13-sector weights were interpolated from the data. The annual nominal value shares of industry were assumed to change exponentially and proportionally to the fixed price dynamics.

The Soviet State Committee of Statistics did not calculate explicit comprehensive price indexes most of the time. Thus comprehensive price indexes had to be calculated with volume indexes as implicit residual indexes. The early Soviet statistical authorities used the factor reversal principle. The choice of the Laspeyres volume-index system was based on practical considerations (Starovskii 1972, pp. 105-110). There were Soviet sample based price indexes for the sixties and late eighties in statistical yearbooks. They disappeared in the meantime. We took the Soviet volume indexes by sectors and calculated synthetic, Laspeyres, Paasche and Fisher indexes for 1960-90. The model of comparisons of synthetic Soviet volume indexes consisted of a 30-year, 13-sector nominal value matrix and the corresponding matrix of 13-sector volume indexes. Out of this data normal Laspeyres, Paasche and Fisher indexes were calculated. Factor reversal test was always assumed to hold. The Natural Divisia, Törnquist and Walsh indexes were calculated, too. It was assumed that the Soviet data was accurate in physical volumes and preserved the qualitative variation of the true series. The quality adjusted main Soviet volume series were assumed to contain possibly linear, quadratic or exponential trends of bias.

The PMI data was structurally analogous to the Soviet data. The PMI is based on sample volume indexes and the Soviet official value structure[17]. The sector classifications and nominal weights of the main sectors were the same for Soviet, PMI, CIA and Eidelman's data. The early Poor Man's index PMI was a **single base-year index**. The choice of 1988 as the base year was due to the fact that for the first time some detailed price data was available for that year[18]. Annual Laspeyres, Paasche and Fisher indexes for the PMI were calculated using the physical volume series of the original 1988 version. For sub-sectors of the 13 main sectors value weights were also interpolated from the Soviet input-output tables and the sample proportions.

When transforming the methodologically heterogeneous model indexes into synthetic measures, we had to solve the issue of **price system references**. In binary comparisons we have two sets of prices P_0 and P_1 as well as two sets volumes Q_0 and Q_1 in addition to the two nominal total production aggregates V_0 and V_1. In addition to binary indexes we calculated standard five year based indexes and annual chain indexes. A volume index based on some mid-year value weights creates its own dynamics different from the binary Laspeyres-Paasche model. Because the Soviet sector indicators were close to binary Fisher indexes on a five-year basis, it is likely that the synthetic Soviet model is somewhat flattened relative to the real LPS in binary 1961-90 indexes.

The CIA indexes applied synthetic nominal value structure based on their own Soviet SNA tables. The main indexes were of total product type in the Soviet and the PMI systems. The CIA index system used **total product indicators** as primitives for value-added GNP-indexes. This was done in order to avoid deflating the value added aggregates lacking commodity representatives. For Soviet agriculture the CIA also calculated a net output index. The CIA total-output index for agriculture is very close to the Soviet total product series 1950-1979 (see JEC 1982, p. 251). For aggregate comparisons we used the

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[17] Soviet physical commodity statistics were conceptually of total product type. There was only limited information about the end use of physical commodities (see e.g. Narkhoz SSSR v 1975 g. p. 785)

[18] In December 1991 the author had an opportunity to visit the GOSKOMSTAT in Moscow. The result was some average commodity prices in fuels, chemicals, construction materials and the forest sector not available in Narkhoz.

sector-specific CIA volume-indexes in our model framework, which was based on the Soviet MPS data. In other words, we robustly transformed the original CIA GNP data for the Soviet economy into our own synthetic TMP mode in the MPS. The CIA used the producer side approach as the main approach, but controlled this by end user side calculations.

Eidelman's data can be used for TMP growth calculation by imputing the missing agriculture, transport and trade sectors and choosing either a binary Fisher index or a Törnquist index. Only agriculture and transport have to be imputed, because the trade index can be calculated analogously to the PMI-model. All indexes were very close to each other in agriculture and transport. Therefore the imputation is not likely to be a biasing factor. For Eidelman's data we could calculate only a whole period binary estimate for 1960-1990. The NMP indexes may be calculated out of this data by double deflation or using total product vectors as proxies and applying value added weights. It is obvious that the producer side volume index models are insensitive to changes in terms trade, because the data come from physical domestic production. In the Soviet data the foreign trade effect on economic growth is included into the end user approach or national income used.

4.2 The Role of Formal Index Theory

Formal index theory helps us in two ways. First we can test the internal consistency of our synthetic index sets and second we can use the formal index theory to find the limits of variance for main index formulas. The standard international index methodology is close to the axiomatic approach, but economic index theory is an interesting point of reference. Theoretical economic indexes are not generally based on observable data and the analysis leads to upper and lower limits for theoretical economic indexes in the terms of the standard Laspeyres and Paasche indexes. Therefore the problem is how to approximate economic indexes with standard indexes.

The functions that generate the optimal behavior of consumers and producers, utility functions, cost functions or production functions, are collectively called **aggregator functions**. If the index function $\mathbf{I(P_0,P_1,Q_0,Q_1)}$ satisfies the following condition:

$\mathbf{I(P_0,P_1,Q_0,Q_1) = f(Q_1)/f(Q_0)}$; where f is an aggregator function,

then the index function is called **exact** for the aggregator function f (Diewert 1976, pp. 116-117). An index function that is exact relative to an aggregator which approximates a linearly homogenous function on the second order level, in other words on the level of second partial derivatives, is called **superlative** (ibid.). Diewert showed in 1978 that the known superlative index functions approximated each other closely. The superlative Törnquist index is exact for **translog functions** and the superlative indexes of Fisher and Walsh are exact to aggregators that are quadratic means of order 2 and 1 respectively. Hence, from a strictly theoretical point of view Fisher, Törnquist and Walsh indexes are proxies for each other. Hill showed that for meaningful approximation other factors have to be observed (Hill 2002). Frequent chaining brings the standard Laspeyres and Paasche indexes and the superlative indexes together.

In the Boskin Commission Report on the biases of **American BLS –CPI,** a lot of space was given for the so-called **upper** and **lower level biases** (see. Baker 1998, pp. 25-28). A fixed basket sample is representative over time only if all the goods have uniform income elasticity. Our own index system is basically a 30-year fixed sample index. The indexes are calculated for all years in the interval, but the commodity sample is fixed, whereas the Soviet index system is an annual system of Lowe-volume indexes.

First we had the Laspeyres and Paasche volume-indexes and the Fisher index. These three indexes were annual, five-year based or binary for the 30-year period 1960-1990. Binary indexes behave differently from chain-indexes. Therefore we studied positive or negative **drifting tendencies** due to chaining. Drifting is the value difference between chained and binary indexes, the index formula *ceteris paribus*. The Divisia indexes chosen were the Natural Divisia index of von Vogt and the continuous Divisia index. The natural index is a fictive path index along a straight line. The natural index can be approximated with an algebraic formula, but there is no analytic solution for the continuous Divisia-index in the general case (Vogt 1977, pp. 78-79). Continuous Divisia indexes are reasonably well approximated by annual and shorter standard chain indexes. The superlative indexes of Fisher, Törnquist and Walsh were used as proxies.

Last we summarize some useful statistical theorems. We try to find the limits of variation for the indexes compared. We also want to know whether some indexes are numerically close enough to be operationally the same measures. Four main statistical and mathematical laws will be referred to. The first concerns the Laspeyres-Paasche spread (LPS).

The Paasche price index is greater than the Laspeyres index if prices and quantities tend to move in the same direction between the base year and the end year; the Laspeyres price index is greater than the Paasche price index if prices and quantities tend to go in opposite directions (Allen 1975 p. 64).

The covariance of prices and volumes is measured with the **weighted Pearson product moment correlation** of price and quantity relatives. The weights are the respective Laspeyres type sector shares. The second theorem concerns the drifting effects of chaining Laspeyres price indexes. Drifting is the deviation of chain indexes from the binary index defined for the same time interval.

There is a positive (upward) drifting effect in chaining Laspeyres price indexes if the terms $(p_{t+1})/(p_t)$ and q_t/q_0 correlate positively in the index data. **If the weighted correlation is negative the drifting effect is negative.** The weights are the same as above (Allen 1975, p. 187). The overall effect depends on the product of sub-intervals.

Laspeyres and Paasche indexes may be considered as general continuous Divisia-indexes integrated on specific paths (Vogt 1977, p. 79). This leads us to the third law about the difference of natural Divisia index and the continuous theoretical Divisia index. The third invariance is as follows:

The logarithm of the quotient of the natural Divisia index and the chained Divisia index (piecewise linear path) may be represented as a **closed line integral** along the true and natural path (See Vogt, 1977, pp. 85-86). Thus the definite integral is a proportional measure of difference between the two Divisia indexes.

The fourth index formula invariance concerns an inequality related to the Fisher and the Natural indexes. This reasoning is based on the Bortkiewicz and factor-quotient indexes (Köves, 1983, pp. 143-146).

Let us define two quotients, the Bortkiewicz quotient $B=P_q/L_q$ and the factor quotient $R= L_P/L_q$. When $B < 1$ and $R < 1$, it follows that NP < FP. If $R = 1$ then NP = FP. Otherwise if $R> 1$ then NP > FP. The inequalities are the opposite if $B >1$. (Köves 1983, p.146).

5. Empirical Results

5.1 Qualitative Notes on Sampling

We consider only the PMI sample. GOSKOMSTAT had census data and Eidelman's sample was robust (Eidelman 1992, 1993). The sample of the CIA was large relative to the one that we have used. They had over 300 commodities for industry and some fifty for agriculture (JEC 1982, p. 49, 175). Obviously they had the randomness and sampling frame problem, too. We used two empirical distance measures for assessing sample designs: the first distance was the percentage share of the alternative mean indicator relative to the Soviet official mean indicator; the second distance measure was the Pearson correlation between the 30 year official and alternative growth rates. The sample properties of the PMI and CIA sector indicators are shown below (Table 5.1.1). Highly correlated with the Soviet series and numerically close to them are electricity, fuels, metallurgy, and agriculture and transport. Their share in the Soviet TMP was about 34% in 1975. These are the generally congruent sectors. Most alternative sector series have correlations around and above 0.8. Only the trade and construction sectors in PMI have clearly lower correlation coefficients. Because they are based on I-O procedures, they not synchronized with the national accounting data. True input-output estimates should have a lagged structure determined by the technology of production. The averages of the alternative indexes move close together.

5.2 The Outlay of the Synthetic Data

The data is represented in Table 5.2.1. The official Soviet Lowe index of TMP has the average annual growth rate of 4.9 %. The Soviet official index has the same total growth figures whether in annual or five-year index bases. The synthetic Soviet TMP index is almost identical to the Soviet yearbook index when shown as five-year based Laspeyres-volume index. The binary synthetic Laspeyres Soviet volume index clearly exceeds the Soviet Lowe index with annual percentages of 5.2% respective to 4.9 %.

Table 5.1.1 Sampling Properties of the CIA and PMI Indexes

(Ordered by growth rate relative to Soviet official growth rate)

Sectors	Correlation with Soviet Narkhoz growth series	Relative growth rates Alternative/Official Soviet
CIATrans	0,81	1,08
PMITrans	0,88	1,05
PMIFuels	0,97	1,04
CIAFuels	0,98	0,94
PMIEl	0,97	0,93
CIAEl	0,97	0,92
PMIAgri	0,92	0,91
PMIFood	0,95	0,86
CIAFood	0,82	0,83
CIAMetlur	0,94	0,80
PMILight	0,92	0,79
CIALight	0,91	0,78
CIATrade	0,73	0,77
CIAAgri	0,92	0,77
PMIChem	0,92	0,76
PMIMetlur	0,91	0,72
CIAChem	0,93	0,70
CIAConmat	0,92	0,67
PMIConst	0,09	0,65
PMIConmat	0,91	0,63
CIAConst	0,77	0,60
PMItrade	0,40	0,57
CIAMBI	0,84	0,49
CIAForest	0,86	0,46
PMIForest	0,88	0,45
PMIMBI	0,91	0,45

