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Value chain analysis methodologies in the context of environment and trade research

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Value Chain Analysis

Methodologies in the Context of

Environment and Trade Research

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Abstract

This paper gives an overview of different methodologies related to value chain analysis in the context of environment and trade research. Four major fields of methodologies are identified: Accounting of input-output flows, general equilibrium models, econometrics, and global commodity chain analysis. Accounting of flows includes different physical (e.g. life cycle assessment) and monetary (e.g. social accounting matrix) accounting frameworks providing the foundation for computable general equilibrium models. Econometric value chain analysis is widespread in the field of impact assessment of value chains. It can be applied to analyze the effects of standards (e.g. food, social, and environmental) as well as transaction costs on the income of households (micro level) or on trade volumes of countries (macro level). Global commodity chain analysis aims to identify and measure the balance of power between the participating actors.

Keywords: Value Chain Analysis, Environment, International Trade, Mapping, Accounting, Econometrics, General Equilibrium Model.

JEL: Q56, D57, D58, C13, L23

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List of Acronyms

CGE	Computable General Equilibrium Model
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour le Développement
DMI	Direct Material Input
e.g.	for example
(E)IO-LCA	(Environmental) Input-Output Life Cycle Assessment
Eds.	Editors
et al.	et alii
EU	European Union
FAO	Food and Agricultural Organizaion of the United Nations
FIAS	Foreign Investment Advisory Service
GCC	Global Commodity Chain
GCCA	Global Commodity Chain Analysis
GDP	Gross Domestic Product
GTZ	German Society for Technical Cooperation
INRA	Institut National de la Recherche Agronomique
IOA	Input-Output Analysis
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
LCEA	Life Cycle Energy Analysis
MFA	Material Flow Accounting
MIPS	Material Intensity Per Unit Service
NAFTA	North American Free Trade Agreement
OECD	Organisation for Economic Co-operation and Development
R&D	Research and Developement
SAM	Social Accounting Matrix
SETAC	Society of Environmental Toxicology and Chemistry
SNA	Social Network Analysis
TMR	Total Material Requirements
UN	United Nations
VA	Value added
VCA	Value Chain Analysis
WTO	World Trade Organization

1 Introduction

In the last decades, globalization has had a strong influence on economic structures of traditional sectors (agricultural production, processing industry, and service sector) (Kim / Shin 2002). This development has led to an increasing international fragmentation of value chains, meaning that production and processing of one product are often carried out by different enterprises and countries. Many companies have outsourced some of their production components to foreign countries. The motivation for this behavior is mostly resource based (better access to natural resources or reducing production costs), or transaction cost based (better integration in foreign markets or a better vertical integration in the value chain). This global extension of vertical chains and its allocation across different countries has led to an increasing trade with inputs, intermediate goods, and final products. It is accompanied by growing transport and marketing activities, interregionally and intraregionally (WTO 2008; Kim / Shin 2002).

However, not only research questions referring to the international allocation of value chain activities became a field of interest in recent years. Integrating the environment in value chain analysis has also become a focus in research, referred to as “greening the value chain” (Irland 2007). Value chains are embedded in the environment because economic activities and particularly agricultural production of e.g. food or energy crops are based on environmental resources. The environment provides the basis for all essential inputs and energy as well as the capacity to dispose of emissions and waste. Thus, the “environmental value chain” moved into the focus of public interest, the perception of consumers has increased, and the environmental impact of products has become a major aspect of environmental policy programs (Boons 2002). Projects related to “carbon neutral” value chains, the “eco-footprint” of products, and the sustainable use of natural resources are based on results of value chain analysis providing information on the input-output flows of products, but also on the effects of e.g. food, social, and environmental standards implemented in different certification schemes (Grote et al. 2007).

Researchers from various disciplines (e.g. economists, environmentalists, and political scientists) work in the field of value chain analysis. Hence, many methods for value chain analysis have evolved in recent years. They can be classified into two groups: The first group consists of methods with a more descriptive and qualitative emphasis (Kaplinsky / Morris 2002), and the second group refers to specialized tools with an analytical focus. They deal with modeling and simulation of supply chains in the field of business administration e.g. optimizing chain logistics (Ondersteijn et al. 2006; Kotzab et al. 2005). There are no publications, which explicitly looked at methods of value chain analysis from the angle of the environment and trade debate. This paper aims to close this gap in the literature by giving a comprehensive overview of different methodologies related to value chain analysis in the context of environment and trade.

The structure of the present paper is the following: In the second chapter, a short introduction into history and concepts of value chain analysis is given. Then, a number of chapters follow outlining different analytical approaches. Chapter 3 describes the mapping of value chain flows and chapter 4 presents the different accounting methods related to flows. Chapter 5 summarizes the theoretical and empirical literature on value chain modeling, whereas chapter 6 gives an overview of different econometric approaches applied to value chain analysis. The paper ends with some conclusions and recommendations for further value chain analysis.

2 Historical Background and Concepts of Value Chain

The present chapter provides a brief overview of the development of the value chain concept during the last decades. It clarifies to what kinds of research questions value chain analysis have been applied and how the term “value chain” is being used.

2.1 Concepts of Value Chain

During the last decades, the underlying concept of value chain was subject to different influences and objectives (table 2.1). The origin of value chain analysis is discussed from two distinct traditions: the French ‘filière concept’ and Wallerstein’s concept of a commodity chain (Raikes et al. 2000; Bair 2005). From both, a couple of derivatives have emerged. Well known is Porter’s concept of the value chain, Gereffi’s global commodity chain, and Humphrey’s world economic triangle, whereas the last two were joined to the concept of the global value chain.

The **‘filière concept’** was developed in the 1960s at the Institut National de la Recherche Agronomique (INRA) and the Centre Internationale en Recherche Agronomique pour le Développement (CIRAD) as an analytical tool for empirical agricultural research. The concept was used to gain a more structured understanding of economic processes within production and distribution systems for agricultural commodities (Raikes et al. 2000). The general filière concept has been applied to the domestic value chains stopping at national boundaries (Kaplinsky / Morris 2002).

In the 1970s, Wallerstein (1974) developed the concept of **commodity chains**[2], embedded in the world systems theory, which is an elaboration of the dependency theory. The concept of a commodity chain is the base for the further developed global commodity chain by Gereffi and others (Raikes et al. 2000). It seeks to explain the dynamics of the distribution of value chain activities in a capitalist world economy. The main driver is the international division of labor between different regions due to varying labor-intensities of production and manufacturing activities within a chain.

[2] The concept splits all countries into three economic regions: (1) The core regions, (2) the semi-periphery regions, and (3) the periphery regions. Stable governments, high wages, and a high import share of raw materials characterize core regions. The hypothesis is that core regions benefit most from the capitalist world economy compared to other regions. In contrast, countries in periphery regions lack strong stable governments, export merely labor-intensive raw materials, and have wages near subsistence level.

Table 2.1: Characterization of existing chain frameworks

	Filière approach (1960s)	**Commodity Chain (1974)**	**Value Chain (1980s)**	**Global Commodity Chain (GCC) (1990s)**	**World economic Triangle (2000s)**	**Global Value Chain**
Theoretical foundation	– No unified theoretical approach	– World systems theory derived from dependency theory	– No unified theoretical foundation	– World systems theory – Organizational sociology	– World systems theory – Organizational sociology	– Global commodity chains
Objectives	– Physical inputs & outputs, prices and value added in marketing chains – Focus on agricultural commodities	– Explanation of the World – capitalist economy	– Focus on industrial firms – Competitive advantage by breaking down its activities into the value added	– Power relations of globally linked production systems (meso and micro level) – Focus on industrial goods	– Upgrade of regions or clusters – Linking cluster development & value chains	– Governance and regulation systems – Linking horizontal and vertical approaches
Underlying Concepts	– No underlying concept (neutral)	– International division of labor – Core-periphery-semi periphery	– Concept of in-house value added	– Governance (consumer-driven / buyer-driven) – Organizational Learning / Upgrading	– Governance – Upgrading of clusters	– Governance – Transaction costs – Upgrading
Character-istics	– Static model – National boundaries	– Holistic point of view – Macro-orientated – Qualitative analysis	– Restricted to production processes at firm level – No attention to international territorial arrangements	– Focus on governance	– Qualitative Analysis	Composition of commodity chain, GCC, World economic Triangle
Key Authors	– Raikes et al. (2000)	– Wallerstein (1974)	– Michael Porter (1985)	– Gereffi (1994a), (1994b), (1999) – Gereffi et al. (2005)	– Messner (2002)	– Gereffi & Kaplinsky (2001) – Humphrey & Schmitz (2000a), – Gereffi et al. (2005)

Source: Adjusted following Bair (2005)

In the mid 1980s, Porter developed the concept of the **value chain** in the context of his work on competitive advantage (Porter 1985). He developed his concept to analyze specific activities through which companies may create value by breaking down their activities into value-added. Porter distinguished two important value-adding activities of an organization: primary activities (inbound logistics, operations, outbound logistics, marketing, and sales) and support activities (strategic planning, human resource management, technology development, and procurement) (Porter 1985). However, Porter's value chain approach is restricted to the firm level neglecting the analysis of up- or downstream activities beyond the company.

In the 1990s, Gereffi and others (1994b) developed the **global commodity chain** (GCC), originally derived from Wallerstein's commodity chain (Bair 2005). Gereffi established four core elements (Kaplinsky / Morris 2002): (a) input-output structure, (b) territorial (international) structure, (c) institutional framework, and (d) governance structure. The focus was set on governance referring to institutional mechanisms and inter-firm relationships. The main attention was paid to balance the power embedded in the coordination of globally fragmented but interlinked production systems. Gereffi concluded that many chains are characterized by some dominant actors, who determine the overall character of the chain. These actors become responsible for upgrading possibilities, knowledge transfer, and interaction coordination within the value chain.

Based on Gereffi's GCC, Messner (2002) developed the **world economic triangle**. Messner's concept is based on the assumption that actors, governance and regulation systems determine the scope of action in the global commodity chains. This approach focuses on upgrading entire regions or clusters through their integration into chains. Hence, the horizontal (cluster development) and vertical approaches (value chain) are linked (Kaplinsky / Morris 2002).

Independent environmental concepts of value chains are not yet developed. However, the integration of natural resource consumption and chain-related emissions in the context of value chain analysis has received growing attention in the last decade. Thus, terms like 'green value chain' or 'environmental value chain' have been used to integrate environment issues in the value chain framework (see table 2.2).

2.2 Chain Notations

Not only the concept of value chain analysis has changed, but also the applied terms and its definition (see table 2.2). "Each of the contending concepts […] has a particular emphasis, which is important to recognize for a chain analysis of the global economy" (Bair 2005 p.162). For instance, the term 'supply chain' is mainly used in the field of business administration, whereas 'input output structure' is mainly used in the field of macroeconomic accounting. Sturgeon (2001) classified the terms according to organizational and spatial scale. The terms 'supply chain', 'value chain' or 'production network' are related to the organizational scale, whereas 'global commodity chain' or 'international production networks' and 'global value chain' fit into the spatial scale.