Sources: Narkhoz 1960-90, JEC 1982, JEC 1990, the PMI-model

Table 5.2.1. The Growth Rates of the Soviet TMP 1960-1990

Binary Laspeyres Volume Index 1960-1990						
	SOFTMP	**PMITMP**	**CIATMP**	**EIDELMAN[1]**	**SOFYB[2]**	**SOFYB-SOFTMP**
	5,2	**3,3**	**3,3**	**3,6**	**4,9**	**-0,2**
Five-year Based Laspayres Volume Indexes						
FYP	**SOFTMP**	**PMITMP**	**CIATMP**		**SOFYB**	**SOFYB-SOFTMP**
					SOFYB is Lowe Index in Narkhoz SSSR	
61-65	**6,4**	**5,8**	**5,6**		**6,5**	**0,1**
66-70	**7,5**	**5,9**	**5,7**		**7,3**	**-0,2**
71-75	**6,1**	**4,2**	**4,0**		**6,3**	**0,2**
76-80	**3,7**	**1,9**	**1,8**		**4,2**	**0,5**
81-85	**3,4**	**1,7**	**1,7**		**3,5**	**0,2**
86-90	**2,3**	**0,9**	**1,0**		**1,8**	**-0,5**
ALL	**4,9**	**3,4**	**3,3**		**4,9**	**0,0**
Annual Laspeyeres Volume Indexes						
Year	**SOFTMP**	**PMITMP**	**CIATMP**		**SOFYB**	**SOFYB-SOFTMP**
1961	**6,5**	**5,9**	**6,3**		**7,0**	**0,5**
1962	**5,9**	**6,1**	**4,5**		**5,6**	**-0,3**
1963	**4,4**	**3,3**	**0,8**		**4,4**	**0,0**
1964	**7,6**	**7,6**	**10,3**		**7,6**	**0,0**
1965	**7,5**	**6,1**	**6,6**		**7,9**	**0,3**
1966	**8,0**	**7,2**	**5,3**		**8,0**	**0,0**
1967	**8,2**	**6,7**	**6,2**		**8,3**	**0,1**
1968	**7,7**	**5,9**	**6,2**		**6,8**	**-0,8**
1969	**4,7**	**3,0**	**3,5**		**4,8**	**0,1**
1970	**8,6**	**6,5**	**7,5**		**8,7**	**0,0**
1971	**6,4**	**3,5**	**3,5**		**7,2**	**0,7**
1972	**4,6**	**3,0**	**2,1**		**4,3**	**-0,2**
1973	**8,1**	**7,0**	**7,4**		**8,3**	**0,2**
1974	**5,8**	**4,0**	**4,5**		**6,4**	**0,6**
1975	**5,3**	**3,4**	**2,5**		**5,6**	**0,3**
1976	**4,6**	**4,4**	**3,9**		**5,2**	**0,6**
1977	**4,9**	**2,8**	**2,6**		**4,9**	**0,0**
1978	**4,4**	**2,8**	**2,1**		**4,7**	**0,3**
1979	**1,7**	**-1,2**	**0,1**		**2,7**	**1,0**
1980	**2,7**	**0,9**	**0,3**		**3,5**	**0,8**
1981	**2,8**	**1,0**	**0,9**		**3,0**	**0,2**
1982	**3,0**	**1,9**	**2,0**		**3,9**	**0,9**
1983	**4,6**	**2,8**	**3,0**		**4,0**	**-0,5**
1984	**3,1**	**1,5**	**1,8**		**3,6**	**0,5**
1985	**3,1**	**1,4**	**0,8**		**3,2**	**0,2**
1986	**4,9**	**3,2**	**3,3**		**3,3**	**-1,6**
1987	**2,8**	**1,3**	**1,6**		**2,6**	**-0,2**
1988	**4,1**	**1,6**	**2,4**		**3,5**	**-0,6**
1989	**1,9**	**0,8**	**1,1**		**1,9**	**0,0**
1990	**-2,2**	**-2,2**	**-3,1**		**-2,0**	**0,2**
ALL	**4,8**	**3,4**	**3,3**		**4,9**	**0,1**
STDEV	**2,41**	**2,51**	**2,76**		**2,33**	

[1]**Synthetic Eidelman TMP index from incomplete data. Extrapolated from 1988 to 90.**

[2]**SOFYB= Soviet Yearbook data**

As predicted by standard index theory, the Soviet Lowe dominates, albeit very thinly, the five-year synthetic SOF Laspeyres volume indexes. The dominance was stronger in 1960-80 and evened out by the end of the eighties. The alternative indexes are close to each other at binary and five-year levels. There is more variation on annual level. The revealed annual difference between the Soviet TMP synthetic indicator and alternative index series, due to quality imputation and sampling effects, is about 1.5 % annually. The CIA figures in the tables are slightly different from their authorized GNP figures, but this is as it should be, because we have transformed the data into our model and **TMP** indicator.

The annual, five-year and binary growth rates are presented for all six index formulas (Tables 5.2.2 and 5.2.3). Laspeyres and Paasche indexes are clearly different on every level. However, in our Soviet data the three **superlative indexes** Fisher, Törnquist and Walsh are practically identical. By the fourth invariance above the Natural Divisia index should dominate over the Fisher index (see Section 4.3). In the synthetic model data this is the case with binary and five-year indexes with respective differences of 0.2% and 0.1% annually. In the annual data this difference disappears. All binary averaging indexes are close estimators to the Soviet comparative price Lowe volume index. The SOF Natural Divisia is closest the Soviet Yearbook index. The PMI synthetic data are rather insensitive to the index formula used. The annual difference of the LPS is 0.3 % on binary level. On the five-year level the differences are 0.1% or less. The Soviet planned prices had an efficiency philosophy. The fastest growing sectors tended to have declining relative prices. Measured with alternative price developments the efficiency tendencies were less clear. Thus, the LPS and drift test correlations were smaller.

5.3 Index Theory, LPS and Other Considerations

Conventional textbook wisdom separates two main cases regarding the **LPS**. First we have the normal market economy, where the behavior of prices and quantities is governed by normal demand laws. The weighted correlation of price and volume relatives is then negative. The second case is the supplier controlled planned economy or highly imperfect market economy. Here the weighted correlation of price relatives and volume relatives may be positive. In the first situation Laspeyres indexes

Table 5.2.2 Soviet Synthetic TMP Growth Rates by Index Types
Annual Percents 1961-1990

YEAR	LPVOL	PAASVOL	FISHVOL	TORNVOL	NDIVOL	WALSHVOL
61	6,5	6,5	6,5	6,5	6,5	6,5
62	5,9	5,8	5,8	5,8	5,8	5,8
63	4,4	4,2	4,3	4,3	4,3	4,3
64	7,6	7,5	7,6	7,6	7,6	7,6
65	7,5	7,4	7,5	7,5	7,5	7,5
66	8,0	8,0	8,0	8,0	8,0	8,0
67	8,2	8,3	8,2	8,2	8,2	8,2
68	7,7	7,6	7,6	7,6	7,6	7,6
69	4,7	4,6	4,7	4,7	4,7	4,7
70	8,6	8,7	8,7	8,7	8,7	8,7
71	6,4	6,4	6,4	6,4	6,4	6,4
72	4,6	4,4	4,5	4,5	4,5	4,5
73	8,1	8,0	8,0	8,0	8,0	8,0
74	5,8	5,7	5,7	5,7	5,7	5,7
75	5,3	5,1	5,2	5,2	5,2	5,2
76	4,6	4,5	4,6	4,6	4,6	4,6
77	4,9	4,9	4,9	4,9	4,9	4,9
78	4,4	4,3	4,3	4,3	4,3	4,3
79	1,7	1,7	1,7	1,7	1,7	1,7
80	2,7	2,7	2,7	2,7	2,7	2,7
81	2,8	2,8	2,8	2,8	2,8	2,8
82	3,0	2,9	2,9	2,9	2,9	2,9
83	4,6	4,6	4,6	4,6	4,6	4,6
84	3,1	3,1	3,1	3,1	3,1	3,1
85	3,1	3,0	3,1	3,1	3,1	3,1
86	4,9	4,8	4,8	4,8	4,8	4,8
87	2,8	2,8	2,8	2,8	2,8	2,8
88	4,1	4,1	4,1	4,1	4,1	4,1
89	1,9	1,8	1,8	1,8	1,8	1,8
90	-2,2	-2,4	-2,3	-2,3	-2,3	-2,3
ALL	**4,83**	**4,77**	**4,80**	**4,80**	**4,80**	**4,80**
FYP						
61-65	6,4	6,2	6,3	6,3	6,3	6,3
66-70	7,5	7,4	7,4	7,4	7,4	7,4
71-75	6,1	5,8	6,0	6,0	6,0	6,0
76-80	3,7	3,6	3,7	3,7	3,7	3,7
81-85	3,4	3,2	3,3	3,3	3,3	3,3
86-90	2,3	2,1	2,2	2,2	2,2	2,2
ALL	**4,89**	**4,72**	**4,80**	**4,80**	**4,81**	**4,80**
BINARY	**5,15**	**4,28**	**4,71**	**4,72**	**4,87**	**4,73**

Table 5.2.3 Soviet TMP Growth Rates by the PMI Index and Index Types
Annual Percent in 1961-1990

YEAR	LPVOL	PAASVOL	FISHVOL	TORNVOL	NDIVOL	WALSHVOL
61	5,9	5,8	5,8	5,8	5,8	5,8
62	6,1	5,9	6,0	6,0	6,0	6,0
63	3,3	3,2	3,2	3,2	3,2	3,2
64	7,6	7,5	7,5	7,5	7,5	7,5
65	6,1	5,9	6,0	6,0	6,0	6,0
66	7,2	7,2	7,2	7,2	7,2	7,2
67	6,7	6,8	6,8	6,8	6,8	6,8
68	5,9	5,9	5,9	5,9	5,9	5,9
69	3,0	3,0	3,0	3,0	3,0	3,0
70	6,5	6,5	6,5	6,5	6,5	6,5
71	3,5	3,5	3,5	3,5	3,5	3,5
72	3,0	3,0	3,0	3,0	3,0	3,0
73	7,0	6,9	6,9	6,9	6,9	6,9
74	4,0	3,9	4,0	4,0	4,0	4,0
75	3,4	3,2	3,3	3,3	3,3	3,3
76	4,4	4,4	4,4	4,4	4,4	4,4
77	2,8	2,8	2,8	2,8	2,8	2,8
78	2,8	2,8	2,8	2,8	2,8	2,8
79	-1,2	-1,3	-1,2	-1,2	-1,2	-1,2
80	0,9	0,9	0,9	0,9	0,9	0,9
81	1,0	0,9	1,0	1,0	1,0	1,0
82	1,9	1,9	1,9	1,9	1,9	1,9
83	2,8	2,8	2,8	2,8	2,8	2,8
84	1,5	1,5	1,5	1,5	1,5	1,5
85	1,4	1,4	1,4	1,4	1,4	1,4
86	3,2	3,2	3,2	3,2	3,2	3,2
87	1,3	1,3	1,3	1,3	1,3	1,3
88	1,6	1,5	1,6	1,6	1,6	1,6
89	0,8	0,7	0,8	0,8	0,8	0,8
90	-2,2	-2,2	-2,2	-2,2	-2,2	-2,2
ALL	3,4	3,3	3,4	3,4	3,4	3,4
FYP						
61-65	5,8	5,6	5,7	5,7	5,7	5,7
66-70	5,9	5,9	5,9	5,9	5,9	5,9
71-75	4,2	4,1	4,1	4,1	4,1	4,1
76-80	1,9	1,9	1,9	1,9	1,9	1,9
81-85	1,7	1,7	1,7	1,7	1,7	1,7
86-90	0,9	0,9	0,9	0,9	0,9	0,9
ALL	3,4	3,3	3,4	3,4	3,4	3,4

BINARY	3,5	3,2	3,4	3,4	3,4	3,4

dominate and in the second Paasche indexes. A textbook guess is that the second case is more common in the planned economies. Irving Fisher himself believed that both cases are equally frequent in reality (Köves 1983, p.72-75). Köves in turn, who studied indexes in planned economies, thought that positive correlations between price and volume relatives are rare (ibid.). In the empirical reference system chosen, the negative correlation seems to be the most general case.

The annual Soviet indexes were quite standard as to formulas, but the price references used were not. The fixed price bases used for the period 1960-1990 were 1958 for 1961-65, 1967 for 1966-1975, 1973 for 1976-1985 and 1983 for 1986-1988. For the last two years 1989-90 annual deflators were used (Narkhoz 1990, p.686-687). The modern practice started then. The price references listed above were used for integration of NMP and TMP. For indexes in industry and agriculture different base years were used (see. e.g. Narkhoz 1990, p. 697-701). This is a potential source of bias, since we use these sector level indexes to form our synthetic Soviet indexes. The largest gap between nominal and fixed prices was at the beginning of the 1960s and in the late 1980s (Chernikov 1982, p. 37, Narkhoz 1990).

In our data the binary Laspeyres indexes dominated Paasche indexes (Table 5.3.1). This is also true on the level of five-year volume indexes. With the synthetic Soviet TMP indexes there are two periods when Paasche indexes dominated Laspeyres indexes at the level of annual indexes. The first period is 1966-1970. With the exception of the year 1969, the Paasche index dominated. This was the starting period of the Kosygin reform. Later, in 1980, the Paasche index exceeded the Laspeyres index. Generally the congruence is as it should be, but the occasional Paasche dominance was rather weak and in some cases there was numerical imprecision as the indexes and the correlations are calculated with different algorithms and precision. The standard microeconomic interpretation is that when the LPS is less than unity this may indicate inefficiency. Qualitative LPS dynamics is essentially the same for SOF and PMI data (Table 5.3.1). At the precision level used there are instances of Paasche dominance in the PMI data, too. Obviously, Köves was right about the LPS trends in planned economies (Köves ibid.). However, the Laspeyres dominance in the data was also very weak.