Table 2.2: Chain notations and definitions

Term	Definition	Scale
Input-Output Structures[1)]	"The set of products and services linked together in a sequence of value adding economic activities".	Organizational
Supply Chain[2)]	"A generic label for an input-output structure of value-adding activities beginning with raw materials and ending with the finished product." It is concerned with logistics rather than market development.	Organizational
Value Chain[3)]	Full range of activities which are required to bring a product or a service from conception, through the different phases of production (involving a combination of physical transformation and the input of various producer services), delivery to final consumers.	Organizational
Production Network[2)]	"A set of inter-firm relationships that bind a group of firms into a larger economic unit".	Organizational
Global Value Chain[3)]	The sequence of activities required to produce a final product. It refers to all activities from conception of a product to its consumption. A value chain is 'global' when activities are carried out in different countries.	Spatial
International Production Network[2)]	"A focus on the international production networks in which multinational corporations act as 'global network flagships'".	Spatial
Environmental or Green Supply Chain[4)]	Physical and monetary flows are integrated with information on natural resources throughout the product life cycle.	Spatial

Source: 1) McCormick/Schmitz (2001), 2) Roduner (2004), 3) Kaplinsky / Morris (2002), 4) Levner (2007)

There is a common understanding that all definitions of chains comprise all stages from production to consumption as well as waste utilization of a certain product (Bair 2005; Sturgeon 2001). Kaplinsky and Morris (2002) developed a generally accepted definition: "The value chain describes the full range of activities, which are required to bring a product or service from conception, through the different phases of production (involving a combination of physical transformation and the input of various producer services), to delivery to final consumers, and final disposal after use" (Kaplinsky / Morris 2002 p.4). Based on the definition of Kaplinsky and Morris, the most commonly used value chain consists of six stages (see figure 2.1).

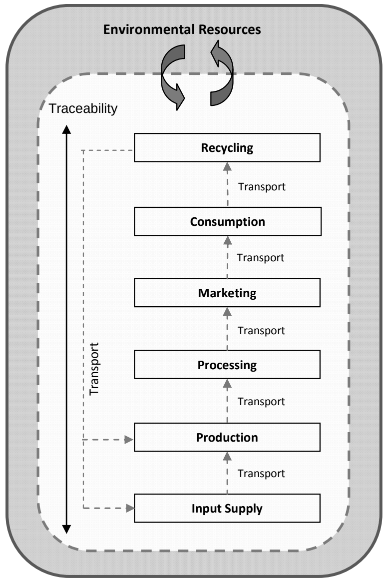

Figure 2.1: Six stages of a value chain

Source: Own illustration

The value chain, as shown in figure 2.1, is often termed as ‘vertical’ value chain. However, the point of view can also be ‘horizontal’ by establishing so-called clusters, e.g. similar enterprises in a certain region. In practice, value chains are certainly more complex compared to this linear conceptual illustration. There can be multiple links within a chain and various connections to other chains, e.g. using the same input suppliers. Typically, intermediary producers or traders are involved in more than only one chain denoted as a value chain network (Roduner 2004).

2.3 Evolvement of Literature on Value Chains

In the last years, many descriptive handbooks for different aspects on value chain analysis have been published. A brief overview is given in table A1. The handbook written by Kaplinsky and Morris (2002) summarized mainly theoretical and conceptual aspects based on Gereffi’s global commodity chain suggesting some descriptive indicators. Roduner (2004) summarized value chain concepts of relevance to development cooperation. A manual published by McCormick and Schmitz (2001) gives a practical orientation of data collection for value chain analysis by suggesting how to prepare questionnaires and how to conduct interviews using the example of homeworkers in the garment industry. Schmitz (2005) published a handbook with major attention to value chain analysis for policy-makers and practitioners. Stamm (2004) emphasized the relevance of value chain analysis for development policy according to challenges for trade policy to assess the economic relationships. The German Technical Agency (GTZ) (2007) and the Foreign Investment Advisory Service (FIAS 2007) together with the World Bank provide methodologies for value chain promotion in developing projects. The target groups are public agencies and practitioners whose the participatory value chain approach gains more and more importance. Mayoux (2003) and Bernet et al. (2006) elaborated the importance of participatory value chain analysis similar to the GTZ value chain approach (GTZ 2004, GTZ 2007).

Besides these descriptive manuals, McCormick and Schmitz (2001) as well as Kaplinsky and Morris (2002) emphasize the analytical focus of value chain analysis. The Food and Agricultural Organization of the United Nations (FAO) (2005a-e) developed several stepwise modules to conduct financial and economic value chain analysis (table A 2). These modules are some of the few available handbooks, which offer a quantitative analytical approach. The methodical framework of the FAO is described in chapter 3.1 and 4.1.

Looking into peer-reviewed scientific databases[3], the number of publications using any term related to "value chain" in the title, abstract or key words, increased from 140 publications in 1995 to 3.550 in 2007 (figure 2.2).

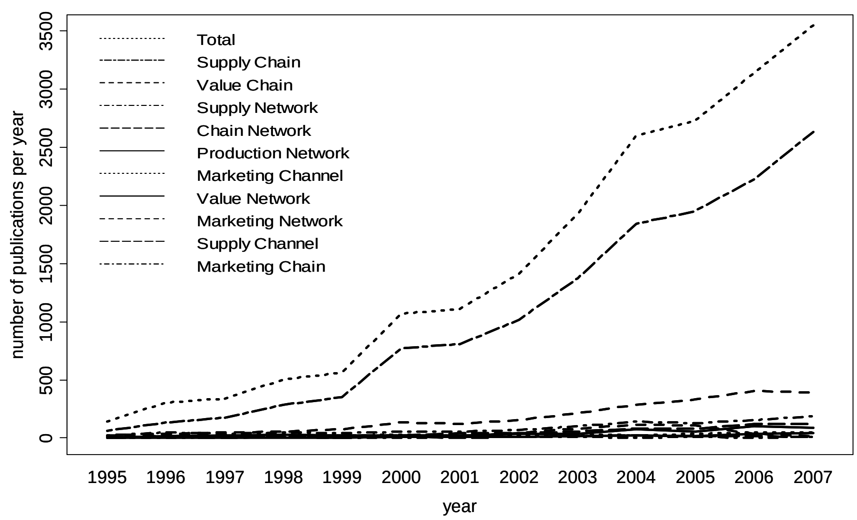

Figure 2.2: Number of publications per year

Source: Own illustration, data: scopus.com, 01.12.2008

This notable development of publications signifies an increasing interest in research related to value chains over the last decade. In 2007, the greatest portion of publications

[3] Scopus database of peer-reviewed literature, including articles, conference paper, editorials and reports (www.scopus.com).

can be attributed to studies referring to supply chains (focusing on the field of business administration) covering more than 75 % of the 3.550 papers. The term ‘value chain’ was mentioned in about 11 % of the publications. The remaining terms are summed up to 14%. Almost 23 % (n=822) of the papers published in the field of value and supply chains in 2007 are directly related to environment and trade.

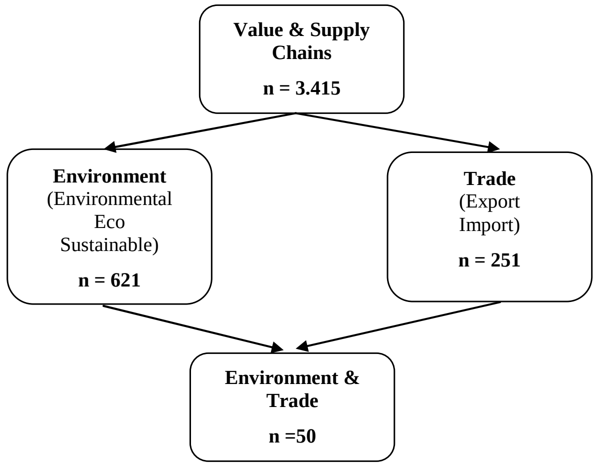

Figure 2.3: Number of papers in the context of environment and trade in 2007

Source: Own illustration, data: scopus.com, 01.12.2008

The methodologies, which have been applied to analyze value chains in the context of environment and trade, can be classified in three major blocks of modeling, accounting, and econometrics (see figure 2.4). The largest number of publications is related to modeling, which often focuses on logistics optimizing the enterprises’ environment.

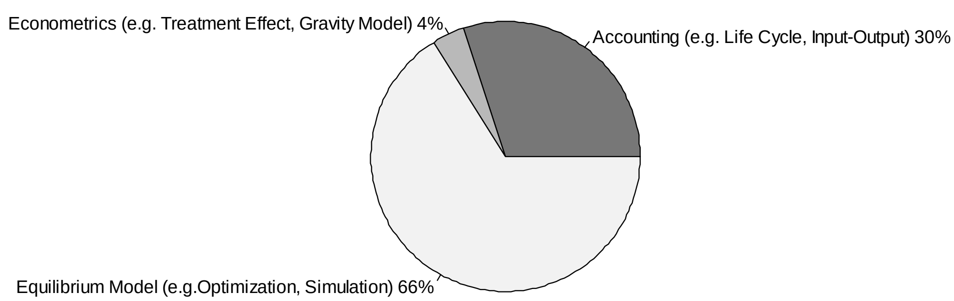

Figure 2.4: Methodologies applied to value chain analysis in the context of environment and trade

Note: Covered paper: n=342 out of 822 value chain & supply chain publications in 2007.
Source: Own illustration, data: scopus.com, 01.12.2008

One third of the publications cover accounting methods including life cycle assessment, which are of major importance in environmental value chain analysis. Only about 4% relate to econometrics.

3 Mapping the Value Chain

The first step of a value chain analysis is the so-called mapping. In order to do so, the boundaries to other chains need to be defined. The main idea is initially to identify the actors and then to ‘map’ the traced product flows within the chain including input supply, production, processing, and marketing activities. The objective is to give an illustrative representation of the identified chain actors and the related product flows. A mapped value chain includes the actors, their relationships, and economic activities at each stage with the related physical and monetary flows. There are two different kinds of approaches used for mapping.

3.1 Functional and Institutional Analysis

The FAO provides a set of modules, which presents a systematic approach to value chain analysis for agricultural commodities (see figure A 3). The mapping is denoted as a functional and institutional analysis (FAO 2005a) which starts with constructing a ‘preliminary map’ of a particular chain to provide an overview of all chain actors (institutional analysis) and the type of interaction between them (functional analysis). The results can be presented either in a table or in a flow chart, which is called the ‘preliminary map’ of the chain. The FAO methodology includes three essential aspects for developing a preliminary map (FAO 2005a):

- The *principal functions* of each stage
- The *agents* carrying out these functions
- The principal *products* in the chain and their various forms into which they are transformed along the entire chain

Once the flow chart has been drawn, these flows are quantified, both in physical and monetary terms,. The procedure allows assessing the relative importance of the different stages or segments of the chain. Applied was this methodology for example by Rudenko (2008) identifying and mapping the relevant value chain stages for the cotton and wheat value chain in Uzbekistan.