Table 5.3.1.Soviet TMP Growth Rates and LPSs in 1961-90 with Bortkiewicz's Test Correlations

SOF					PMI	
YEAR	**LPVOL**	**PAASVOL**	**LPS**	**TestCORR**[1]	**LPVOLPMI**	**LPSPMI**
	Growth Factors					
1961	1,065	1,065	1,0002	-0,288	1,0587	1,0004
1962	1,059	1,058	1,0013	-0,298	1,0605	1,0011
1963	1,044	1,042	1,0018	-0,689	1,0327	1,0009
1964	1,076	1,075	1,0005	-0,483	1,0759	1,0010
1965	1,075	1,074	1,0012	-0,453	1,0607	1,0018
1966	1,080	1,080	1,0002	0,082	1,0725	1,0001
1967	1,082	1,083	0,9997	0,474	1,0673	0,9996
1968	1,077	1,076	1,0003	0,099	1,0592	1,0001
1969	1,047	1,046	1,0009	-0,459	1,0303	1,0003
1970	1,086	1,087	0,9999	0,097	1,0650	1,0000
1971	1,064	1,064	1,0006	-0,508	1,0350	1,0002
1972	1,046	1,044	1,0012	-0,640	1,0302	1,0006
1973	1,081	1,080	1,0010	-0,587	1,0699	1,0012
1974	1,058	1,057	1,0010	-0,560	1,0399	1,0008
1975	1,053	1,051	1,0012	-0,550	1,0339	1,0014
1976	1,046	1,045	1,0006	-0,284	1,0443	1,0007
1977	1,049	1,049	1,0000	-0,098	1,0282	1,0006
1978	1,044	1,043	1,0001	-0,076	1,0280	1,0003
1979	1,017	1,017	1,0007	-0,268	0,9883	1,0008
1980	1,027	1,027	0,9999	0,057	1,0093	1,0001
1981	1,028	1,028	1,0006	-0,301	1,0099	1,0006
1982	1,030	1,029	1,0003	-0,105	1,0195	1,0007
1983	1,046	1,046	1,0000	-0,113	1,0279	0,9999
1984	1,031	1,031	1,0006	-0,340	1,0153	1,0001
1985	1,031	1,030	1,0005	-0,530	1,0145	1,0001
1986	1,049	1,048	1,0001	-0,247	1,0320	1,0001
1987	1,028	1,028	1,0002	-0,219	1,0135	1,0003
1988	1,041	1,041	1,0004	-0,147	1,0160	1,0006
1989	1,019	1,018	1,0002	-0,083	1,0079	1,0004
1990	0,978	0,976	1,0020	-0,324	0,9780	1,0002

Calculated from sample based synthetic SOF TMP index data and PMI data

[1]For test correlation see e.g. Allen 1975, pp. 62-64.

If we compare regular annual Laspeyres indexes with a regular binary Laspeyres index (1960-1990), we see a drifting effect (Table 5.2.2). The calculated test correlations for drifting effect are **negative** and the chained Paasche volume index generally approaches the binary Fisher index from below and symmetrically the chained Laspeyres volume index approaches the binary Fisher index from above (see Section 4.6). There are also chaining effects within the fixed price sub-periods. This illustrates empirically that chaining usually narrows the LPS. It is obvious from Vogt's interpretation of standard indexes as line integrals and the extension of Stokes' theorem that averaging binary indexes are close to the annual chain index when the over all growth is proximately smoothly distributed (Vogt, 1977, pp. 84-86). The Soviet annual growth figures showed a smooth linear declining trend.

The superlative indexes of Walsh, Fisher and Törnquist move close together (Hill 2002). Two quotients, the **Bortkiewicz quotien**t $B=P_q/L_q$ and the **factor quotient** $R= L_P/L_q$ can be used to find the relative sizes of some other binary index formulas. When $B < 1$ and $R < 1$, as it is in our data, it follows that NP < FP (Köves 1982, p.146). Due to the factor reversal property it is seen that NQ > FQ (Table. 5.2.2). That is the Natural –Divisia volume index will surpass the Fisher volume-index (see Section 4.3). Thus all four averaging binary indexes go together in our data.

Using the base years 1980 and 1982 for the Soviet data gives respective annual growth rates of 4.63 and 4.65 % for TMP. Accordingly the growth measured in 1980 and 1982 prices is practically the same as when annually chained Laspeyres volume-indexes are used. From this point of view the CIA base year of 1982 seems close enough for comparisons with the Soviet annual indexes. The PMI primitive indexes are even more Paasche type than the CIA indexes, because in internal weighting 1988 data was used.

The TMP measure of the CIA is 3.3 % (Table 5.2.1). The CIA assumed that in basic series the value added moves in a fixed proportion to global production. In the 1980s the nominal NMP and GNP measures started to diverge. This somewhat widens the differences between the CIA GNP and PMI NMP estimates.

The results of A. Ponomarenko for Russia in 1960-1990 are not fully comparable, because Russia constituted only some 60% of the Soviet production capacity, but both the qualitative and quantitative behavior of his data is interesting because the growth data of Russian Federation and the USSR moved close together. An important difference from the approach we used here was that Ponomarenko studied GDP series. He compared five series of data: First a binary Paasche volume index of the Russian GDP, secondly a chained GDP index using the GDP-weights he calculated and Soviet official volume indexes by sectors. The third series was formed by deflating his synthetic nominal Russian SNA series by Soviet implicit price indexes. These are implicit Paasche price indexes and the series was thus a Lowe or Laspeyres type volume index measure for the Russian GDP. Further, he presented a pure volume GDP series for Russia. His own estimate is based on the pure volume series and an expert based quality determination matrix for various sectors of the GDP. He called this series adapted or ***soglosovannii*** (see Table 5.3.2). The first series was calculated by Kuboniwa (Kuboniwa 1996). The first series is a binary Paasche volume index and the third variant C an approximate 5-year Laspeyres volume index, because it is very close to the Soviet official Lowe setting. The annual chain index variant B is in between, because with increasing chaining Laspeyres moves downwards and the binary Paasche is lowest. The results for this part are similar to the LPS behavior in our synthetic Soviet TMP data. Ponomarenko's pure volume index for Russia in 1961-1990 is practically the same as the TMP growth rate of the alternative indexes (CIA, PMI, and Eidelman) for the Soviet Union in 1961-90.

5.4 The Soviet Revealed Growth Residual

The Soviet revealed growth residual is very similar to all three alternative full period indexes. The PMI TMP indicator is more volatile on an annual basis than the Soviet indicators (Table 5.2.1). This is why we examine the Soviet growth residual on the level of five-year averages. The overall average on the TMP level is about 1.5% annually (Table 5.4.1). There was a clear bell-shaped trend by five-year, plan periods (ibid. sub-table C). Starting with 0.6%, peaking at 1.8 % in 1971-75 and then declining to 1.4 % in 1986-90. In annual data a quadratic trend fits better than linear (Figure 5.4.1). The residual is highest in MBI, about 5% annually for 1961-90. The forest industry, chemicals, construction materials, and trade showed respectively residuals of 2.2%, 2.0%, 2.0% and 1.3% for 1961-90.

Table 5.3.2 Russian Alternative Indexes 1961-1990

The Series are GDP Measures

Year	Variant A	Variant B	Variant C	Variant D	Variant E
1961	4,5	5,6	*6,5*	7,5	7,2
1962	5,1	3,6	6,4	6,3	7,4
1963	0,5	3,9	6	2,9	4
1964	7,5	6,7	7,2	6,3	6,5
1965	4,6	5,8	6,9	5,1	5,5
1966	7	7	7,4	6	7,1
1967	6,3	7,3	8,3	5,7	6,3
1968	6,3	6,7	7,6	5,4	6,2
1969	2,1	3,9	2,4	3,3	2,6
1970	8	7,7	10,1	5,7	8,4
1971	4,5	5,6	5,5	3,3	4,2
1972	2,2	3,9	3,8	2,4	2,9
1973	8,8	9	10	7,3	2,9
1974	3,4	5,1	5,8	4	4,4
1975	3,5	5,1	5,5	3,4	4,9
1976	3,2	3,7	4,9	3	3,9
1977	4,3	4,4	4,7	2,8	3,9
1978	3,3	3,7	5,1	2	2,7
1979	0,8	1,5	2,8	0,7	1,8
1980	2	2,5	4,4	2,4	4,3
1981	1,5	2	3,1	1	2
1982	3,6	2,8	3,1	1,4	1,4
1983	3,8	3,5	3,1	2,2	2,8
1984	2	1,9	1,9	1,1	1,2
1985	2,4	1,8	3,5	1	2,3
1986	4,1	4,5	4,4	3,2	3,3
1987	2,1	2,4	1,7	1,1	0,7
1988	3,4	3,5	4,2	2,3	2,4
1989	2,2	2	2,6	1,3	1,5
1990	-0,4	-0,9	-4,9	-0,8	-1,7
1961-90	3,73	4,18	4,76	3,28	3,74

(Ponomarenko 2002, pp. 232-233)

A = Binary Paasche by Kuboniwa in GDP
B = Chained annual Laspeyres volume indexes in GDP structure
C = Nominal GDP deflated by implicit NMP Paasche price indexes
D = Ponomarenko's pure volume index
E = Ponomarenko's quality imputed pure volume series

Table 5.4.1 Soviet Revealed Growth Residual in 1961-1990 (SOFTMP-PMITMP)

Subtable A	Average annual growth rates SOFTMP (synthetic)						
SOFTMP	**1961-65**	**1966-70**	**1971-75**	**1976-80**	**1981-85**	**1986-90**	**RowMean**
EL	12,2	8,6	7,1	5,0	4,3	2,3	6,6
FUEL	6,5	5,8	5,9	3,0	1,2	0,4	3,8
METLUR	9,3	6,3	5,0	2,7	2,1	1,4	4,4
CHEM	14,4	12,2	10,6	5,7	4,8	2,7	8,4
MBI	12,3	11,7	11,6	8,2	6,2	4,2	9,0
FOREST	5,1	5,6	5,2	1,6	3,5	2,5	3,9
CONMAT	9,0	8,4	7,3	1,9	3,0	2,7	5,4
LIGHT	2,7	8,6	4,6	3,4	1,5	1,6	3,7
FOOD	7,3	5,9	5,2	1,4	3,4	2,5	4,3
CONST	4,1	7,6	6,0	3,2	3,2	3,4	4,6
AGRI	2,3	4,2	0,8	1,5	2,1	0,9	2,0
TRANS	7,7	8,3	7,2	3,6	3,0	-2,2	4,6
TRADE	6,2	7,0	6,3	3,9	2,5	3,5	4,9
TMP	6,4	7,5	6,1	3,7	3,4	2,3	4,89

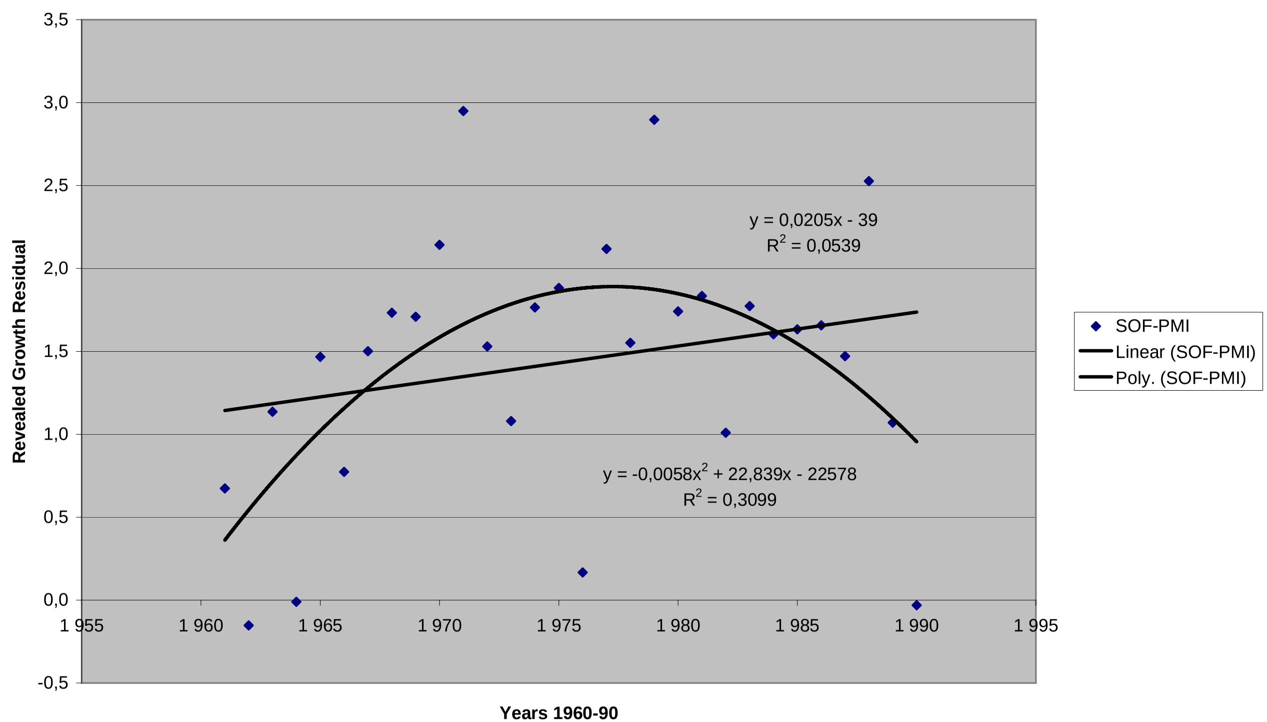
Subtable C	SOFTMP-PMITMP /Revealed Growth Residual						
TMP	**1961-65**	**1966-70**	**1971-75**	**1976-80**	**1981-85**	**1986-90**	**1961-90**
EL	0,6	0,7	0,1	0,5	0,7	0,0	0,4
FUEL	-0,9	0,2	0,4	-0,7	0,1	0,1	-0,1
METLUR	2,1	0,8	0,8	1,9	1,1	0,7	1,2
CHEM	2,4	3,3	1,3	2,5	0,7	2,1	2,0
MBI	3,8	5,0	6,2	5,7	4,4	4,7	5,0
FOREST	2,2	2,1	2,2	2,4	1,6	2,5	2,2
CONMAT	1,3	2,9	2,2	1,9	1,3	2,3	2,0
LIGHT	0,5	1,8	1,0	0,7	0,6	0,2	0,8
FOOD	0,4	0,6	1,1	0,3	1,2	0,1	0,6
CONST	-2,3	1,5	1,1	1,3	1,4	2,6	0,9
AGRI	0,3	-0,2	0,9	0,2	1,0	-0,7	0,2
TRANS	-0,2	0,8	0,6	-0,5	0,8	-3,1	-0,3
TRADE	0,0	1,0	1,6	2,0	0,7	2,7	1,3
TMP	0,6	1,6	1,8	1,7	1,6	1,4	1,5