Kaplinsky and Morris (2002) suggest similar procedures for implementing value chain analysis. Their concept consists of two steps in order to map the value chain of interest. The first step includes drawing an ‘initial map’, which shows the chain boundaries including the main actors, activities, connections and some initial indicators of size and importance. The second step consists of elaborating the refined map by quantifying key variables such as value-added, and by identifying strategic and non-strategic activities. This refined map can be understood as a framework for showing chain statistics (McCormick / Schmitz 2001).

3.2 Social Network Analysis

Another approach for mapping value chains is the social network analysis (SNA) originated in social sciences. Similar to the FAO concept, it serves as a tool for mapping and analyzing relationships and flows between people, groups, and organizations. The initial flow chart of the chain consists of various nodes and links arranged in form of a matrix. The nodes represent the actors while the links describe the relationships and flows between the nodes. SNA is used when the value chain is more characterized by a network than a single vertical chain. Special software is available to study the structure of chain networks e.g. UCINET (http://www.analytictech.com/downloaduc6.htm) or AGNA (http://www.geocities.com/imbenta/agna/). SNA provides both visual and mathematical analysis of chain relationships, but it is still in the early stages to be used in value chain analysis. So far, only a few studies have applied this approach.

Clottey et al. (2007) used SNA to map the small livestock production system in Northern Ghana for a value network analysis. The objective was to analyze the introduction of animal health care services in the region. Thus, the value-creating linkages were mapped. Afterwards, SNA was employed to determine the pathways of value exchanges and individual relationships among the small farmers and enterprises. As a result, the authors found out that the input supply is weakly linked with the upstream livestock chain activities. In addition, the knowledge flow among farmers and actors from research and development (R&D) needed to be improved to strengthen the entire livestock production chain.

Another example is the study of Kim and Shin (2002). The authors applied SNA to analyze the development of international and interregional trade flows between 1959 and 1996. Kim and Shin concluded that the world became increasingly globalized in the sense that the analyzed countries traded significantly more in 1996 than in 1959, both interregional and intraregional.

4 Accounting of Flows

Generally, accounting of flows (physically or monetarily) is defined as a service activity, which provides "quantitative information […] about economic entities that is useful in making decisions […] among alternative courses of action" (Riahi-Belkaoui, 2000, p.32). Since value chains are characterized by input-output structures (McCormick / Schmitz 2001; Wood 2001), many studies aim to account for important stages of the value chain according to the study purpose. There are different 'accounting' methods for value chain analysis, which measure input-output flows for a certain product. Inputs and outputs can include material or energy flows with their - if possible and requested - related monetary evaluation. In the literature, two different levels of accounting are found (see table 4.1):

(a) Product level: Measuring input-output flows based on a defined functional unit of a commodity without being site-specific

(b) Regional level: Describing input-output flows within a defined economy, e.g. country-specific

These two levels of analysis can either take an economic focus, an environmental focus, or a combination of both. In the case of combined methods, the origin can be found most often in either the economic or the environmental field of research: green accounting is derived from the economic input-output analysis extended by environmental accounts whereas life cycle costing is derived from life cycle assessment.

Table 4.1: Common accounting methods for value chain analysis

Level	1) Economic Focus	2) Environmental & Economic Focus	3) Environmental Focus
a) Product Level	– Financial and Economic Analysis	– Life Cycle Assessment (LCA) incl. Life Cycle costing (LCC)	– Material Flow Accounting – Ecological Backpack – Material Intensity per Service Unit – Ecological Footprint
b) Regional Level	– Input-Output-Analysis – Social Accounting Matrix	– Green Social Accounting Matrix – Satellite Accounts – Input-Output-Life-Cycle Assessment	– Material Flow Accounting – Material Requirements – Substance Accounting – Energy Accountings

Source: Adapted from Finnveden / Moberg (2005)

In the following subsections, the accounting methods for value chain analysis are described in detail.

4.1 Financial and Economic Value Chain Analysis

As mentioned in chapter 3.1, the FAO provides a methodology for commodity chain analysis focusing on the product level (figure A2). Generally, the FAO methodology comprises two separate parts: (a) financial analysis, and (b) economic analysis.

Financial analysis is undertaken from the perspective of individual agents. The aim is to determine their financial costs and benefits. In contrast, economic analysis is undertaken from the perspective of the society or the overall economic system (national economy, sector, or chain), considering shadow prices and opportunity costs in its calculation. Both analyses are conducted for a defined period, usually one year. For financial and economic commodity chain analysis, different indicators are calculated based on the concept of value added to derive findings according to the chain performance and impact on agents and the government.

Hence, the value added for each step of the chain as well as the overall value added of the entire chain are calculated and interpreted as the creation of economic wealth by one or more productive activities (FAO 2005b). By definition, the amount of total value added "measures the contribution of the commodity chain to Gross Domestic (or National) Product" (FAO 2005b p.13). The calculation of the value-added (VA) is defined as:

$$VA_{ij} = Y_{ij} - II_{ij}$$

The value of the intermediate inputs (denoted as *II*) used in the productive activities has to be subtracted from the value of the output of a product *i* (denoted as *Y*). The difference represents the value-added from an individual agent *j*. Thus, to calculate the value added, all costs and sales for the relevant stages have to be measured. In addition, the underlying product and input prices are essential. Hence, financial and economic analyses differ in the underlying price. While financial analysis is based on actual market prices, economic analysis is based on shadow prices. Consequently, if there are any price distortions, the financial analysis will reflect those.

The overall value added is the following:

$$VA_{chain} = Y_{chain} - II_{chain} = \sum VA_{agents}$$

Now it is possible to identify which stage contributes to the highest share of the value added, which stage to the lowest, and if there is an overall positive value added. Afterwards, the question that arises is: how is the created wealth distributed among the four fundamental agents (e.g. the household, financial institutions, government administration, and non-financial enterprises) in the chain? This is especially interesting for policy makers, who want the households to get a fair share in the profit. Thus, another possibility of calculating the value-added is the following:

$$VA_{ij} = (GP_{ij} - d_{ij}) + w_{ij} + s_{ij} + i_{ij} + t_{ij}$$

Households receive the return of labor and social payments (*w*), financial institutions the interest charges (*i*), the government administration the taxes (*t*), and the enterprises get the gross profit less the depreciation (*d*). Based on the results of value added, other indicators of the financial probability, the overall efficiency of the chain, the processes of price determination, and transfers between agents can be identified (FAO 2005b). Details on indicators for financial economic value chain analysis are provided in the modules of the FAO (2005 a-d).

After calculating the creation and distribution of the value added among the agents, the next step is the economic impact analysis. It includes the investigation of upstream-induced effects of productive activities because of the demand for intermediate inputs from the rest of the national economy. In this part of the analysis, the chain is viewed as an integral part of the national economy similar to input-output analysis (see next chapter 4.2). Indicators are built to evaluate the chain's impact on growth and income in terms of chain distribution to developmental policy objectives (FAO 2005c). An overview on the various indicators for economic analysis is compiled in table A4. Here the impact on the four targets can be calculated: (a) agents, (b) government, (c) foreign exchange rate, and (d) economic growth (FAO 2005b). The value added - now calculated by shadow prices - is again the basis to compute the indicators for economic growth.

Indicators for environmental integration and international trade are not taken into consideration by the FAO methodology. As already mentioned in chapter 3.1, the FAO methodology is not very often applied in empirical studies. Rudenko (2008) applied the FAO methodology on value chain analysis in the case of cotton, wheat, fruit, and vegetable value chains in Uzbekistan. In this context, the author analyzed and compared the performance of the individual chains and their impact on the national economy.

4.2 Input-Output Analysis and Social Accounting Matrix

The impact assessment provided by the FAO focuses only on single indicators representing the economic importance. However, the approach is not able to assess consistently the interdependencies between existing sectors in the economy. This can be achieved by traditional input-output analyses (IOA), developed first by Leontief in the 1930s (Hecht 2007). As an ex-post consideration, it allows tracing monetary flows of all goods and services between sectors and industries within an economy directly and especially indirectly. Thus, IOA has become an important tool in value chain analysis. The underlying concept is that each sector's product is viewed both as a product for final consumption and as an intermediary input for further production activity in other sectors. Therefore, the demand in IOA is differentiated in intermediate, final and total demand. The first refers to inter-industry trading of intermediates to process final goods. These final processed products are sold to households, governments, exporters, or used for investments (final demand). The total demand results from the final demand and the intermediate demand (Hecht 2007).

Input-output tables present the database for an IOA. In principle, input-output tables only allow descriptive evaluation. The classical structure of an input-output table is illustrated in figure 4.1.

		PRODUCERS								FINAL DEMAND			
		Agriculture	Mining	Construction	Manufacturing	Trade	Transportation	Services	Other	Personal Consumption Expenditures	Gross Private Domestic Investment	Net Exports of Goods and Services	Government Purchases of Goods and Services
PRODUCERS	Agriculture												
	Mining												
	Construction												
	Manufacturing												
	Trade												
	Transportation												
	Services												
	Other												
VALUE ADDED	Employees	Employee compensation											
	Owners of Business and Capital	Profit: type income and capital consumption allowances											
	Government	Indirect business taxes											

Figure 4.1: Structure of an input-output table

Source: Sousa e Silva (2001)

There are several underlying assumptions of an IOA. First, local resources are efficiently employed; there is no underemployment of resources. Second, the model assumes constant returns to scale and a linear production function. Hence, the amount of each input necessary to produce one unit of a certain output is constant. If the output level of a sector changes, the input requirements change proportionally. This can be considered as major limitation for value chain analysis, because scenarios in terms of increasing economics of scale or higher efficiency cannot be included. In cases where innovative technology allows either input-substitution or greater efficiencies in the use of inputs, impacts to supplying sectors may be critically over- or underestimated by the assumption of linearity.

In addition to the input-output table, the social accounting matrix (SAM) takes the interrelationships of income and transfer flows between the different institutional units (households, companies, government) into consideration. A SAM is defined as a “presentation of the system of national accounts in a matrix format, which elaborates on the linkages between supply and use tables and institutional sector accounts”. The matrix describes the interaction between production, income, consumption, and capital accumulation (UN 1993 p. 461). It is more applicable for value chain analysis because it includes households and the government administration as a part of the chain. Thus, it provides a conceptual basis for examining both growth and distributional issues within a single analytical framework in an economy. The structure of a national SAM is shown in figure 4.2[4].