Subtable B	Average annual growth rates PMITMP						
PMITMP	**1961-65**	**1966-70**	**1971-75**	**1976-80**	**1981-85**	**1986-90**	**1961-90**
EL	11,6	7,9	7,0	4,5	3,6	2,3	6,1
FUEL	7,4	5,6	5,5	3,7	1,1	0,3	3,9
METLUR	7,1	5,5	4,1	0,9	1,0	0,7	3,2
CHEM	12,0	8,9	9,3	3,1	4,1	0,6	6,3
MBI	8,5	6,7	5,4	2,4	1,8	-0,4	4,0
FOREST	2,9	3,4	3,0	-0,8	1,9	0,0	1,7
CONMAT	7,7	5,6	5,1	0,0	1,7	0,3	3,4
LIGHT	2,2	6,7	3,6	2,7	0,9	1,4	2,9
FOOD	6,9	5,3	4,2	1,0	2,1	2,4	3,6
CONST	6,4	6,1	4,8	1,9	1,8	0,8	3,6
AGRI	2,0	4,5	-0,1	1,3	1,1	1,6	1,7
TRANS	7,9	7,5	6,6	4,0	2,2	1,0	4,8
TRADE	6,2	6,0	4,6	1,9	1,8	0,8	3,5
TMP	5,8	5,9	4,2	1,9	1,7	0,9	3,39

Subtable D	The Relative Contribution of Sectors to TMP Revealed Residual %						
TMP	**1961-65**	**1966-70**	**1971-75**	**1976-80**	**1981-85**	**1986-90**	**1961-90**
EL	0,01	0,01	0,00	0,01	0,01	0,00	0,01
FUEL	-0,07	0,01	0,01	-0,01	0,00	0,00	-0,01
METLUR	0,16	0,03	0,03	0,08	0,05	0,03	0,06
CHEM	0,10	0,08	0,03	0,06	0,02	0,07	0,06
MBI	0,70	0,45	0,51	0,56	0,51	0,62	0,56
FOREST	0,15	0,05	0,04	0,04	0,03	0,05	0,06
CONMAT	0,05	0,05	0,03	0,03	0,02	0,04	0,04
LIGHT	0,09	0,13	0,06	0,04	0,04	0,01	0,06
FOOD	0,09	0,06	0,08	0,03	0,09	0,00	0,06
CONST	-0,35	0,09	0,06	0,07	0,08	0,20	0,03
AGRI	0,07	-0,02	0,08	0,02	0,09	-0,09	0,03
TRANS	-0,01	0,02	0,01	-0,01	0,02	-0,11	-0,01
TRADE	0,00	0,04	0,05	0,08	0,04	0,16	0,06
Sum	1,00	1,00	1,00	1,00	1,00	1,00	100,0
TMP	0,9	1,7	2,4	1,7	1,6	1,1	1,6

Weighted by 5-year average current weights

Figure 5.4.1 Soviet Growth Residual Revealed by PMI TMP



Some 56% of the mean residual at TMP level originated from MBI. The three next largest long term sources are forest industries, construction materials and chemicals.

We have too many degrees of freedom to solve the residual equation unambiguously. The residual may be due to hidden inflation, correct quality adjustment by the Soviet State Price Committee and it also may be due to biased sampling. Because the alternative indexes are rather close to each other in all sectors, excluding the MBI, where Eidelman's pure volume growth is about 1% bigger than the PMI growth rate, we may assume that the revealed residual is mainly a combination of hidden inflation and correct quality imputation into volume indexes. There are some peculiarities with the Soviet asserted quality contribution, although there is only limited data to compare with market economies by sectors. First, the MBI dominates heavily as the source of quality improvement. Second, the MBI contribution is quite stable over FYPs. Whatever the pure volume growth rate of the MBI, the quality imputation is around 5%. The long-term average quality imputation of 1.3 % in trade repeats the overall residual of 1.5 %. The recent quality imputation debate in the OECD gives an impression of increasing quality adjustment (see Baker 1998, Rossiter 2005). The Soviet bell-shaped quality imputation is against the trend. In the OECD data it is difficult to find pure volume indexes. There are empirical calculations for West Germany in 1970-80 and the USA GNP in 1958-1977 by Boretsky (Boretsky 1987, 1990). In order to asses the reliability of the CIA's volume index methods in the Soviet case, Boretsky calculated volume indexes similar to those the CIA had used for the Soviet Union for West Germany and the USA. The GNP annual residual was 1 % for West Germany and 0.5 % for the USA (Boretsky 1986, pp. 523-525). The CIA type index exaggerated production in construction in both countries. The opportunity for exaggeration also exists in the Soviet case. The Soviet quality and hidden inflation residual was about 1.75% in 1970-1980 (Table 5.4.1). The residual in the MBI was 0.7% for West-Germany and 1.5 % for the USA in contrast to about 4.6 % in the Soviet data. Total factor productivity for Germany in 1971-1985 was 1.9 % annually and 1.0 % for the USA in 1970-1980 (Gregory & Stuart 1998, p. 232, Mankiw 2003, p. 233). Theoretically TFP does not contain the improvement of the quality of capital stock.

With long-term constant returns to scale total factor productivity is a crude measure of quality change. The total factor productivity measure has an interpretation in the context of a **macro production function**. The quality imputation into price or volume indexes relates more to flow data in an input-output model. In innovation terms, measuring total factor productivity is connected with **process innovation** and adjusting quality for indexes with **product innovation**. Although TFP and imputed quality are logically independent, process and product innovations normally take place simultaneously. It is not enough to assume constant returns to scale to achieve comparability between countries. The quality imputation revealed by pure volume growth and TFP are very close only if capital stock is measured without quality change. Hence, the following is only an illustration. The combined factor inputs in USA left about 1% of GNP growth in 1970-80 for the TFP. In 1995 the quality imputation reduced the USA CPI about 1.5 % (Baker 1998, p. 123). Normally quality residual should be larger than TFP. In 1990-99 total factor productivity in the USA was about 0.9% (Mankiw ibid.). To be precise about the quality residual the index types must also be matched. The CPI is a Laspeyres index and the GDP implicit deflator is a Paasche-type index. The latter is used to calculate the total factor productivity residual.

Ponomarenko in his study on the Russian historical GNP adjusted pure volume growth series with *ex post* experts based quality coefficients (Ponomarenko 2002, pp. 95-98). He estimated that about 50% of the assumed Soviet quality improvement in industry generally was real. In the MBI this share was about 65% and in chemicals 45%. As in the long run almost 90% of the assumed Soviet quality improvement was due to industry, the true average for the SOF models on the TMP level would be some 0.6% of annual quality rise (Table 5.4.1 , Ponomarenko ibid). How precise Ponomarenko's procedure is, remains open. Faltsman's early results in 1984 showed that quality improvement in MBI measured with capacity change relative to counted numbers was some 2 % annually in 1971-1985 (Faltsman 1984, pp. 39-40).[19] This is close to Ponomarenko's judgment about quality change in the Russian MBI. In an article in ***Voprosy Ekonomiki*** Rutgaizer, Sheviakhov and Zubova referred to a study by the research institute of the State Price Committee reporting a CPI inflation of about 43% in 1971-1983 (Rutgaizer et al. 1988, p, 33).[20] This more than exhausts the PMI induced annual residual of TMP growth 1.7 % for 1971-1983. This result can be in line with our alternative growth studies only, if the Price Committee study was based on unadjusted quality. There may also have been less inflation in capital goods. Nevertheless, the assumption of zero or clearly decreasing Soviet quality seems unsubstantiated. Provided constant returns to scale, **TFP** measured with pure volume TMP or

[19] The inflation rate is subtracted from the MBI revealed residual.
[20] The GOSKOMSTAT figure for the same period was about 8%.

GNP estimates should be rather modest (see e.g. Gregory & Stuart, 1998, p. 232). This is not corroboration for zero quality contribution. The Soviet implied quality improvement was highest in the MBI. No quality improvement in Soviet aerospace industries, power plants, cars or armaments in 1960-1990 seems implausible. Quality improvement is domestic and relative. In this sense references to Western quality standards may be misleading. The Soviet defense establishment dominated the MBI. The share of defense in the GDP was estimated to be 10-23% in the mid-1980s (see Hanson 2003, pp. 30-34; Kudrov 2006, pp. 453-456). In national accounting defense was not consumption or investment in fixed capital. Thus much of the new Soviet quality was silently consigned to defense. Making quality imputation internationally commensurate is impossible without common statistical methodology. The Soviet quality measurement seems to have been cost-based and inclined on technical performance indicators (Nazarov 1985, pp. 230-236). This was in a context of seller's markets.

5.5 Differences between Net and Gross Measures

The CIA alternative data on the Soviet economy was published in the SNA style and GNP was the main macroeconomic aggregate. The congruence of the NMP and GDP growth rates depends on depreciation time series as well on how closely the service- sector time series follow the material product category as defined by the MPS. We solved this problem by transforming part of the CIA data into MPS. This is not as antediluvian as it seems, because our general target was to investigate hidden inflation in Soviet MPS data in light of the chosen alternative index sets. The differences within the MPS-system are related to three measures: The total product TMP, the gross material product GMP that is a gross value-added category in input-output tables and the Soviet regular measure of national income NMP that is a net national income concept. The PMI and the CIA index system used the producer side approach and assumed that the total product development moves closely together with value-added aggregates. If we denote the intermediate production **IMP**, then the concepts are related by the equation:

TMP = GMP + IMP = NMP + Depr. + IMP. (producer side quadrants in I-O)

It is apparent that the gross material product GMP is a conceptual cognate of GDP or GNP. The GMP, produced or end use, was used only in Soviet input-output tables (***uslovno-tshistaia/ konetsnaia produktsiia***). The first term refers to value added and the latter to final product. The statistical value-added indicator in Narkhoz was NMP. A traditional topic in the Soviet economic debate was whether the so-called **material intensity** of production was rising in the seventies and eighties. The material intensity of production could be measured for instance with the shares I_m = TMP/GMP or TMP/NMP (Granberg, 1978, p. 283). The above definition is a scalar ratio. It is also possible to study the dynamics material intensity by vector components i.e. I_{nx1} = TMP**.** /GMP[1]. Growing material intensity means that total product grows faster than value added. The Soviet input-output tables were compiled using the **GMP** as the dividing value-added category (see e.g. Narkhoz SSSR v 1990 godu, pp. 292-297). Both the producer side value added and final product side were gross material product GMP measures.

Nominally the Soviet intermediate production and the value added grew very similarly. The proportion NMP/TMP decreased nominally from 48% in 1959 to 43% in 1990 (Narkhoz 1960-1990). Especially the depreciations grew faster than the value-added in nominal terms. The effect of this should show more distinctively in NMP than in TMP. By the Soviet data material intensity grew about 5% in 1971-75 and remained relatively stable in the eighties (A Study of the Soviet …, vol. 1., p. 88). In the Soviet data all measures seem, however, to be very close to each other whether net or gross national income, intermediate production or total product. The GMP can be calculated directly from the input-output tables. By accounting rules the value added and the final product are equal. We used the 1972 5-sector table and calculated final product in 1975 prices. We obtained respectively 4.6 % and 4.8 % for the annual growth of GMP and TMP in the SOF model. We obtained an annual growth rate of 4.4 % for national income in 1960-1990, when the TMP sector indexes were weighted with NMP-weights that excluded the turnover tax. These weights were from ‘A Study of the Soviet Economy’ published by the World Bank, IFM and the OECD.

We present three alternative ways to calculate the NMP based on Soviet sector indexes (Table 5.5.1). The Soviet NMP index in ***Narkhoz*** was calculated using the volume index variant of double deflation on the producer side. The proxy index for the Soviet NMP calculated with

[1] This is a **Matlab** notation for division by components.

Table 5.5.1 A Cross Check of Material Intensity of the Soviet Data 1961-90

FYP	**Narkhoz SSSR 1960-1990** *Lowe-Laspeyres 1960-88, 1989-90 annual*			**CMEA-Yearbook** *5-year Laspeyres*	**SOF-Model** *5-year Laspeyres*			
	NMP	**TMP**	**GNPsoviet**	**NMP**[1]	**NMP**[2]	**NMP**[3]	**TMP**	**IMP**[4]
				Recombined	***TMP proxy***	***Double.def.***		
61-65	6,50	6,5	6,5	6,7	6,2	5,5	6,4	7,3
66-70	7,8	7,4	7,6	7,7	7,2	6,9	7,5	8,0
71-75	5,7	6,3	6,2	5,7	5,7	4,6	6,1	7,3
76-80	4,3	4,2	4,8	3,9	3,6	3,5	3,7	3,8
81-85	3,2	3,3	3,7	2,6	3,2	2,4	3,4	4,1
86-90	1,3	1,8	2,4	2,1	2,3	2,5	2,3	2,2
61-90	4,8	4,9	5,2	4,8	4,7	4,2	4,9	5,4

[1]Calculated with the CMEA Yearbook NMP sector indexes and Soviet NMP weights

[2]Calculated with Soviet TMP sector indexes and Soviet NMP weights

[3]Indirect double deflation, TMP% = (IMP/TMP) ●IMP% + (NMP/TMP)●NMP%

[4]Intermediate annual production calculated from Soviet nominal data

Soviet TMP sector volume indexes and NMP-weights (TMP proxy) was on average very close to the Soviet Yearbook index. The recombined NMP was calculated with the CMEA statistical yearbook NMP sector indexes and the Soviet NMP-weights. Double-deflated SOF model NMP was based on simplified double deflation. Some of the difference between the Soviet Lowe-Laspeyres indexes in Narkhoz and the SOF-model 5-year Laspeyres alternative style NMP indexes was due the dominance of the Lowe-index relative to the standard Laspeyres index. These differences are decimals of one percentage.

The most affected FYP was 1976-80. There were some anomalies in the Soviet NMP data in the eighties due the anti-alcohol campaign. The campaign effected the turnover tax accumulation (see e.g. Vanous 1987). The SOF model synthetic growth figures in the 1980s followed more the Soviet GNP growth than TMP or NMP. The differences between the Soviet Yearbook NMP and the recombined NMP should mainly indicate differences due to index types. The yearbook NMP and the SOF model double deflated NMP differed about half a percent annually in 1960-90. Both indexes are double deflated but there are probably differences as to including depreciation and the balance of foreign trade. The disappearance of most nominal growth in material intensity is explained by the fact that Soviet real data showed deflationary trends especially in the industry sectors (Figure 3.2.1). Thus the yearbook double deflated NMP index and the TMP proxy index were highly congruent. Material intensity may be studied by transforming the I-O tables from 1959, 1972 and 1989 into the same prices. We did a crude exercise for 5-sector tables using 1975 prices as constant prices. The 1972 table was taken in nominal terms. The results are shown below (Table 5.5.2). In current prices the material intensity seems to grow somewhat. Considering both the Soviet official inflation and the PMI inflation, induced by PMI volume indexes, total material intensity in 1975 prices fell slightly in 1959-1989. Growing depreciations seem to be responsible for the slight rise in the nominal material intensity of the Soviet TMP in 1960-90. To calculate the final product for 1960-1990 the input-output tables must be somehow averaged. We calculated the PMI total material product in 1975 prices and the PMI gross final material product with the 1972 five-sector Soviet input-output table in 1975 prices. The results were respectively 3.3% and 3.26 % annually. Because the share of depreciations was increasing, it is obvious that the NMP grew somewhat slower than TMP or GMP. Thus, the material intensity as defined here seemed to deteriorate only slightly irrespective of the estimated hidden inflation.

Table 5.5.2 Five-Sector Input-Output Tables for 1959, 1972 and 1989

	Original tables						Inflation adapted tables											
YEAR	**Current Prices**						**In 1975 Prices (PMI inflation)**						**In 1975 Prices (Soviet Inflation)**					
1959	0,376	0,487	0,103	0,297	0,146		0,437	0,420	0,119	0,196	0,111		0,376	0,387	0,058	0,312	0,142	
	0,000	0,000	0,000	0,000	0,000		0,000	0,000	0,000	0,000	0,000		0,000	0,000	0,000	0,000	0,000	
	0,113	0,027	0,237	0,002	0,001		0,217	0,001	0,169	0,000	0,009		0,202	0,038	0,237	0,003	0,002	
	0,054	0,001	0,015	0,004	0,014		0,031	0,013	0,012	0,000	0,013		0,051	0,001	0,008	0,004	0,013	
	0,048	0,009	0,056	0,000	0,001		0,050	0,000	0,011	0,000	0,023		0,049	0,008	0,032	0,000	0,001	
Sum	**0,591**	**0,524**	**0,411**	**0,303**	**0,162**		**0,734**	**0,434**	**0,311**	**0,196**	**0,156**		**0,679**	**0,434**	**0,335**	**0,320**	**0,158**	
1972	0,387	0,569	0,157	0,232	0,193		0,387	0,569	0,157	0,232	0,193		0,387	0,569	0,157	0,232	0,193	
	0,000	0,000	0,000	0,000	0,000		0,000	0,000	0,000	0,000	0,000		0,000	0,000	0,000	0,000	0,000	
	0,120	0,000	0,211	0,000	0,007		0,120	0,000	0,211	0,000	0,007		0,120	0,000	0,211	0,000	0,007	
	0,029	0,001	0,010	0,000	0,015		0,029	0,001	0,010	0,000	0,015		0,029	0,001	0,010	0,000	0,015	
	0,037	0,000	0,007	0,000	0,022		0,037	0,000	0,007	0,000	0,022		0,037	0,000	0,007	0,000	0,022	
Sum	**0,573**	**0,571**	**0,384**	**0,232**	**0,238**		**0,573**	**0,571**	**0,384**	**0,232**	**0,238**		**0,573**	**0,571**	**0,384**	**0,232**	**0,238**	
1989	0,437	0,407	0,171	0,150	0,098		0,437	0,441	0,249	0,176	0,143		0,376	0,549	0,198	0,539	0,220	
	0,000	0,000	0,000	0,000	0,000		0,000	0,000	0,000	0,000	0,000		0,000	0,000	0,000	0,000	0,000	
	0,151	0,000	0,169	0,000	0,006		0,103	0,000	0,169	0,000	0,006		0,059	0,016	0,237	0,002	0,001	
	0,040	0,017	0,022	0,000	0,015		0,034	0,016	0,027	0,000	0,018		0,030	0,001	0,015	0,004	0,012	
	0,056	0,000	0,018	0,000	0,023		0,039	0,000	0,018	0,000	0,023		0,032	0,007	0,072	0,000	0,001	
Sum	**0,684**	**0,424**	**0,380**	**0,150**	**0,142**		**0,613**	**0,457**	**0,463**	**0,176**	**0,190**		**0,497**	**0,572**	**0,522**	**0,545**	**0,233**	
All Inputs by Sectors						**WM**						**WM**						**WM**
1959	**0,5911**	**0,524**	**0,4115**	**0,3029**	**0,1622**	**0,51**	**0,7343**	**0,4336**	**0,3107**	**0,1957**	**0,1557**	**0,571**	**0,679**	**0,4341**	**0,3347**	**0,32**	**0,1584**	**0,5464**
1972	**0,573**	**0,571**	**0,384**	**0,232**	**0,238**	**0,51**	**0,5727**	**0,571**	**0,384**	**0,232**	**0,238**	**0,511**	**0,573**	**0,5708**	**0,384**	**0,232**	**0,238**	**0,5105**
1989	**0,684**	**0,424**	**0,380**	**0,150**	**0,142**	**0,53**	**0,6131**	**0,457**	**0,463**	**0,176**	**0,190**	**0,513**	**0,497**	**0,5721**	**0,522**	**0,545**	**0,233**	**0,4902**

WM= Weighted mean

The approximate 5-sector tables were calculated from Dadaian 1973, p. 138; PE 1976, p. 376 and Narkhoz 1990, p. 297.

The tables are not very strictly comparable.

The input-output sectors are: Industry, construction, agriculture, transports and trade.

6. Triangulating the Differences

6.1 General Observations

When using triangulation instead of standard stochastic arguments much precision is lost. Often the operational definitions of categories are also different. By triangulation we try to find out the likely sources of differences in growth rates. Having narrowed the research task several times, the factors to control are the potential sampling bias in the alternative indexes and the question whether the quality gap was within the normal paradigm. Obviously the randomness of sampling and biased sampling-frame were a problem. In operational terms we used two distance measures for assessing sample designs: the first distance was the percentage share of the alternative mean indicator relative to the Soviet official mean indicator. The second distance measure was the Pearson correlation between the 30-year official and alternative percentage series (Table 5.1.1). Highly correlated with the Soviet series as well as numerically close to them are **electricity, fuels, metallurgy, agriculture and transport**. These were the generally congruent sectors. Most alternative sector series have correlations around and above 0.8. The mean values of the alternative indexes were close each other. In the correlation dimension the PMI construction and trade were clearly less correlated with the Soviet series than other sectors. The problem for these sectors was that because they were technical indexes based on I-O tables and the sample indexes of other indexes, their lag structure was not precisely current. We may conclude that **fuels, electricity, agriculture** and **transport** form the most congruent group in terms of sampling and average growth rates. The 30 year average annual residual relative to the Soviet official synthetic or the Soviet Yearbook series was less than 0.5%. In food and light industry series the deviance is within [0.5%-1.0%]. Classes including the forest industry, construction materials, metallurgy, and chemicals are the next group within deviance interval of [1.0%-2.5%]. In technical terms the MBI, construction and trade seem to be the problem. In the MBI there clearly was a sample problem although the correlation with the Soviet index was quite high. The fact that Eidelman's figure on the MBI was clearly bigger than PMI renders added plausibility to this hypothesis (see. Eidelman 1992). The trade indicator repeats the residual of other sectors.

6.2 The Case of the Machine Building Industries

The annual difference in the machine building industry between Soviet and PMI series for 1960-1990 is in average 5 %. The corresponding figure for the CIA data is 4.6 %. If the time series of actual differences is tested, it can be seen that the standard deviation of the differences is rather small. This means that the difference is not far from the average whatever the actual Soviet growth figure. The fact that the difference between Soviet and alternative series tends to be constant at least in the form of a moving average and the fact that machine building contributes about half of the residual leads us to the hypothesis that the distribution of quality improvement and hidden inflation contribution among sectors is specific to the Soviet planned economy. This distribution of quality imputation may be seen as a result of following a fixed policy of technical progress and ad hoc financing in order to smooth out the ever increasing tautness of planning. The macro reasons for increasing tautness are obvious: declining demographic development, waning rate of investments, heavy defense burden and the efficiency of the Western technology trade embargo. The progress in national economy was according to the official technology policy and economic policy concept to spring from most advanced capital goods industries (see e.g. Nove 1988, p. 357). In a planned economy prophecies are often self-fulfilling. Much of the same logic seems to apply to the chemical industries.

Detailed data on the distribution of quality imputations in different sectors of the national economy is scarce in the OECD countries. In spite of this, if we compare the Soviet data with the Boskin-Commission calculations about the US consumer price index, we may conjecture that the quality imputation was more concentrated onto a few sectors in the Soviet Union than in the USA (Baker 1998, p. 102). Therefore, we must differentiate between whether the quality imputation in Soviet statistics was correct at the level of national income and whether this was so as for the sectors of national economy.

The biased sample frame in the Soviet machine building industries led to three problems. First the nomenclature of the machine building industries was diversified, but this was not reflected in Soviet statistical yearbooks. Secondly there was the special problem of military hardware. The CIA indexes estimated the military related production separately by a special methodology (JEC 1982, p.189).

The third problem was production related to unique projects which were not reflected in the statistical yearbooks. If very general and highly aggregated commodity categories are used the quality aspect remains hidden. The PMI growth figure for the machine building industry of 3.9 % is TMP, whereas the CIA figure of 4.4 % is based on value added series. The main measurement problem in the Soviet MBI data was **instruments** and **automation**. The share of this sector was rather high in overall machine building and the related official production data were mainly in terms of rubles. The PMI index contained a physical series in instruments and automation. Whether this series was representative is uncertain. Without instruments and automation the PMI-index is about 0.5 % lower.

Obviously there was a distinct underestimation of the machine building industry in the PMI index set. The PMI figure of 3.9% is close to the real world lower limit. This is so because it is close to the growth rate of the most important input item: **rolled steel**. The PMI figure for metallurgy is an annual growth of 3.2 %. The corresponding Soviet index for metallurgy is 4.4. In this sense a reasonable input floor may be around 4 % for MBI. We obtain a similar result if we calculate a regular input index for the machine building industries using input-output tables. *Ceteris paribus* Eidelman's results in the MBI, the revealed growth residual in the Soviet MBI, could be about 4 %. According to Ponomarenko, some 65% of the alleged Russian quality improvement in the MBI was real (Ponomarenko 2002, p. 95). This suggests an annual quality contribution of about 2.6 % in the Soviet MBI in 1960-1990.

6.3 The Best Guess with Soviet Data

Finally, we made the best Soviet guess. We observed that most alternative indexes had some weak points. We thought that the MBI index was underestimated in volume terms except in Eidelman's index. We chose Soviet official indexes for electricity and fuels and Eidelman's data for the remaining industries because of his robust sampling. As for construction, we assumed that its growth rate should be higher than or very near the TMP. This is because investments most of the time grew faster than the TMP. If we take the 1972 5-sector I-O table as a benchmark, it can be seen that the input index of construction depends almost exclusively on industrial production (Table 5.2.2). In input-output accounts the construction sector sold only final product. Using the above mentioned I-O table to calculate the final product of construction and the construction input index we note that they are rather close to each other in 1972 prices. If we calculate a Törnquist volume index for construction using the structure of construction works in 1960 and 1990 as value weights and the production of the MBI and building materials as volume series, we get 4.3 % (Eidelman 1993, p. 17). A similar reasoning with inflation as revealed by Eidelman leads to 2.4 % open inflation in construction. The value index for construction is about 5.7. Thus, the lower limit for pure volume construction growth is about 3.3% using deflation. We calculated construction as final product with the 1972 5-sector table in 1975 prices (Table 5.5.2). There is a consensus for agriculture and transport and we here accepted the Soviet official volume measures. Trade is a mark-up on retail and wholesale trade. Irrespective of the savings ratio, the real production of trade should follow TMP growth rate. We calculated trade as intermediate sales with the 1972 5-sector I-O table. Lastly, we calculated a Törnquist binary index for a 13- sector model. The first row shows the indexes and the second average weights for 1960-90. The results are presented below.