	Expenditure				
Receipts	Activity	Commodity	Factors	Institutions	World
Activity		Domestic sales			exports
Commodity	Intermediate Inputs			Final demand	
Factors	Value added (wages/rentals)				
Institutions			Factor Income		Capital inflow
World		Imports			
Totals	Total costs	Total absorption	Total factor income	Gross domestic income	Foreign exchange inflow

Figure 4.2: Structure of a social accounting matrix

Source: Robinson / El-Said (1997)

To assess the impacts of this additional demand on other sectors and institutions, multipliers are commonly calculated. They summarize the total impact that can be expected from an exogenous intermediate or final demand in a given economic activity, e.g. an increasing export demand. Multipliers can be interpreted as simple ratios: the higher the multiplier, the greater the effect on the economy.

Multipliers are composed of direct, indirect, and induced effects:

- *Direct effects* occur to companies / farmers that produce the additionally demanded goods. They represent the direct or initial spending.
- *Indirect effects* occur to up- and downstream industries that supply the producing firm or buy intermediates from them.

[4] A SAM is characterized by a square matrix in which the corresponding columns present the expenditures and rows the receipt accounts of economic actors. Each cell represents a payment from a column account to a row account. With respect to accounting identity, the income should correspond with the expenditures.

- *Induced effects* result from households spending more of the additional income they received due to higher production activities.

Hence, a multiplier analysis has the ability to capture all direct and indirect effects of exogenous demand consistently. Additionally, the direction (positive or negative) and magnitude of the effects can be identified. The direct, indirect, and induced effects are used to build three different types of multipliers:

- *Type I:* (Direct effects + Indirect effects) / Direct effects
- *Type II:* (Direct effects + Indirect effects + Induced effects) / Direct effects
- *Type III*: Modified type II multipliers

Type III multipliers are generally known as social accounting matrix multipliers. SAM multipliers enable the researcher to take the distribution of the value added among institutions[5] into consideration.

It is important to emphasize that both input-output tables and SAM only provide a static snapshot of the regional economy. Both types of methods are traditionally a top-down approach. Disaggregation on a certain level is possible, if data is given. The essential goal of both methods is to measure impacts of aggregated product value chains (product categories) within an economy. In such a case, both approaches have a big advantage because all linkages and connections among industries within the economy can be traced along the aggregated value chain. However, the SAM approach has a major advantage over the IOA due to the integration of households and the government as part of the value chain. Hence, income distribution effects can be analyzed in a consistent way, which is not feasible in an IOA.

A SAM can be developed either for a value chain analysis at national level (macro SAM) or at local level (micro SAM). Indeed, the SAM at local level is rarely applied yet, but it receives more and more attention due to its potential. One of the first SAM developed on village level was conducted by Adelman, Taylor and Vogel (1988) analyszing the economic structure of a migrant-sending rural economy in Central Mexico. The authors calculated matrix multiplier and its decompositions derived from the SAM utilised in policy scenarios on the production, its value added, income, and investment flows of the village.

[5] Institutions comprise households, enterprises and government and correspond therefore with the fundamental agents of the FAO methodology.

Subramanian and Qaim (2009) developed a micro SAM to simulate direct and indirect effects of introduced Bacillus thuringiensis (BT) cotton production on benefits for small- and large-scale production (Subramanian / Qaim 2009). The authors conducted a census survey of a representative village in India to get the entire information for all occurring transactions between the households within the village. On this basis, they simulated the effects of introducing the BT cotton production on small- and large-scale farmers.

An environmental extended village SAM has been developed by Shiferaw and Holden (2008) including the change in the value of the soil stock into the SAM under the capital account. These changes reflect the soil degradation resulting from annual production activities valued in terms of lost crop production.

4.3 Life Cycle Assessment

In order to assess the environmental impact of a value chain, especially for hazardous products or unsustainable production methods, the framework of life cycle assessment (LCA) has been developed. LCA, often denoted as "cradle to grave" analysis, represents an accounting framework assessing environmental impacts attributable to the value chain of a defined product. It analyses the links between the use of natural inputs (resources) and the related environmental outputs (emissions and waste) of all value chain activities (cultivation, production, processing, transportation, consumption, and final disposal). Due to its application to the product level, LCA is not necessarily related to a certain region. The purpose is to build impact indicators[6], which identify and quantify possible environmental impacts[7], e.g. the global warming potential of one unit of production. On this basis, recommendations can be made which products should be promoted or improved concerning e.g. production efficiency. Due to the way the LCA model is formulated, recommendations tend to favor recycling and the re-use of products and by-products and increasing the efficiency during the production as a way to reduce environmental waste (Rebitzer et al. 2004).

One major obstacle is the standardization of the conceptual framework of a LCA (Rebitzer et al. 2004). In the past, there have been developments on standardization of LCA, mainly under the Society of Environmental Toxicology and Chemistry (SETAC) and the advanced ISO 14000 (International Organization for Standardization) series. The

[6] In contrast to volume based indicators, which may not be used to indicate specific effects rather than an environmental pressure associated with resource consumption. Usually these volume-based indicators relate to resource extraction (OECD, 2003).

[7] For instance environmental impacts are climatic change, stratospheric ozone depletion, eutrophication, depletion of resources, water and land use.

objective of harmonization was to enable the comparison of results between different LCA studies, which is still a problem of different underlying assumptions. The procedure recommended by ISO 14000 is illustrated in figure 3.3. The way of proceeding of the single steps according to the ISO series is well explained in Azapagic (1999), Rebitzer et al. (2004), Pennington et al. (2004), and Tukker (2006). A comprehensive manual is provided by Jensen et al. (1997) from the European Environment Agency.

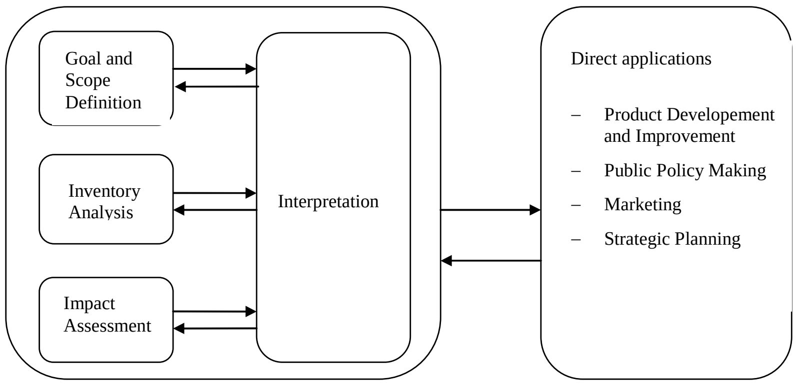

Figure 4.3: Life cycle assessment framework

Source: Rebitzer et al. (2004)

Applications of LCA are manifold and enjoy an increasing popularity in the last years. Keen interest arose with respect to the environmental impact of bioenergy production and the carbon footprint of food and energy products in general.

Concerning energy products, Lee et al. (2004) used the LCA approach for the analysis of the electricity sector in Korea. Their functional unit corresponds to one kg CO_2 per kilowatt-hour (kWh) of usable electricity. The authors found that the emissions of air pollutants from power generations and direct emissions were much greater in quantity compared to those from upstream processes. With respect to bioenergy, LCA is a very important tool to analyze the sustainability of bioenergy compared to other substitutes and calculate the often-discussed greenhouse gas balance. One study conducted by Achten et al. (2007) presents an overall framework to quantify the environmental impact of biodiesel production from Jatropha curcas (L.) in developing countries. Uihlein et al. (2008) compared the utilization options of miscanthus versus mineral wool. Zhiyuan et al. (2004) analyzed the CO_2 emissions of cassava-based ethanol as an alternative automotive fuel. Other studies in this field are published by Mattsson et al. (2000) on soybean from Brazil, rapeseed from Sweden, oil palm from Malaysia; Eriksson (2007) did a comparison of waste incineration, biomass and natural gas combustion.

As for the food sector, LCA can also be applied to assess the environmental impact of food chains. Similar to the LCA of energy products, the focus is predominantly on carbon footprint to assess the impact on global warming and climate change. Jones (2002) applied the LCA methodology on a case study on dessert apples. The results showed that transportation is responsible for a considerable fraction of the total energy consumption in the life cycle of fresh apples. In the case of imported fresh apples, the analysis has shown that the transport energy consumption is even greater than the energy consumed in intensive commercial production. Similar studies of apples in the LCA framework are done by Blanke and Burdick (2005) who compared the food miles of apples production, trade and consumption patterns or Mila` i Canals et al. (2006) with a case study focusing on environmental and health impacts of integrated fruit production in New Zealand. Another LCA study on environmental and health impacts due to pesticides was conducted by Margnis et al. (2002).

With respect to trade, Ghertner and Fripp (2007) analyzed to what extent the US has shifted the environmental impact associated with the goods the country consumes to other countries through trade. To quantify this, the authors applied a LCA to analyze the national environmental trend for the years 1998-2004. They found proof that the environmental impact, which was traded away, exceeds 20% for global warming and energy and 80% for lead emissions and toxics.

Since LCA typically does not address economic or social impacts of a product chain, "*life cycle costing*" (Warren / Weitz 1994) and "*social life cycle impact assessment*" was developed, whereas the latter is very rarely applied. Only one study was found which applied the social LCA: Dreyer (2006). In addition, "*life cycle energy assessment*", should be mentioned due to the rising concerns of energy consumption in a value chain (Ding 2007; EMSD 2007).

Life cycle costing (LCC), a concept of cost accounting, is defined as the calculation of "all internal and external costs associated with a product, process, project, or activity throughout its entire life cycle" (Warren / Weitz 1994). Internal costs are attributed directly to an enterprise or farm e.g. capital, labor, and energy. External costs indirectly result from resource depletion, water contamination, or human health effects. Such external costs typically extend beyond conventional LCA boundaries, but include consequences on society and environment as a whole (Mearig et al. 1999). LCC is used in the same system boundaries of an LCA. Studies, which implemented LCC, are Reich (2005), or Hu et al. (2004).

In addition, companies like Sony-Ericsson (Cerin / Ramirez 1999) and Continental[8] among others introduced LCA to measure their own production efficiency in order to identify under-optimized production processes. The major advantage is that companies only need to analyze the life cycle of their own production system without considering any upstream or downstream value chain activities.

Similar to LCC, life cycle energy assessment (LCEA) is an additional approach within the LCA framework. An early expression used for the LCEA approach is energy accounting (see chapter 4.5). LCEA can be interpreted as a variant of energy analysis within the boundaries of a traditional LCA. Therein, all energy inputs related to a certain product are accounted for. Not only direct energy inputs are utilized during production and manufacture; also, indirect energy, which is needed to produce intermediate inputs, is recommended to be taken into account. Examples of application are the assessment energy efficiency of public buildings (Ding 2007) or the evaluation of the energy efficiency of alternative water supply systems (Stokes / Horvath 2006).