Table 6.3.1 The Best Soviet Guess

Index 61-90	**6.69**	**3.04**	**2.56**	**5.76**	**4.57**	**1.76**	**3.05**	**1.71**	**2.51**	**2.9**	**1.79**	**3.8**	**2.85**
Weights	**0.02**	**0.05**	**0.05**	**0.03**	**0.14**	**0.04**	**0.02**	**0.12**	**0.13**	**0.1**	**0.17**	**0.05**	**0.08**
TT vol. Ind													**3,37 %**

The best guess for Soviet pure volume growth rate is 3.37%. The Soviet data results are not different from the CIA or the PMI results. In all cases the alternative indexes fall into the interval [3.2-3.4]. The conclusion is that the discussion about alternative indexes is saturated. To gain new insights more data is needed.

7. Conclusions

Because our calculations were limited, we are cautious about numbers. Regarding the methodological comparability of the data, we have established through theoretical and empirical tests that binary Fisher indexes may be used as common measures. We also saw that the 5-year Laspeyres synthetic Soviet volume-indexes were close to the Soviet Yearbook Lowe indexes. If the base period is five years, then all averaging indexes Fisher, Natural Divisia, Törnquist and Walsh are good proxies, too. The alternative indexes were producer side, total product volume indexes. Considering the above check on material intensity, it is likely that using total product proxies for value-added indexes was not a grave source of error (Tables 5.5.1 and 5.5.2). The Soviet indicators of real production were conceptually similar to their OECD counterparts. The main index type was Lowe-Laspeyres type volume indexes with implicit Paasche price indexes. This was in line with the OECD GDP-deflator practices. The Lowe volume indexes were, as we saw, highly compliant with a 5-year based synthetic Soviet NMP/TMP volume index system. The main differences from the OECD were the Soviet comprehensive sampling system and the procedures for quality imputation into the indexes. The latter task was part of price planning. From a technical point of view the MPS-system was appropriate for studying hidden inflation. This is so because the MPS is based on material production and the combined residual of hidden inflation, quality contribution and sample bias was revealed by pure volume commodity indexes. It is much more difficult to think up pure volume indexes for services.

Important changes took place in the 1960s. First the debate on planned Soviet prices ended up adopting Marx's **production prices** concept. This meant that for the first time in the Soviet economy wide capital costs were introduced into planned prices. This change was related to prices from the 1966-70 FYP onwards. Later the so-called **Kosygin reform** of the second half of the sixties led to more decentralized pricing. The state planning committee **GOSPLAN** gave new instructions on pricing high technology products in the late 1960s, too.

In line with the basic Solow-growth model, the Soviet economy was moving towards a stabilizing growth path with **expiring inputs of new labor**, **declining rate of investment** and heavy constraints on utilizing the **comparative advantage** in foreign trade and integration. The lack of free trade and the **Western technology embargo** dampened the effects of traditional technology transfer-procedures. As the MBI was dominated by **defense interests**, much of the new technology remained hidden in these inventory markets.

In light of Eidelman's data it is plausible that the Soviet Statistical Yearbook Narkhoz SSSR was a satisfactory, robust sample frame, with reservations mainly for the machine-building industries. Modeling the Soviet MBI fully adequately was not possible using only Narkhoz volume data. During the period reviewed the **quality imputation level** for the U.S. consumer price index rose from 0.8 % to 1.8 % at the beginning of the nineties. The share of CPI in the GDP in the USA is about 70%. The gap between the binary PMI Fisher volume-index and the binary Soviet Fisher volume-index was 1.5 % for the whole period of 1960-1990. The quality gap was heavily concentrated in the MBI in the Soviet data. On the level of TMP the Soviet quality gap is dynamically bell-shaped. During the 61-65 FYP the gap in TMP is 0.6% annually. It is 1.4 % in 1986-1990. But it was1.75 % in 1971-75. In contrast, in the OECD data the quality imputation has been on the rise since the late sixties (see e.g. Baker 1998 and SOU 1999:124). A crude interpretation is that the Soviet quality was near normal in 1961-65 and it was approaching the normal level in 1986-90, but it overshot in the meantime due to creeping hidden inflation related to major economic reforms and tautness of planning.

For the behavior of the quality and hidden inflation residual the explanation could be two-fold. The machine building industry and chemicals added to quality according to planned norms. Trade and construction would seem to have served as absorbers of current budget-policy. Construction suffered from true cost inflation as the economic infrastructure expanded to new peripheries and partly due to the increasing number of unique investment projects. In light of the good congruence of alternative volume data we guess that sampling bias was not a very bad problem. It seems, however, that the true Soviet growth rate could be distinctly more than the pure volume growth. This conclusion was drawn in recent Russian research, too (Ponomarenko 2002). Using an expert judgment the true quality imputation was proportioned to the share of investments in new technology. With this approach the real quality adjustment in Russian industries in 1960-1990 was assumed to be 50% of the alleged level (ibid p. 95-97). According to Ponomarenko, the annual quality contribution in MBI for 1960-90 was about 2.5%. It is reasonable to assume positive true quality adjustment in Soviet data. This is in line with the ideas of Boretsky and Rosefielde, who saw pure volume indexes as lower limit or floor indexes (Rosefielde 1991 p. 601 and Boretsky, 1989 p. 320). To support the contrary argument, empirical data corroborating deteriorating product quality *en masse*, must be put forward. It is obvious that declining TFP may go together with rising commodity quality in some periods. The case for calculating the correct purchasing power parities with the OECD was less successful than measuring the domestic economic growth (e.g. Kudrov 2006, p. 457). Both the quality imputation debate in the nineties and the unification of international PPP-calculation programs occurred too late to have a profound effect on the debate about Soviet economic growth. Thus it is difficult to use PPP-studies as benchmarks for quality adjustment studies.

The Soviet quality imputation was concentrated on priority sectors only. The quality imputation methodology of the Soviet period seems to have been a **blend of financial policies** and a **philosophy of technical progress** as much as pragmatic methodology. In order to achieve a better comparability of growth data the quality assessment should be put on the OECD standard. An assumption is that the Soviet quality adjustment was more cost based and more hedonistic than in the OECD. We do not know which part of the planned quality imputations in the Soviet economy would have been accepted by free markets. The planners lacked methodological instruments for detecting hidden inflation. In Soviet political economy inflation was **another man's disease** and the myth of perfect planner blocked the profit seeking arguments of the new institutional economics from Soviet economic theory.

On a high theoretical level the main question is whether or not the MPS system was an adequate framework for cost and capital accounting when the collective decision function was insensitive to short run and especially to long run costs including great human losses and environmental damage. A careful study of waste and losses in production may downgrade the methodologically correct growth rates. We wanted to find out whether the GOSKOMSTAT followed prudent practice of statistical accounting *ceteris paribus* the volume data.

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APPENDIX I : SOVIET TMP SECTOR INDEXES 1960-1990

Soviet Comparative price volume indexes

Year	El.	Fuels	Metlur	Chem	MBI	Forest	Build. M	Light	Food	Const	Agric.	Trans.	Trade
	1	2	3	4	5	6	7	8	9	10	11	12	13
1960	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
1961	1,12	1,05	1,09	1,13	1,15	1,04	1,12	1,04	1,07	1,06	1,03	1,06	1,03
1962	1,27	1,11	1,21	1,30	1,32	1,09	1,21	1,07	1,16	1,04	1,04	1,12	1,10
1963	1,44	1,20	1,32	1,50	1,50	1,16	1,30	1,09	1,22	1,07	0,96	1,22	1,15
1964	1,60	1,29	1,44	1,73	1,64	1,23	1,41	1,13	1,26	1,11	1,10	1,34	1,21
1965	1,78	1,37	1,56	1,96	1,79	1,28	1,54	1,14	1,42	1,22	1,12	1,45	1,35
1966	1,94	1,46	1,68	2,21	2,01	1,32	1,69	1,24	1,49	1,29	1,22	1,57	1,45
1967	2,10	1,55	1,82	2,53	2,26	1,42	1,85	1,38	1,60	1,43	1,23	1,73	1,57
1968	2,33	1,62	1,94	2,81	2,52	1,50	2,00	1,49	1,69	1,56	1,29	1,89	1,71
1969	2,54	1,71	1,99	3,12	2,81	1,57	2,09	1,59	1,76	1,62	1,24	1,98	1,80
1970	2,69	1,82	2,11	3,49	3,12	1,68	2,31	1,72	1,89	1,76	1,38	2,16	1,89
1971	2,93	1,93	2,22	3,85	3,46	1,78	2,52	1,84	1,98	1,90	1,39	2,30	2,02
1972	3,14	2,04	2,33	4,21	3,86	1,87	2,68	1,89	2,06	1,99	1,34	2,45	2,14
1973	3,36	2,15	2,44	4,68	4,33	1,95	2,89	1,96	2,15	2,08	1,56	2,62	2,27
1974	3,57	2,27	2,57	5,19	4,83	2,05	3,07	2,05	2,32	2,23	1,50	2,83	2,40
1975	3,79	2,42	2,69	5,77	5,39	2,17	3,28	2,15	2,44	2,35	1,43	3,06	2,56
1976	4,09	2,51	2,90	6,20	5,93	2,21	3,38	2,24	2,39	2,44	1,50	3,18	2,66
1977	4,24	2,61	2,97	6,63	6,47	2,28	3,51	2,32	2,51	2,49	1,57	3,34	2,79
1978	4,44	2,71	3,08	6,92	7,01	2,32	3,57	2,41	2,56	2,64	1,61	3,50	2,91
1979	4,59	2,76	3,08	7,21	7,55	2,30	3,57	2,45	2,61	2,65	1,54	3,52	3,00
1980	4,85	2,81	3,08	7,60	7,98	2,35	3,61	2,54	2,61	2,75	1,54	3,65	3,10
1981	4,94	2,83	3,09	7,98	8,46	2,42	3,68	2,61	2,66	2,83	1,53	3,80	3,22
1982	5,14	2,89	3,11	8,27	8,85	2,51	3,77	2,61	2,76	2,89	1,61	3,91	3,22
1983	5,37	2,95	3,23	8,65	9,41	2,60	3,93	2,64	2,92	3,03	1,71	4,09	3,32
1984	5,73	2,98	3,32	9,13	10,05	2,70	4,04	2,66	3,02	3,11	1,71	4,12	3,44
1985	5,97	2,98	3,42	9,62	10,77	2,79	4,18	2,74	3,08	3,22	1,71	4,23	3,50
1986	6,15	3,10	3,55	10,19	11,52	2,93	4,39	2,79	3,14	3,58	1,80	4,38	3,53
1987	6,45	3,15	3,62	10,67	12,17	3,02	4,56	2,85	3,26	3,80	1,79	4,42	3,50
1988	6,57	3,18	3,72	11,15	12,81	3,13	4,77	2,93	3,38	4,10	1,82	4,67	3,69
1989	6,63	3,15	3,76	11,25	13,14	3,18	4,85	3,01	3,51	4,15	1,85	4,34	3,97
1990	6,69	3,04	3,65	10,96	13,25	3,16	4,77	2,96	3,48	3,80	1,79	3,80	4,15