Life cycle analysis is subject to some underlying assumptions. Similar to IOA in chapter 4.2, LCA is characterized being a linear and static accounting model. Therefore, environmental outputs e.g. waste and emissions are typically assumed to scale linearly related to the product flows (Rebitzer at al. 2004). However, in contrast to IOA, LCA is not used as top down but as a bottom up approach (table 4.2). This leads to a much more detailed analysis compared to IOA, which only considers pre-use and final consumption and does not distinguish single stages especially if they appear in the same aggregated sector.

Table 4.2: Differences between life cycle assessment and input-output analysis

Differences	Life Cycle Assessment	Input-Output Analysis
Data sources	Unit process data	Economic national accounts
Way of Proceeding	Bottom-Up Approach	Top Down Approach
Commodity unit flows	Physical flows	Monetary valued flows
Level	Micro level	Macro level
Covered life cycle stages	Complete life cycle	Pre-use and consumption stages

Source: Rebitzer et al. (2004)

[8] http://www.conti-online.com/generator/www/com/en/continental/portal/themes//esh/life_cycle_assessments_en/life_cycle_assessment_en.html

Generally, LCA is evaluated as a “powerful and fairly robust methodological framework” (Rebitzer et al. 2004), but nevertheless there are some critical aspects related to the overall model (Lenzen 2001; Tukker / Jansen 2006; Rebitzer et al. 2004; Cerin / Laestadius 2005, Schaltenegger 1997).

- Definition of boundaries of the life cycle system
- Availability of comprehensive and detailed data and data quality[9] (table A5)

The definition of boundaries has a huge impact on the LCA results. Broader boundaries also consider indirect input suppliers and hence, can lead to increasing environmental impacts compared to a more narrow definition. Ignoring these indirect effects by defining rather narrow boundaries can lead to an underestimation of environmental impacts of the considered product. This miscalculation is also denoted as truncation error. Lenzen (2001), Rebitzer et al. (2004), Tukker and Jansen (2006) showed that the amount of the truncation error depends also on the commodity under analysis. Energy-intensive commodities such as production of basic metals have lower truncation errors compared to non-energy intensive services like the finance sector. The rationale is the following: in value chains with energy intensive commodities, the direct energy consumption is higher than the indirect consumption, whereas in the finance sector energy consumption is more equally distributed. Hence, the truncation error depends not directly on the boundaries but on the specific input characteristics of a product. To reduce the truncation error, the authors suggested the combination of LCA with an IOA as presented in the next chapter.

4.4 Input-Output-Life-Cycle Assessment

Many of the shortcomings of an LCA based value chain analysis can be overcome when combining IOA or SAM with an LCA, denoted as hybrid LCA approach or (Environmental) Input-output-life-cycle assessment ((E)I/O-LCA) (Lenzen 2001). I/O-LCA is a specialized subset of the growing field of “Integrated Environmental and Economic Accounting”, a field of methods combining economic input-output data and with environmental and resource data from LCA (Rebitzer et al. 2004). Two principal approaches of I/O-LCA simplifications are: (a) tiered hybrid analysis and (b) mixed units hybrid analysis

In a *tiered hybrid analysis*, two different steps are performed. First, direct requirements and some important lower-order upstream requirements of the functional unit are

[9] The challenges due to problems of data availability and quality are discussed in chapter 4.1.

examined in a detailed LCA analysis. Second, remaining higher-order requirements (e.g. for materials extraction or manufacturing) are covered by IOA (Lenzen 2001).

Another possibility is augmenting input-output tables and social accounting matrices with sectoral physical data. This data can simply be added in a separate matrix row and columns, respectively. Since the traditional tables and matrices are in monetary terms, this procedure is called a *mixed-units hybrid analysis* (Lenzen 2001).

Altogether, I/O-LCA is more complete in terms of economy-wide system boundaries also capturing indirect effects of value chains, but it lacks process specificity and the differentiation between similar products is very limited (Rebitzer et al. 2004). Therefore, suitable applications for I/O-LCA are research questions, where the overall effect of new technologies on a regional or national level has to be analyzed including a rough estimation of the overall environmental impacts.

Overview articles worth mentioning are from Mathews and Hendrickson (2002) and Hendrickson et al. (1998). Together with others from the Green Design Institute, they developed software to conduct an EIO-LCA together with a profound database (www.eiolca.net).

4.5 Material Flow and Energy Accounting

Material flow accounting (MFA) is another family of methods for physical accounting (Finnveden / Moberg 2005). MFA accounts for physical units of inputs and outputs e.g. substances, raw materials, waste, emissions to air, water, or soil, which are involved in the production, processing, consumption, and recycling of materials. The purpose is to build volume indicators assessing the environmental resource extraction (input side) or the emission of waste (output side). These indicators are often applied to environmental impact assessment of value chain activities even in LCA studies. MFA is applied in the framework of the Driving Force-Pressure-State-Impact-Response[10] (DPSIR) scheme established by the European Environmental Agency (EEA) (OECD 2003).

Table 4.3 gives an overview of different indicators. Besides the input- or output-oriented indicators, consumption indicators, balance or trade indicators as well as efficiency indicators are applicable (OECD 2003). Efficiency indictors are relevant for indications of economic performance in relation to material losses to the environment. For instance,

[10] "The extraction of resources on the input side and the release of emissions and waste on the output side relate to environmental pressures, (sectoral) activities represent driving forces, the flows may change the state of environment which give rise to various impacts and the societal or political response may influence the metabolic situation towards sustainability" (OECD, 2003, p. 18).

GDP per Direct Material Input (DMI) indicates the productivity of direct materials. Gross domestic product (GDP) per Total Domestic Output (TDO) estimates the economic performance in relation to material losses to the environment. Setting the value added in relation to the most important inputs and outputs provides information on the eco-efficiency of an economy (OECD 2003).

Table 4.3: Indicators derived from material flow accounting

Category	Indicator	Description
Input Indicator	Direct Material Input (DMI)	All materials which are of economic value and are used in production and consumption activities
	Total Material Requirement(TMR)	DMI + upstream hidden material flows, which are associated with imports and predominantly burden the environment in other countries
Output Indicator	Domestic Processed Output (DPO)	Total mass of materials, which have been used in the domestic economy, before flowing into the environment, exported and recycled materials are excluded
	Total Domestic Output (TDO)	Total quantity of material outputs to the environment released on the domestic territory by economic activity
	Direct Material Output (DMO):	Total quantity of direct material outputs leaving the economy after use either towards the environment or towards the rest of the world (Sum of DPO and exports)
	Total Material Output (TMO)	Total of material that leaves the economy (Sum of TDO and exports)
Consumption Indicators	Domestic Material Consumption (DMC)	Total amount of material directly used in an economy, excluding hidden flows (DMC equals DMI minus exports)
	Total Material Consumption (TMC)	Total primary material requirement associated with domestic consumption activities (TMC equals TMR minus exports and their hidden flows)
Balance Indicator	Net Additions to Stock (NAS)	Physical growth rate of an economy
	Physical Trade Balance (PTB)	Physical trade surplus or deficit of an economy
Efficiency Indicators	Physical Indicators (above) per GDP or Value Added	Services provided or economic performance in terms of value added or GDP; may be related to either input or output indicators to provide efficiency measures

Source: OECD (2003)

All these indicators are calculated on a regional level. However, there are some volume-based indicators, which are grounded on material volume flows on product level.

If the input indicator “Total Material Requirement” is applied at a functional level and does not refer to an economy, the indicator is similar to the ‘*material intensity per unit service*’ (MIPS). The MIPS concept was originally developed by a team led by Schmidt-Bleek in the 1990s, which aimed to quantify the use of natural resources during the production of a specified product. Typically, data aggregation is being done by assigning the physical flows into five categories (Finnveden / Moberg 2005): (1) Abiotic materials,

(2) Biotic materials, (3) Water, (4) Air, and (5) Soil. After assigning all input flows to the five categories, an indicator like the ecological backpack can be calculated. If the calculated sum of the input flows refers to a service unit, e.g. emissions of a car per driven kilometre and co-driver, then the indicator is called “material flow intensity per service unit” (MIPS). A little different is the ecological footprint, developed by Rees (1992) and Wackernagel (Wackernagel 2004; Kitzes / Wackernagel 2008). This indicator, measured in global hectares[11], is applied to both regional and product level. The indicator measures how much land and water area a human population requires to produce its consumption and to absorb its waste under the prevailing technology (www.footprintnetwork.org).

In contrast to MIPS focusing on all inputs needed to produce a good, the ‘substance flow analysis’ (SFA) focuses on specific – mainly hazardous – substances, either within a region or on a product level in a value chain. Examples are the nitrogen flows within an agricultural commodity chain. A review paper is published by the OECD Working Group on Environmental Information and Outlooks (WGEIO 2000). Danius (2002) published a paper on data uncertainties in material flow analysis.

Many empirical studies conducting MFA are available. However, often MFA and LCA are combined within one study and sometimes improperly referred to collectively as MFA. Indeed, LCA can be a follow-up method of an MFA, but MFA itself is as such not a tool for impact assessment. One noteworthy paper is written by Dahlström / Ekins (2006) using MFA to analyze the value chain of the iron and steel sector in the UK with an emphasis on their import and export quantities and its environmental impact.

Energy Accounting

Another important aspect of material accounting gaining more importance in value chain analysis is measuring the energy flows along the product chain denoted as e*nergy accounting*. It is often used as an evaluation technique for different types of products or processing techniques evaluating how much energy is used as a chain-input. (Finnveden / Moberg 2005). There are two important types of energy measures: (a) exergy and (b) emergy analysis.

The concept of *exergy analysis* is based on the first and second law of thermodynamics (Szargut et al. 1988). Exergy, described as quality of energy, measures the ability of a

[11] The global hectare is a measurement of biocapacity of the entire earth. It is the average biocapacity of all hectare measurements of any biologically productive areas on the planet. If taken the sum of the world's biocapacity, then divide it by the number of hectares on the earth's surface, it results in the biocapacity of one global hectare (Wackernagel 2004)

source to produce a unit of work. Thus, exergy refers to a thermodynamic unit (e.g. joule), that gives a numerical value to present energy quality (Apaiah et al. 2006). Traditional applications of exergy analysis have focused on the optimization of energy use and the decrease of resource consumption. Calculated indicators are e.g. the ratio 'exergy input' / 'exergy output' as a measure for energy losses associated with production of a unit of product. Exergy input is the exergy required to produce something, whereas exergy output is the fraction of exergy still contained in the substance (Szargut et al. 1988). The exergy concept has been applied to nations, products, and process engineering systems (Finnveden / Moberg 2005). If exergy analysis is applied to the product level, it is applicable in the boundaries of an LCA (Finnveden / Ostlund 1997). With respect to value chain analysis, Apaiah et al. (2005) applied the exergy approach to explore the sustainability of three different food supply chains: pork mincemeat, novel protein food made from dry peas and pea soup. As exergy is always expressed in the same unit, 'joule', energy inputs and outputs of each chain are easily comparable.

The objective of *emergy analysis* is to quantify the energy value of both direct energy and material resources. This implies that all required inputs of material, information, and labor are aggregated using emergy equivalents - expressed in the equivalent solar energy - resulting in the accumulated energy associated with a product (Castellini et al. 2006). Emergy accounting has been developed in the last three decades as a tool for environmental policy. Based on the analysis several indicators can be developed, e.g. 'transformity', which measures how much emergy is taken to generate one unit of output, regardless of whether or not the input is renewable. Another useful indicator is 'renewability', which is the percentage of renewable emergy used by the system (Cavalett / Ortega 2007). Cavalett and Ortega (2007) used the emergy approach to evaluate the soybean chain including agricultural production, processing, and trade in order to assess the environmental sustainability of the soybean value chain in Brazil. The authors estimated the amount of emergy exchanged in the international soybean trade. The main findings were that 94% of the emergy flows were used by the agricultural production system, one percent by transport to processing industry, four percent by crushing, and one percent for oil refining. Secondly, the emergy indicators showed negative sustainability trends throughout the stages of the chain. The emergy exchange ratio demonstrated that soybean farmers are delivering around five times more emergy with the soybean sold than the emergy they receive with the money paid for it (Cavalett / Ortega 2007). Other studies have been published by Brown and Herendeen (1995), Brown and Ulgiati (1997) and (2001), Cavalett et al. (2006), Lefroy and Rydberg (2003), and Cuadra and Rydberg (2006).

5 Value Chain Modeling

Globalization trends have significantly increased the scale and complexity of firms experiencing internal and external uncertainties. Internal uncertainties refer to the field of research and project development due to technological risks; external uncertainties cover price uncertainties, exchange rate fluctuations, as well as demand variations. In a fast moving economic environment, it is necessary to have tools to evaluate potential outcomes of changes, and to capture complex surroundings in a simplified model. Value chain modeling is a meaningful instrument to analyze multifaceted questions. Definitely, the basis of any model is a consistent data framework representing the benchmark situation for the system of interest. Each model starts by explaining these initial conditions. In the next step, specific scenarios define expected changes that might destabilize the operation of the current system; finally, the model explains adaptation strategies to these shocks to reach a new efficient equilibrium point. We introduce some standard methods of value chain modeling in the following section. Focus is on mathematical programming tools covering optimization procedures and general equilibrium modeling. Risk assessment is another tool to reduce for example environmental hazards of production activities and their resulting costs. The remaining subject is the inclusion of bargaining models in value chain modeling having a strong impact on the distribution of profit and information flows.

5.1 Equilibrium Model

Economists try to explain the numerous economic activities of different agents. In doing so, they pose standard assumptions on the behaviour of certain agents. The primary assumption of an equilibrium model is rationality. Until today, the Walras model is considered the fundamental theory to explain the functioning of independent markets where flexible prices determine the allocation of scarce resources, and rational producers and consumers maximize profits and utility respectively (Takayama 1985).

Here, two major groups of models are distinguished: general equilibrium models, and partial equilibrium models. In contrast to partial equilibrium models that focus on particular sectors of interest, general equilibrium models represent the complete economy determining all transactions endogenously. Computable general equilibrium (CGE) models are based on the socio-economic structure of the social accounting matrix (SAM). They represent a mathematical model of an entire economic system that can be closed or related to external agents via trade. The benchmark situation describes an equilibrium point of the system where all accounts are balanced and all markets are cleared. The standard CGE explains all the payments and receipts displayed in the SAM by mathematical statements. Following the notation of the SAM, the CGE is also characterized by its flexible multi-product, multi-sector, multi-institution disaggregation. Basically, CGE models have been developed to explain the economic performance of countries. Existing applications also cover regions or single villages, and the structure can also be applied to represent a single household. The standard model is specified in real terms; it is supposed that agents base their multiple decisions on relative prices. However, while the SAM-multiplier model is completely demand-driven, and adjustments are always linear in this model, the behaviour of agents might be specified quite differently within the CGE model (Böhringer / Löschel 2006). The CGE may contain more sophisticated functional forms and non-linear Engel curves that are more consistent with empirical evidence. A further advantageous feature of the CGE is the switch between different activities due to technical progress, and the change of the cost structure. This feature is supported by a special solving procedure, the so-called “mixed complementarity program” (MCP). It notably facilitates modeling of the value chain, where fluctuations and innovations are meaningful and require permanent reorganizations of the chain (Nicholson / Bishop 2004).

Winter et al. (2008) applied a CGE model at the village level to analyze the impacts of an innovative energy value chain on land use systems and degraded forests in Kenya. A value chain for different wood substitutes such as *Jatropha curcas* was implemented to analyze the impact of its cultivation on the consumption of natural resources, and on income distribution and food security within the village level. Combined with a game theoretical approach, simulations illustrate potential benefits of cooperative forest and community land management compared to a situation of unregulated resource competition among stakeholders in the Kakamega District of Western Kenya.

Partial equilibrium models represent a comparative static framework with the focus on a sector. They calculate the effects of policy changes in one good, while ignoring the effects on other goods, based on the assumption that the good being examined is too small to have a significant impact on the rest of the economy. Thus, these models do not include all production and consumption accounts in an economy, nor do they attempt to capture all of the economy's markets and prices. The approach allows the researchers to trace the impact of changes in one market or one value chain on other markets or value chains, but it only captures such changes in the markets included in the model. Partial equilibrium models are best suited to analyze sector reforms that are less likely to have large impacts on macroeconomic aggregates.

Nielsen (2008) developed a partial equilibrium framework to identify welfare effects of fish trade liberalization in presence of complex but realistic management schemes, e.g. regulated open access and regulated restricted access. The results showed that the welfare effect of trade liberalization in an exporter country is negative under open access and positive under regulated restricted access.

Lundmark (2007) applied a partial equilibrium model of the forest cluster assessing the impact of changing market conditions for the sawmill industry. The focus of the study was to analyze the interdependencies between the different sectors that are dependent from the product “wood”. The results confirmed that due to dependencies between the sectors, changing market conditions in one sector could have profound effects on other sectors. The analysis indicated that both production and consumption patterns are sensitive to changes in the demand for sawn wood products.

5.2 Value Chain Optimization and Simulation

The value chain model shows how intermediate and final goods flow through design, manufacturing and distribution activities. While single companies usually are responsible for the success of their own scope of production, the whole chain is responsible for successful product delivery and customer satisfaction. Existing methods for an in-depth analysis for value chain performance can be classified into two main categories: (a) methods for solution evaluation and (b) methods for solution generations (Chwif et al. 2002).

The first category refers to the evaluation of possible configurations of a value chain design in a “What-If” scenario, which includes simulation and spreadsheet techniques. The second category aims to generate the best configuration for a given objective, which includes classical optimization methods sometimes in combination with a simulation (also denoted as simulation-optimization).

Chwif et al. (2002) analyzed the difference between both evaluation methods: Spreadsheet based analysis and simulations. The authors argued that simulations are very rarely applied because this method is a more complex approach and more complicated to handle. Spreadsheet analysis is easier to apply but it does not consider dynamic behavior of a value chain and it does not account for variability. In contrast, simulation technique is a dynamic-stochastic tool, which considers dynamic behavior of the chain and accounts for variability, which is an advantage for the goodness of the consequent results. By comparing both approaches on one case study of a large aluminium-processing firm in Brazil, Chwif et al. (2002) gave proof that the variation in demand plays a key role in the performance of the chain. If this is the case, a supply chain analysis should be evaluated by a simulation because otherwise the static analysis from spreadsheets could lead to misleading results. The same conclusion has been drawn by Vos and Akkermans (1996) (Chwif et al. 2002).

With regard to the second category, chain optimization is applied to generate the best configuration for a given objective. Questions on optimization are usually related to minimize costs (transportation or production costs) or maximize internal production efficiency and profit to increase competitiveness. Traditionally, these problems are solved using linear programming, e.g. simplex algorithm, dynamic programming, or a mixed integer linear programming (de Mol et al. 1997). De Mol et al. (1997) developed a model for both simulation and optimization of logistics in the case of biomass fuel collection. The main goal of the study was to simulate and optimize (minimize) the logistical costs, because logistics costs are major cost component. First, the simulation model has been developed to calculate the costs of biomass logistics for one year depending on different scenarios. Then the optimization model was aimed at giving the annual flows of biomass with minimal costs. Singer and Donoso (2008) applied the optimization approach for the sawmill industry to the question whether companies in the natural resources industry (e.g. mining, timber, farming and fishery) should focus on the upstream or on the downstream value chain. The main aim of the study was to maximize production efficiency. The results suggested that the company should concentrate on the upstream activities. Geunes and Pardalos (2005) published a collection of papers on the topic "supply chain optimization" with focus on the logistics within and between enterprises.

5.3 Game Theoretic Analysis

Since in most value chains governance plays an important role, the analysis of the coordination of information and the allocation of pofit between actors became a focus of interest. To study these research questions, equilibrium models are augmented by game theory. Game theory can be defined as the "study of mathematical models of conflict and cooperation between intelligent rational decision makers" (Thun 2005). Thus, game theory models situations where players make decisions to maximize their own utility, while taking into account that other players are doing the same. Consequently, the decisions made by one player have an impact on each other's utilities. Game theory can be distinguished into two concepts: a) the cooperative and b) non-cooperative approach. Both differ in theoretical content and methodology.

The non-cooperative game theory, including the concept of Nash's equilibrium, is strategy-oriented, i.e. it is applied to study what one actor may expect other players to do and the basic details of how they get there. Whereas the non-cooperative theory focuses on detailed descriptions of what happens, the cooperative game theory focuses on a different scope (Nagarajan / Sosic 2006). It directly looks at the set of possible outcomes and analyzes what players can achieve, what coalitions will they form, how the coalitions divide the outcome, and whether the outcomes are stable or not. The key assumption of cooperative game theory is that players can negotiate effectively (Thun 2005).

Radhakrishnan and Srinidhi (2005) focused on the analysis of information exchange in a value chain. The authors argued that information exchange improves resource coordination. Their non-cooperative model consists of a bilateral monopoly with a manufacturer and a retailer, where retailers get private demand information, which has potential for improving the manufacturer's resource decisions. The underlying assumption is that it is always beneficial for the value chain to implement information exchange. The results showed that the manufacturer benefits both by improved resource coordination and by reduced payment for information rent, while the retailer is not motivated to adopt information exchange only by a resource-based costing and pricing system. Nagarajan and Sosic (2006) studied applications on cooperative game theory models. Their emphasis was placed on two aspects of cooperative games: profit allocation and its stability. The authors described the construction of the set of feasible outcomes in commonly seen supply chain models, and uses cooperative bargaining models to find allocations of the profit-fractions between value chain partners. Thun (2005) also applied the cooperative approach. He assumed that different actors collectively maximize the global benefit, for what reason the cooperative game theory is more appropriate than non-cooperative. Consequently, the players can cooperate with each other based on binding agreements in order to generate stabile conjoint outcome. According to stability, Thun aimed, similar to Nagarajan and Sosic (2006), at a stable allocation of profits in cooperation. He argued that the stability of cooperation depends mainly on the payoff for each player. Thus, no incentive exists that leads value chain partners to abandon cooperation.