Narkhoz SSSR 1960-1990

TMP is the Soviet valovoi obshestvennii produkt VOP

Year	APPENDIX I I : SOVIET TMP SECTOR INDEXES 1960-1990 (current rubles in billions)													Soviet TMP
	El.	Fuels	Metlur	Chem	MBI	Forest	Build. M	Light	Food	Const	Agric.	Trans.	Trade	Billions of
	1	2	3	4	5	6	7	8	9	10	11	12	13	Rubles
1960	4,61	14,99	13,99	7,52	32,61	13,52	7,86	44,13	49,78	32,00	49,00	13,00	21,00	304,00
1961	5,16	15,86	15,24	8,60	36,53	14,13	8,50	45,13	53,04	32,68	51,59	13,46	20,51	320,42
1962	5,83	16,97	16,78	9,91	41,30	14,92	9,30	46,58	57,16	32,78	58,31	13,80	21,39	345,04
1963	6,53	18,05	18,36	11,31	46,34	15,66	10,12	47,69	61,24	34,66	58,37	14,96	21,52	364,80
1964	7,19	18,90	19,78	12,66	51,08	16,16	10,83	47,93	64,58	36,60	63,90	16,30	22,70	388,60
1965	7,98	19,95	21,47	14,25	56,71	16,81	11,68	48,45	68,68	40,00	71,00	18,00	25,00	420,00
1966	8,53	20,71	23,37	15,72	62,05	17,44	12,41	51,44	72,33	43,00	80,00	19,00	25,00	451,00
1967	9,66	22,74	26,92	18,34	71,83	19,13	13,94	57,82	80,63	50,00	81,00	21,00	29,00	502,00
1968	10,72	24,47	30,41	20,98	81,54	20,57	15,38	63,76	88,17	53,00	87,00	22,00	32,00	550,00
1969	11,49	25,40	33,14	23,13	89,27	21,33	16,36	67,85	93,02	60,00	88,00	23,00	35,00	587,00
1970	12,36	26,41	36,21	25,56	97,99	22,15	17,47	72,43	98,42	67,00	104,00	25,00	38,00	643,00
1971	13,15	27,75	41,13	27,56	104,50	22,98	18,47	76,29	102,47	74,70	108,10	27,70	40,50	685,30
1972	13,92	28,98	46,23	29,53	110,77	23,69	19,41	79,87	106,01	77,40	108,80	29,50	43,30	717,40
1973	14,92	30,65	52,44	32,04	118,93	24,71	20,67	84,69	111,04	80,90	121,90	31,70	46,30	770,90
1974	16,04	32,52	59,47	34,87	128,09	25,85	22,07	90,08	116,62	86,40	122,10	34,10	48,50	816,70
1975	17,08	34,16	66,61	37,57	136,63	26,76	23,34	94,88	121,26	91,70	122,30	36,70	53,60	862,60
1976	17,71	34,95	67,78	39,45	147,29	27,04	23,62	97,50	123,05	94,20	132,40	38,60	60,30	903,90
1977	18,57	36,14	69,68	41,84	160,20	27,60	24,13	101,24	126,11	96,20	141,70	41,10	65,10	949,60
1978	19,43	37,31	71,51	44,32	173,79	28,11	24,61	104,99	129,03	99,20	147,00	43,70	69,10	992,10
1979	20,20	38,23	72,83	46,59	186,90	28,40	24,90	108,06	130,98	101,10	151,90	45,20	77,10	1032,40
1980	20,94	39,08	73,97	48,85	200,28	28,61	25,12	110,96	132,59	104,20	150,20	47,00	90,50	1072,30
1981	23,26	42,56	75,97	51,12	207,93	30,56	26,60	114,25	136,75	106,40	160,00	49,80	97,60	1122,80
1982	27,63	49,64	83,69	57,40	231,62	34,99	30,22	126,20	151,32	115,10	170,30	55,20	102,70	1236,00
1983	29,51	52,17	83,20	58,18	232,88	36,15	30,98	125,81	151,12	119,30	207,90	58,00	107,50	1292,70
1984	32,19	56,05	84,68	60,37	239,75	38,22	32,51	128,41	154,51	132,30	217,00	59,50	110,30	1345,80
1985	34,61	59,45	85,19	61,94	244,03	39,93	33,72	129,56	156,18	136,30	219,50	66,00	117,20	1383,60
1986	33,24	61,58	85,80	63,66	252,66	41,20	34,39	131,05	158,92	147,90	232,60	68,80	114,00	1425,80
1987	32,22	64,60	87,53	66,28	264,97	43,05	35,53	134,28	163,83	155,90	234,90	70,30	111,10	1464,50
1988	30,73	66,97	88,24	68,20	274,60	44,47	36,29	135,99	166,92	165,50	259,70	73,50	113,90	1525,00
1989	29,48	70,20	89,95	70,97	287,74	46,44	37,47	139,25	171,99	173,60	276,70	72,70	127,00	1593,50
1990	27,37	71,64	89,25	71,91	293,54	47,22	37,68	138,84	172,55	169,10	296,00	83,80	132,70	1631,60

Narkhoz SSSR 1960-1990

TMP is the Soviet valovoi obshestvennii produkt VOP

APPENDIX I I I : SOVIET TMP SECTOR INDEXES 1960-1990 , the Synthetic PMI model

A sample based small index set

Year	El.	Fuels	Metlur	Chem	MBI	Forest	Build. M	Light	Food	Const	Agric.	Trans.	Trade
	1	2	3	4	5	6	7	8	9	10	11	12	13
1960	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
1961	1,12	1,06	1,08	1,11	1,10	1,00	1,12	1,03	1,07	1,07	1,02	1,07	1,06
1962	1,26	1,15	1,18	1,23	1,21	1,03	1,21	1,08	1,15	1,14	1,02	1,15	1,14
1963	1,41	1,24	1,24	1,35	1,31	1,07	1,28	1,09	1,19	1,20	0,95	1,24	1,19
1964	1,57	1,33	1,31	1,55	1,39	1,12	1,38	1,12	1,24	1,27	1,11	1,35	1,26
1965	1,73	1,43	1,41	1,77	1,50	1,15	1,45	1,11	1,40	1,36	1,11	1,47	1,35
1966	1,86	1,52	1,51	1,94	1,64	1,17	1,57	1,20	1,44	1,45	1,23	1,57	1,44
1967	2,01	1,61	1,62	2,14	1,79	1,23	1,67	1,29	1,56	1,56	1,24	1,72	1,55
1968	2,19	1,69	1,70	2,32	1,91	1,26	1,70	1,37	1,65	1,65	1,32	1,87	1,63
1969	2,36	1,77	1,74	2,44	2,00	1,29	1,77	1,46	1,69	1,73	1,27	1,97	1,70
1970	2,54	1,88	1,84	2,71	2,08	1,36	1,90	1,54	1,80	1,83	1,37	2,10	1,80
1971	2,74	1,98	1,92	2,93	2,17	1,41	1,99	1,61	1,85	1,91	1,37	2,21	1,88
1972	2,93	2,07	2,00	3,17	2,28	1,44	2,08	1,65	1,93	1,99	1,31	2,34	1,95
1973	3,13	2,18	2,09	3,47	2,41	1,48	2,22	1,71	2,00	2,09	1,54	2,50	2,06
1974	3,34	2,31	2,11	3,82	2,57	1,52	2,33	1,77	2,13	2,20	1,49	2,68	2,16
1975	3,55	2,45	2,26	4,23	2,71	1,58	2,44	1,84	2,21	2,32	1,36	2,89	2,26
1976	3,80	2,58	2,32	4,43	2,85	1,58	2,53	1,93	2,18	2,39	1,53	3,02	2,34
1977	3,93	2,69	2,34	4,66	2,96	1,59	2,53	1,97	2,31	2,47	1,52	3,12	2,42
1978	4,11	2,80	2,41	4,80	3,03	1,57	2,55	2,02	2,33	2,52	1,61	3,29	2,47
1979	4,24	2,87	2,36	4,69	2,99	1,50	2,45	2,05	2,35	2,52	1,50	3,35	2,46
1980	4,43	2,94	2,36	4,94	3,05	1,52	2,43	2,10	2,33	2,55	1,45	3,52	2,49
1981	4,54	2,97	2,36	5,16	3,12	1,54	2,45	2,15	2,36	2,60	1,39	3,62	2,53
1982	4,68	3,03	2,33	5,23	3,16	1,53	2,43	2,14	2,43	2,63	1,49	3,69	2,56
1983	4,85	3,07	2,43	5,59	3,18	1,58	2,55	2,15	2,54	2,70	1,55	3,79	2,63
1984	5,10	3,10	2,45	5,80	3,24	1,62	2,60	2,18	2,58	2,75	1,54	3,85	2,68
1985	5,28	3,11	2,48	6,04	3,33	1,67	2,65	2,20	2,59	2,80	1,54	3,93	2,72
1986	5,47	3,24	2,56	6,30	3,39	1,78	2,75	2,22	2,63	2,87	1,64	4,06	2,79
1987	5,70	3,31	2,61	6,51	3,38	1,82	2,80	2,28	2,73	2,92	1,61	4,11	2,84
1988	5,83	3,36	2,65	6,68	3,43	1,82	2,86	2,34	2,82	2,99	1,59	4,22	2,90
1989	5,89	3,30	2,64	6,53	3,38	1,80	2,82	2,39	2,92	2,99	1,66	4,21	2,91
1990	5,91	3,17	2,56	6,22	3,26	1,67	2,70	2,36	2,91	2,90	1,66	4,13	2,83

Narkhoz SSSR 1960-1990

TMP is the Soviet valovoi obshestvennii produkt VOP

	APPENDIX IV	**PMI Physical Indicators**		
Narkhoz weights for 13 I-O sectors		*I-O weights for sub sectors, extrapolated and interpolated with Narkhoz*		
	BRANCH	**Units**	**Indicator**	*sub sector indexes or physical sample index*
INDUSTRY	**Electricity**		KWH	
	Fuels	Tons	Coal	
			Oil	
		Cubic meter	Gas	
	Metallurgy	Tons	Steel	
	Chemicals	Tons	Fertilizers	
			Sulphuric acid	
			Plastics	
			Fibers	
			Paints	
		Pieces	Tires	
	MBI	Pieces or Capacity	Small electric motors	
			Machine tools	
			Presses	
			Bearings	
			Compressors	
			Auto- and semi automatic lines	
			Trucks	
			Tractors	
	Forest Industry	Cubic meters	Raw timber	
			Saw timber	
		Square meters	Plywood	
			Chipboard	
			Fiberboard	
		Tons	Pulp	
			Paper	
			Cartoon	
	Building materials	Tons	Cement	
		Cubic meters	Prefabricated concrete blocks	
		Cubic meters	Bricks	
		Square meters	Ruberoids	
			Window glass	
	Light industry	Square meters	Cotton clothes	
			Wool clothes	
			Silk clothes	
			Confectionary SOF index	
		Pieces	Shoes	
	Food industry	Tons	Raw fish	
		Pieces	canned fish	
		Tons	Meat	
			Milk powder	
			Sugar	
			Bakery products	
			Animal fats	
		Pieces	Conserves cans	
		Volume m.	Wine	
			Vodka	
		Tons	Bread products	
			Pastry	
CONSTRUCTION			I-O input index	
AGRICULTURE			Grain	
			Potatoes	
			Vegetable	
			Fruits	
			Grapes	
			Sugarbeet	
			Cotton clothes	
			Meat	
			Milk	
		Pieecs	Eggs	
		Tons	Wool	
TRANSPORTS		Ton kilometers	Railway	
		costs in rubles	River	
			Sea	
			Trucks	**Sources: Narkhoz 1960-1990,**
			Tube lines	I-O tables 1959, 1972, 1989, sample relate
			Air	
TRADE			I-O sales index	

APPENDIX V: The Index Formulas

Q_0, Q_1 = the base year and the reference year volume vectors
P_0, P_1 = the prices of the base and reference years

$\sum PQ = P \bullet Q$

Laspeyres indexes:

Volume $L_q = P_0 \bullet Q_1 / P_0 \bullet Q_0$; Price $L_p = P_1 \bullet Q_0 / P_0 \bullet Q_0$

Paasche indexes:

Volume $P_q = P_1 \bullet Q_1 / P_1 \bullet Q_0$; Price $P_p = P_1 \bullet Q_1 / P_0 \bullet Q_1$

Fisher indexes

Volume $F_q = (L_q P_q)^{1/2}$; Price $F_p = (L_p P_p)^{1/2}$

Walsh price index

$Q_r = (Q_0.* Q_1)^{1/2}$, Product by vector components

$W_p = P_1 \bullet Q_r / P_0 \bullet Q_r$, Normally Walsh index is used in price index variant.

Törnquist volume index:

W_0=base year relative prices;
W_1=current year relative price
$W_m = (W_0 + W_1)/2$
$Q = Q_1./Q_0$, division by vector components

$T_q = \text{prod}(Q.^{\wedge Wm})$, $Q.^{\wedge Wm}$ is notation for power raising by components

Natural Divisia volume index

Let (Q(t),P(t)) be a value function in $Q^n x P^n$, Q and P real vectors.

The theoretical natural index is a line integral along the line C that connects (P_0,Q_0) and (P_1,Q_1)

We define the **Natural Divisia-price index** as:

$P_{div}C = \exp \int [D(P(t))Q(t)/P(t)Q(t)]dt$; where C is the **linear path** of integration,

and the **Divisia volume index** as:

$Q_{div}C = \exp \int [D(Q(t))P(t)/P(t)Q(t)]dt$; where C is the **linear path** of integration,

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ESSAYS ON THE MEASUREMENT OF ECONOMIC GROWTH

Concluding the Discussion

Academic Dissertation
Tampere University 2008
Faculty of Social Sciences
Department of Accounting and Economics

Concluding the Discussion

Contents

Concluding the Discussion

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1. The Research Task

The initial core research task was to study empirically the issue of hidden inflation in Soviet official statistical data 1960-1990. The established approach, dating right back to such pre-war pioneers as Jasny and Bergson, was to construct an alternative standard index. Since the fifties, this tradition was continued among others by Bergson, Beckerman and the CIA. As a rule a volume index was chosen for the measurement of growth. These, unlike the price indexes were not quality adjusted and were based on limited samples. The Western Sovietological tradition was to construct one's own separate SNA-type frame for Soviet production data. This is rather complicated. Thus, the only feasible option for an individual scholar was to study the problem of hidden inflation within the Soviet material product system (MPS).

Our early attempts to build a growth index were made in the late eighties and at the beginning of the nineties. Later when some more water had flown under the bridges of the Moscow River, the pursuit turned more into a methodological study in growth measurement than fresh news about Soviet economic growth. The empirical study was to be a part of a dissertation in economics. Hence, it produced two independent essays on economic theory: one on the theory of national accounting and another on statistical index methodology. To put the Soviet growth measurement into an institutional and doctrine related context, a story about indexes in Soviet economic theory was written. As a result the study consists of two main stream theoretical and methodological reviews, one essay on doctrine history concerning economic measurement in the Soviet Union and lastly of an empirical review study about alternative measurement of Soviet economic growth.