6 Econometrics

After analyzing input-output structures of value chains and its territorial allocation, the question arises, which factors might determine the allocation of value chain activities among countries (on macro level) and companies or farmers (on micro level), respectively. In the literature, two major answers are given: (a) the concept of barriers to trade on macro level and (b) the concept of barriers to entry on a micro level.

In the literature, various definitions of barriers are suggested, but generally the term implies an “impediment that makes it more difficult for a firm to enter a market” (OECD 2005, p.9). Thus, barriers do not completely prevent agents from entering a market in order to affect competition, but they represent obstacles, which need additional effort to be overcome. Barriers have experienced growing attention especially with respect to international trade, e.g. tariffs and non-tariff barriers as well as compulsory certification schemes including social and environmental standards impeding exports to other countries (macro level). The first subsection 6.1 deals with determinants of bilateral trade among partner countries in a value chain. The applied method is the gravity model, which is often used to identify catalysts and barriers of trade for specific commodities.

Secondly, barriers to entry do not only occur in international markets, but also on micro level, especially in developing countries. In the latter case, small-scale farmers often experience higher barriers to entry to international markets compared to farmers from more industrialized countries. Here, the important issue is how the poor fraction of the population can be integrated into international value chain activities in order to create economic growth and wealth. Consequently, the question arises, why farmers are involved in a specific value chain, whereas others are not, and which impact do certain activities have on farmers, especially on their net income. To come up with an appropriate answer, the determinants of participation (barriers and catalysts) have to be analyzed. In this context, mandatory standards, e.g. food, social or environmental standards play an important role, but also transaction costs, e.g. access to markets and agricultural inputs. Subsection 6.2 deals with assessing barriers to entry for compliance with standards, transaction costs as well as the impact of participation on the revenue. In the majority of cases, the applied methodology on micro level[12] is a treatment effect model.

[12] Regarding the impact assessment on macro-level, the multiplier analysis was introduced in chapter 4.2 and some single indicators of value added were presented in the FAO Framework (see chapter 4.1).

6.1 Gravity Model

The gravity model is one possible way to get quantitative information on determinants of trade flows in value chains. In most cases, it is applied to evaluate the impact of bilateral or multilateral trade agreements on the amount of trade flows. Other scopes of application are the determinants of foreign direct investment, tourism and migration flows (Martinez-Zarzoso 2003). The linkage between the gravity model and value chain analysis can be illustrated by the fact that the majority of tradable commodities are not processed or consumed completely in the country of production for several reasons. Many products are traded globally between countries involved in the same value chain. Thus, it is necessary to have the gravity model as an analytical instrument to assess the constraints of trade between countries.

The gravity model, derived from Newton's gravitational concept (1668) in mechanics, is defined as "the gravitational pull between two physical bodies proportional to the product of each body's mass divided by the square of the distance between their respective centers of gravity" (Christie 2002, p. 1). The analogy between Newton's gravity law and trade is the following: The gravity equation describes amount of trade between two countries as directly related to the size of the two countries involved and inversely related to the geographical distance between them. The basic theoretical model of the gravity model on trade between two countries takes the form of:

$$X_{ij} = A \frac{M_i M_j}{D_{ij}}$$

In which X_{ij} represents the trade flows in values from origin i to destination j. A is a constant of proportionality, M_i and M_j express the economic sizes of origin i and destination j, respectively, and D represents the distance as a proxy for transportation costs which results in lower trade flows.

The first gravity model of international trade was developed by Tinbergen (1962) and Pöyhönen (1963). Later, several authors namely Anderson (1979), Bergstrand[13] (1985, 1989), Deardorff, (1995), Feenstra et al. (2001), Evenett / Keller (2002) and Bröcker (1989) developed a theoretical and microeconomic foundation of the gravity model. The last important paper providing a theoretical justification is published by Anderson and Wincoop (2003). The econometric form of the basic gravity equation is as follows:

[13] For the two-country case, Bergstrand showed the compatibility between the gravity model the Heckscher-Ohlin Model (HOM), and thus gave a microeconomic foundation.

$$X_{ij} = A_0 (M_i)^{\alpha_1} (M_j)^{\alpha_2} (D_{ij})^{\alpha_5} u_{ij}$$

The linear equation of the gravity model is as follows:

$$\ln(X_{ij}) = \alpha_0 + \alpha_1 \ln(M_i) + \alpha_2 \ln(M_j) + \alpha_3 (D_{ij}) + u_{ij}$$

All the variables (except dummy-variables) are transformed in natural logarithms, because the gravity equation has a multiplicative character. The log-transformation allows estimating a classic linear regression[14] and interpreting the estimated parameters as elasticities of the volume of trade. Recently, Santos Silver and Tenreyro (2006) and subsequently Martínez-Zarzoso et al. (2006) gave an overview concerning further non-linear estimators, which are more robust for econometric problems due to heteroscedasticity and zero trade flows.

As shown before, the traditional gravity equation includes variables for the size of the economy GDP of both countries and the distance D_{ij} between them. In the majority of applications, the gravity equation is enhanced because of a huge fraction of variance in the explanatory variable of trade flows, which the classic equation cannot explain. The augmented model usually includes additional variables depending on the question of interest, e.g. exchange ratios, tariffs, common language, shared border, colonial history as a proxy ‘cultural distance’, or transaction costs.

Up to now, the model has often been used to evaluate the impact of treaties, alliances, and regional trade agreements on international trade flows. Martinez-Zarzoso for example (2003) applied the gravity model to test the effectiveness of preferential agreements e.g. the membership between several economic blocs (e.g. EU or NAFTA). To analyze the effects of trade agreements, the author included a dummy, whether the country is involved in a specific trade agreement or not. A significant positive coefficient led the author to conclude that trade agreements lead to the consolidation of trade and work as an integration scheme.

Another important focus regarding the application of gravity model is the inclusion of environmental variables. Cagatay and Mihci (2006) used the model to construct an index

[14] In the past, the data basis was cross-sectional and estimated by ordinary least squares method. Recently, Santos Silver and Tenreyro (2006) introduced the poisson maximum likelihood estimator as the new working horse. However, most of the recent applications use now panel-data applying a fixed effects model to control for country specific heterogeneity (e.g. Dascal et al. 2002; Martinez-Zarzoso, 2003, Egger / Pfaffermayr, 2003). The advantage is increasing the efficiency of estimators due to the increased degrees of freedom and the decreased collinearity among the explanatory variables (Dascal et al. 2002). If no panel data are available, cross-sectional data are usually analyzed.

of environmental sensitivity performance. The index was used in a cross-country trade model in order to analyze the effect of various degrees of environmental stringency on trade patterns, especially on the export performance of countries. The authors showed that environmental stringency has a significant negative impact on exports. The authors support the argument that the environmental stringency level differentiated between developing and developed countries is a crucial criterion in terms of explaining shifts in trade patterns and international specialization of the countries.

The gravity equation is also used for estimating the impact of transaction costs on bilateral trade, interpreted as trade frictions, which becomes a more and more important parameter for the evaluation of trade. Transaction costs are costs that are related to (cultural) distance and are estimated by certain proxies. The larger the distance between two potential trading partners is, the higher the transaction costs, which leads also to increasing market prices (production price plus transaction costs). This can result in declining demand, because the rate of return decreases or could even become negative. Hausman et al. (2005) applied the gravity equation to logistic friction in terms of specific quantitative metrics of logistics performance as e.g. time, costs, and variability in time. The authors found prove that the introduced variables relating directly to logistics performance have a statistically significant negative relationship to the level of bilateral trade.

Some authors used the gravity model not as a model of explanation but as a predictor model to forecast potential trade (Sargento 2007). The results implied that the gravity model is not adequate in estimating unknown trade data. Comparisons showed that the estimated flows varied a lot from the real data.

In most articles, the gravity approach is denoted as a rather simple but robust approach to estimate bilateral trade flows (Head 2003). Due to its simple application to different aspects on trade, it is very attractive for researchers. Since the theoretical foundations of the gravity model are better understood and developed, the application is also justified by the economic theory. Sargento (2007) declared that the major advantage of the approach “rely on its simplicity and its good capacity to produce aggregate results”, even with “much aggregated information and using very simple measures of spatial separation”. In addition, not only aggregated data can be used. Sargento also indicates the possibility to adapt the gravity model to more regional questions and less aggregated product categories, depending on data availability (Sargento 2007).

6.2 Treatment Effect Model

The increase of world trade is hypothesized to help to overcome underdevelopment and poverty in less developed countries. Thus, the question arises, whether it is possible to link and integrate poor farmers or population sections into international trade and which costs farmers have to bear (Maltsoglou / Tanyeri-Abur 2005). Schipmann (2006) argued that an integration into international food chains offer additional benefits, for instance higher income, income diversification, or value chain upgrading possibilities. However, barriers to entry are often assumed higher for international value chains compared to domestic chains and could at worst neutralize eventual benefits. Barriers normally include e.g. initial qualifications of the producer, product quality and quantity specifications, ability of frequent supply, production costs, transaction costs (distance to the purchaser and markets, access to inputs and credits) and standards, whereas the last two attract a lot of attention in the framework of impact assessment in development economics. In this section, the focus is on the impact of standards and transaction costs on the intensity of chain participation and on the income. In order to measure the effects, a treatment effect model can be applied.

The treatment effect model is applied when the effect of a specific treatment, e.g. certification schemes or transaction costs, needs to be measured on a response, e.g. participation in a value chain on the household income. Econometricians contribute different econometric models in order to solve this scientific question such as sample selection models, instrumental variables, structural equations, propensity score matching, or switching regression models from labor economics (Lee 2005). The large number of different methods is derived from different problems during the estimation procedure, e.g. self-selection problem and endogeneity. However, it is not an aim of this paper to go into the details of regression estimation problems.

In almost every value chain related to agricultural products (especially in international chains), producers have to comply with certain compulsory food, social, and/or environmental standards. Compliance with these standards requires various investment in variable inputs and long-term investments bearing additional costs. In addition, beneficial integration has something to do with the personal ability of farmers to comply with standards regarding human capital e.g. experience, education or risk awareness. Thus, especially small-scale farmers from developing countries, who are often characterized by financial constraints and weak human resources, experience higher barriers in complying with standards than large-scale farmers.