2. Methodological Issues

The Soviet MPS volume data was representative only in the category of total material product (TMP). First, we reconstructed a full Soviet official frame in the TMP. This started from the Soviet nominal value structure, published in Narkhoz SSSR 1960-1990. Nominal value data was complemented with Soviet I-O data. The Soviet fixed production indexes did not form a complete TMP frame. Indexes for industry and agriculture were standard, whereas indexes for construction, trade and transports were proxies. We solved this problem with input-output tables. In Soviet I-O tables, the construction sector produces only final product. Thus, it was possible to use the construction index of NMP type. This was regularly published in Narkhoz. Transports were estimated in ton kilometers for various transport flows. Trade was added as an intermediate sales vector produced by I-O tables for 1972. The resulting TMP model was called SOFTMP. Since one research task was to triangulate the differences between SOFTMP and the chosen alternative indexes, these indexes were transformed into the TMP form with the Soviet nominal value TMP matrix for 1960-90 and the alternative sector indexes.

The index methodology had to be standardized, too. The Soviet index system was analyzed. This was at first sight complicated because census type data gathering was used and the system of real volume indexes was in a veiled form. It was discovered that the Soviet TMP that was a Lowe type volume index system, behaved very close to a system of five year based Laspeyres volume indexes. The SOFTMP and the alternative indexes were calculated then as thirty year binary indexes, five-year Laspeyres volume and Paasche indexes and annual chain indexes. The three superlative indexes: Fisher, Törnquist and Walsh were calculated for each index and sample period. The data was added with Natural Divisia indexes. The purpose of the exercise was to minimize the differences due to Laspeyres-Paasche spread and chaining. It was seen that binary Fisher indexes were fairly good proxies for chain indexes. Generally, the three superlative indexes and the Natural Divisia index were close to each other.

Theoretically, the difference between the Soviet official, quality adjusted index and an alternative pure volume index should consist of: true quality adjustment, hidden inflation and the sample bias of the alternative indexes. The problem was that in the Soviet Union fully systematic data was not published in most branches of production. Simply, the official statistics were not a complete sample frame. To build an alternative index set it proved necessary in some branches to employ technological reasoning. To start with, we had a *biased sample* frame and a *convenience sample*. For this reason it was thought that statistical testing is not preferable and a qualitative research approach was chosen instead. Hence, the conclusions made are not a statistically tested set of volume estimators, but a well founded quantitative hypothesis on Soviet hidden inflation. We recall that the sampling problem concerns only alternative index data. The rigor in analysis was further softened by the absence of common standard for quality adjustment in the international national accounting systems the MPS and the SNA. To put the Soviet quality adjustment into some quantitative benchmarks, the quality adjustment discussion in the OECD in the nineties and in 2000s was reviewed.

3. Summing up Main Results

3.1 National Accounting

We emphasize the evolutionary aspect of national accounting theory. To be an object of measurement the economic system must be somehow integrated. In principle the existence of a *numéraire* is enough, but modern measurement presupposes a monetized economy. The conceptual fundament of national accounting is the emergence of business accounting. This was first codified by Luca Pacioli in 1494. In the end of the line, we come to the MPS and the SNA through among others the physiocrats and François Quesnay. The formal methodological thread of national accounting is the theory of real linear systems. Business accounting has a system interpretation and a modern national accounting system can be represented as an input-output system either in institutional or pure sector version. At the beginning of the line we have for example the Egyptian inventory accounting that had the form of a vector dimensional linear stock and flow system. This is the general formal part of national accounting valid for all systems of production with somehow developed system of exchange.

For production statistics to be comparable in different economic systems a production boundary must be defined. Since the latter part of the nineteenth century, the differences have related to the bifurcated tradition of classical value theory. The Neoclassical tradition extended the production concept to all market goods, material or non material. The Marxian tradition held to the classic Greek morals concerning trade and services. The national income (NMP) of planned economies was about 20-25% smaller than their gross national product. Total production is aggregated with prices and the market economies and planned economies had different price systems. The minimum common ground for analysis of production in different systems was the linear theory of production. Productivity of a linear system may be studied in the natural form as well as value form. The measure of productivity is the same in all similar I-O matrices, natural and value termed. There is no unique way to introduce prices into a theoretical system of production. Thus, all comparisons must be made with definite qualifications. Increasing trade and economic integration led to more unified technology and slowly converging world prices. It is apparent that unification in economic systems is intermediated fairly effectively even outside direct exchange. In a connected world, successful technologies tend to diffuse likewise patterns of consumption and production. The SNA from 1993 has recently become the unique global standard.

3.2 Index Systems

Aggregate economic indexes of the 19th century like those of Young, Lowe, Laspeyres and Paasche were the first serious measures of inflation. Real production always refers to some economic aggregate and thus national accounting theory was indispensable for the precise measurement of production. Historically in 1920-1990, index methodologies developed separately in market and planned economies. From the beginning of the twenties it was required that the price and volume indexes must fulfill the so called factor reversal test. In other words, their product is to be the value index. The value index has a unique absolute value in difference from alternative real indexes. The formal price and volume index systems are logically independent of the national accounting system. The Soviet Union adopted the minimal, technical core of the contemporary price index technology in the late twenties and early thirties.

In market economies, there was a quest to find a basis for index systems in mainstream economic theory. Paradoxically, this approach was initiated in the Soviet Union in the twenties by Konüs and Bushgens. The problem with true price indexes related to the CPI and various types of economic producer price indexes is that they are mostly non-observable theoretical indexes. In the case of the true price index, there is a problem already on the individual level. It is difficult to find realistic assumptions about individual preferences. Aggregating over consumers leads to even stricter limits for individual preferences. As for producer price indexes, it is easier to estimate production functions than utility functions. Their economically meaningful aggregation is, however, a problem. The solution in both cases is to find upper and lower limits for aggregated theoretical individual indexes in terms of ordinary aggregate Laspeyres and Paasche indexes.

In statistical index theory, the Laspeyres-Paasche spread and the related theorems of Bortkiewicz on chaining and drifting play an important role. It is not possible to fit the theoretical indexes in all cases into the LPS. When we fix the time span of the indexes used, we may look for so called superlative indexes like the Fisher, Törnquist and Walsh indexes that approximate the theoretical index in small time environments. For a fixed time span, we have a binary Laspeyres or Paasche index, superlative indexes or chain indexes. These may all be clearly distinct in the time interval. Chaining brings Laspeyres, Paasche and the superlative indexes closer together. Thus with frequent enough chaining the economic approach and the axiomatic approach lead to the same index formulas. Even if different formulas are used, calculations lead to very similar numerical values. The continuous Divisia index is a useful general tool to bring all relevant formulas together. Most standard indexes have a continuous Divisia representation. Quite generally, if the growth gradient is roughly evenly distributed over time in the sample interval, then binary superlative indexes are close substitutes for chain indexes. The ninety year long theoretical discussion since the appearance of Fisher's '*The Making of Index Numbers*' in 1922 has legitimized annual Laspeyres-volume indexes as basic measures of economic growth. Because the Laspeyres, Paasche and the Walsh indexes are consistent in aggregation most problems related to the additivity real accounts are also solved. The Fisher index is an ideal annual index, but it is not additive.

It is difficult to construct a theory for quality adjustment for price indexes. In pure theory, the volume coordinates have fixed metrics. When physical attributes of commodities change, we must decide weather to establish a new coordinate axis or conceptually adjust the metrics of an existing axis. Thus if we have an axis for black and white TV sets we cannot continue direct counting of TV sets when color television sets are introduced. Our arithmetic becomes conventional and we count e.g. one black and white plus one color set is three black and white TV-sets. Adopting the SNA and annually chained indexes solves the formal problems of comparisons between countries and economic systems.

Making quality adjustment comparable calls for standard methodology. This is more difficult to formalize than the national accounting system or the index methodology. Technically quality adjustment may be done on either price or volume indexes. The standard procedure is to do it for price indexes. Changing quality corresponds to a time indexed diagonal matrix that simultaneously adjusts the metrics of the volume vector. This matrix is the invariant for all indexes. However, when it is applied to various index formulas, the aggregate numerical results vary.

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We may dress up our empirical case study on Soviet hidden inflation in the above language. We have annual volume vectors in the chosen TMP categories and the corresponding matrices of nominal volumes. Considering the true annual path the Soviet economy 1960-1990 in terms of recorded prices and volumes, we must define the optimal common measure for the Soviet and alternative indexes in order to minimize the technical distance between indexes. This distance is due to index formulas and timing. Then we must study the diagonal matrix of revealed residuals. This matrix may then be broken down to a product matrix consisting of the true quality matrix and a bias matrix of hidden inflation and sampling bias.

3.3 Empirical Results on Soviet Hidden Inflation

The problem with the alternative indexes was that their sample may be biased due to the incomplete Soviet sample frame. Because the sampling of alternative indexes was theoretical and not stochastic, despite the near non existence of upper level bias, the problem was aggravated. First, it was seen that on the aggregate level, for sectors and as well as the time, the alternative indexes were rather close to each other. Eidelman's Soviet index was taken as a benchmark, because of its large sample. The main difference from other alternative indexes was in the machine building industry where the difference relative to the PMI was about one percent annually. In other respects, the alternative indexes were coherent with each other. Therefore, studying the revealed residual seemed relevant.

If the sample bias problem may be ignored, then the problem is to find the share of hidden inflation relative to a reasonable measure of quality adjustment. Two things were noted for the qualitative behavior of the difference revealed. The residual was heavily concentrated in some sectors e.g. such as machine building and chemicals. Secondly, the revealed residual made a U-turn peaking in the late seventies and declining towards the end of the eighties. A quadratic time trend for the residual SOFTMP-PMITMP seemed to fit better than a linear trend (see Essay 4, pp. 43-46). The Soviet residual behaved differently from reported Western quality adjustment for the corresponding period. Seen from the perspective the Western benchmarks, the Soviet revealed residual was comparable to quality adjustment related to the USA CPI in 1960-1990. This seems an overstatement of the Soviet quality contribution. There were several qualitative cross checks available. Boretsky studied in the 1980s the pure volume growth rates in West Germany and the USA using the same index technology that the CIA had used for the Soviet Union (Boretsky 1987; Essay no 4). The sub-period best comparable to the Soviet Union was the seventies. The Soviet revealed residual was higher than in West Germany or in the USA. West Germany and the USA had revealed residuals that were less than the corresponding total factor productivity rates. The TFP should be smaller than the GDP quality imputation because the TFP excludes the efficiency growth in the capital stock. In the case of West Germany and the USA, the CIA method seemed to exaggerate the pure volume growth rate especially in construction. Theoretically, there is a similar opportunity in the Soviet case. The countervailing key stone here is Eidelman's index. This had a very wide commodity nomenclature relative to the alternative indexes, including the CIA index,

In the light of our study, it may be stated that the Soviet pure volume growth record has relatively well been covered by the alternative growth studies. Ponomarenko in his retrospective study on Russian economic growth in 1960-1990 assumed that on the level of GDP the true quality adjustment could have been about 0.6% annually (Ponomarenko 2002). This is some 40 % of the officially alleged quality contribution to growth on an annual basis for the NMP. Ponomarenko assumes that only industry and construction contributed to the true quality adjustment. He believed that about half of the revealed growth residual in the case of Russian industry was hidden inflation. His calibration is in rough congruence with the late Soviet critical estimates. Faltsman's figure for quality change in the MBI was about 2 % annual quality raise 1970-1984 (Faltsman 1984). Boretsky's residual for the same period for West-Germany and the USA were 0.7 % and 1.5 % respectively (Essay no 4). Ponomarenko's guess for the Soviet MBI was that a quality rise of some 65 % of the alleged annual rate is real. The results of Rutgeizer and others on hidden consumer inflation 1971-83 of some 2,5% are also congruent with the rest if their index was not adjusted for quality (Rutgaizer et al., 1988). This is a compounded 12 year annual growth rate for the hidden inflation. The 2,5% should then include hidden inflation and the correct quality change coefficient. The open consumer inflation in Narkhoz for the same period was 8 % for 1971-1983. Quality adjustment for price and volume indexes is domestic and relative and its rationale depends on the economic system. To calibrate Ponomarekos' ideas with the OECD standard quality approach would need a sampled case study with a standard check on quality change.

The profile of Soviet hidden inflation seems clear cut. Electricity, fuels, agriculture and transports were sectors, where no quality change was officially assumed. Their official growth rates were coherent with the alternative pure volume growth indexes by Eidelman, the CIA and the PMI. Most of the hidden inflation seems to flow from the MBI. Soviet official quality adjustment was about 5 % annually as revealed by the PMI. Ponomarenko believes that of this 3 % was well founded. Faltsman's limited study refers to 2 % annually. Inflation in agriculture was mostly open and related to correcting Stalin's primitive accumulation pricing. Trade as a sector only repeated the hidden inflation in other sectors. Planning in the Soviet Union was stochastic in its results. In the case of mismatch, prices ultimately adapted. Thus, the construction sector appears to have been a combined case of exaggerated quality adjustment and forced adaptation to contingencies. As a long run phenomenon, hidden inflation seems to have been best under control in the early sixties and control was regained towards the end of the eighties.

Exaggeration of quality adjustment in the Soviet data remains a strong hypothesis. The reason for this seems to be a rather complex blend of the specifics of the Soviet economic system and Soviet economics working under political constraints. However, it is likely that the assumption about zero quality adjustment is not well founded.