First, it is the aim to compare the required costs for investments with the additional benefits for chain participants. Therefore, financial cost-benefit analysis[15] for the specific period of investment is applied to evaluate if the long-term investment is profitable (equivalent to a positive net present value) (Gittinger 1984)[16]. The analysis should include all costs arising from investments if a smallholder wants to participate in a certain value chain compared to the expected benefits e.g. higher income due to higher prices. Not only financial benefits can be included, but also improved health due to less pesticides in agriculture for farmers can be taken into account for benefits integrated e.g. in the case of projects with integrated pest management (Garming 2008, Pearce 2006). The accounting of all occurring costs and benefits to a farmer provides the basis for a treatment effect model.

Various studies have been conducted to compare the characteristics of different value chains with regard to potential benefits for farmers, especially smallholders. Asfaw (2007) studied the impact of stricter food-safety standards imposed by high-income countries on the competitiveness of producers in developing countries. The author hypothesized that actors are impeded from entering or even remaining in international high-value food markets. The results showed that smallholders as compared to large-scale farmers face difficulties in complying with standards due to a range of constraints. Access to information, capital, services and availability of labor are major factors influencing the ability of small-scale producers to adopt. However, standards do not eliminate smallholder farmers as a whole from export markets but they discriminate within the group of smallholder producers (Asfaw 2007). Similar results are shown in Dörr and Grote (2007) concerning the Brazilian fruit sector. The authors analyzed the impact of certification requirements of fresh fruits chains on producers in Brazil.

Besides standards, transaction costs are another important factor for the integration of small-scale farmers in value chains. With respect to market activities, transaction costs result in much less buy- and sell-activities compared to a frictionless economy. Specialization and fragmentation of production and processing activities imply that transaction costs will gain more and more importance as part of the total costs of

[15] Financial cost benefit analysis is implemented by using market prices to assess the effect of investments on household level whereas economic cost benefit analysis uses shadow prices to adjust for market distortions and assess the effect at country level (Gittinger 1984). If the discounted benefits minus discounted costs are positive, the investment is profitable.

[16] Compared to traditional cost-benefit analysis with fixed and variable costs, GTZ developed a slightly different approach in order to calculate costs: the recurrent and non-recurrent costs approach. Non-recurrent costs include all investment costs, which are necessary to comply with the requirements of the chain-participation. Recurrent costs include all costs for maintenance (Chemnitz et al. 2007).

companies, which clarifies the importance of transaction cost analysis referring to value chain analysis. Thus, considering transaction costs is essential to get a better understanding of value chain activities and international operations.

Transaction costs, derived from the new institutional economics, include all costs in trade transactions, either as an exchange of property rights in a market transaction, or as an exchange of responsibilities in a hierarchical situation (Butter 2007). Transaction costs are defined as the "[…] 'costs of arranging a contract *ex-ante* and monitoring a contract *ex-post*' […] or more generally the costs of running the economic system" (Hubbard 1997, pp. 240). In principal, two types of transaction costs can be distinguished (Butter 2007): (a) The hard transaction costs referring to costs, which are directly observable and quantifiable, such as charges for transport, and (b) the soft transaction costs which are much more difficult to observe and quantify, e.g. associated searching, negotiation, monitoring, or enforcement costs.

Another classification of transaction costs is suggested by Key, Sadoulet and de Janvry (2000). The authors distinguish between proportional and fix transaction costs. They estimated a model of supply response of agricultural households when transaction costs generate the situation that some farmers buy, others sell and some do not even participate in the market (Key et al. 2000; see also Taylor and Adelmann 2003). The results show that both types of transaction costs play a significant role in explaining household behavior. However, proportional transaction costs seem to be more important in selling activities rather than in buying decisions.

Several impact studies of standards and transaction costs are published. Asfaw (2007) analyzed the impact of Global Gap Certification on the net income of small-scale farmers and found proof that those who are integrated in such value chains have a higher net income due to the value chain participation than those who do not. Other publications are from Okello and Swinton (2006b), analyzing the effect whether international food safety standards marginalize the poor small-scale farmer in Kenya, and Neven et al. (2005) identifying the impact of domestic supermarkets on Kenya's fresh fruit and vegetable supply system on farm level. Mithöfer et al. (2008) analyzed smallholder access to the export market: the case of vegetables in Kenya.

Because transaction costs are not only analyzed in treatment effect models, the next paragraphs will highlight further methods to analyze the effect.

Transaction cost analysis

The analysis of transaction costs in the literature is manifold. As mentioned in chapter 6.1, the gravity model can be applied to measure the impact of transaction costs on macroeconomic trade flows. Some other applications of transaction cost analysis have focused on the decisions to outsource or to integrate vertical production or processing activities of goods and services. Zsidisin and Siferd (2001) highlighted the role of global buyers in creating global production and marketing networks according to the governance structure. The authors found proof that large and powerful companies develop value chain systems that integrate producers and traders in various countries but without themselves owning any production facilities in order to reduce transaction costs. In agriculture, this concept is also known as contract farming and outgrower schemes (Glover 2008).

Ettlie and Sethuraman (2002) analyzed the place of international supply and manufacturing. Therefore, the authors focused on two different concepts: (a) based on transaction costs according to questions on vertical integration and (b) based on resources according to technical capabilities from the firm’s perspective. The objective of the study was to find out how well enhancements of resources and transaction costs predict the level of global sourcing (global versus regional). The results show that the company’s technical capabilities and transaction costs were directly related to the increased level of company’s global sourcing. The authors concluded that both ways (resource or transaction based) are possible ways to globalize operations.

Lu (2005) estimated transaction costs to measure the efficiency of tomato production and marketing. The author showed that transaction costs have a significant influence on the efficiency of the tomato chain. The author gave proof of the significant impact of transaction costs on the production stage rather than on the marketing stage. At marketing stage, negotiation costs and transportation costs were most important to technical efficiency. Maltsoglou and Tanyeri-Abur (2005) argued that transaction costs and rural institutions are “important in explaining the impacts of globalization on smalholders due to their impact on the ability of smallholders to access markets beyond the local markets” (Maltsoglou / Tanyeri-Abur 2005 pp. 1). Thus, transaction costs can be directly related to barriers to entry for farmers if the access to markets, credits and information is not given. To implement transaction costs analysis properly, appropriate variables regarding the proxies need to be defined. Table A6 provides some possible variables for representing transaction costs. The proxies are only examples of the possible range of variables.

7 Global Commodity Chain Analysis

The Global Commodity Chain (GCC) framework developed by Gereffi has attracted significant attention since the early 1990s (Gereffi 1994b; Raikes et al. 2000). The framework is tied to the concept of governance. The World Bank defines governance as “the exercise of political authority and the use of institutional resources to manage society's problems and affairs” (World Bank 1991). Global commodity chains analysis (GCCA) does not measure input and output flows at various stages of the product’s life cycle quantitatively; instead, it rather evaluates the social relationships and balance of power between all actors involved in the chain qualitatively.

Gereffi’s idea of governance itself focuses on the global organization of industries and enterprises integrated in a value chain (Gereffi 1994b) (see table 2.1). The objective of a GCCA is to analyze which actor enforces parameters under which other up- or downstream actors have to operate. This refers to institutional mechanisms and inter-firm relationships through which non-market coordination can be achieved. The concept of governance itself cannot be evaluated positively or negatively at all. On the one hand, good governance might reduce transaction costs among actors, e.g. due to fix contracts. On the other hand, dominant actors might also set specific requirements in terms of quality standards or quantities, which might have effects similar to market barriers, because some producers are not able to fulfill the requirements.

Humphrey and Schmitz (2002) defined four key parameters set by other downstream actors regarding the question of governance:

- What has to be produced: Definition of the product
- How it has to be produced: Definition of production process (technology, quality, labor and environment standards)
- When it is to be produced: Point of time
- Physical product flow: How much is to be produced

If companies produce under specific conditions set by others, governance structures are required to transmit information on the settings and to enforce compliance. However, it has to be considered that value chains can differ in their form of transactions, e.g. due to specific product or market characteristics. Therefore, it is obvious that different forms of transactions among actors require different levels of governance. In order to classify governance in value chains, Gereffi classified three variables: a) complexity of transactions, b) the ability to codify transactions, and c) the extent to which suppliers have necessary capabilities to meet buyers' requirements (Gereffi 2005) (see table 6.2). However, measurable proxies or indicators are not specified.

Table 7.1: Determinants of governance

Governance Type	Complexity of transactions	Ability to codify transactions	Capabilities in the supply-base	Degree of explicit coordination and power asymmetry
Market	Low	High	High	Low ↑
Modular	High	High	High	
Relational	High	Low	High	
Captive	High	High	High	
Hierarchy	High	Low	High	High ↓

Source: Gereffi et al. (2005)

Based on table 7.1, governance can be classified in five categories. A value chain without any governance is denoted as a 'market-coordination' with no power asymmetry. In this case, transactions are easily codified and product specifications relatively simple. In contrast, 'hierarchal' governance is characterized by the missing ability to codify specifications, high complexity of products, and rare suppliers.

Within a governance structure, Gereffi distinguished between two types of global chain actors, who are key-drivers of information in the globally dispersed chains: (a) 'buyer-driven' and (b) 'producer-driven' chains. In producer-driven chains, the key parameters are set by enterprises, which control specific products and process technologies. The characteristics of producer-driven chains are capital- and technology-intensive industries, e.g. the production of automobiles, aircraft, and computers. Buyer-driven chains are characterized by labor-intensive industries, and therefore highly relevant to developing countries, for instance, the production of footwear, clothing, or agricultural commodities. However, both types of governance chains do not have a tradeoff. Some chains may comprise both, producer- and buyer-driven governance or may develop from producer- to more buyer-driven governance over time (Kaplinsky / Morris 2002; Schätzl 2003).

Many studies include the analysis of the governance structure in value chains. Central conceptual papers are published from Gereffi (1999), Humphrey and Schmitz (2000a) and (2000b), Humphrey and Schmitz (2002), Gereffi et al. 2005, and Messner (2002) who further developed the governance concept to the "world economic triangle" approach. Theoretical papers written by Raikes et al. (2000) and Bair (2005) demarcate the global commodity chain from the French Filière approach. Noteworthy are also some empirical studies from Kaplinsky (2000), Kaplinsky et al. (2003), Dolan and Humphrey (2004) and Humphrey (2003). Kaplinsky et al. (2003) for instance studied the furniture value chain and their prospects for upgrading by developing countries in the case of South Africa. Because of its high natural resource consumption and labor intensity, the wood furniture sector presents an opportunity for developing countries to participate in international markets. The wood furniture chain is increasingly referred to a ‘buyer-driven’ chain. Thus, the authors analyzed the requirements from the producer’s perspective in order to upgrade their chain activities. The authors found proof that the actual performance needs to be corrected in terms of improved information flow from the buyer to the producer level.

8 Conclusions

Different methodologies and concepts are available to analyze different aspects of value chains e.g. income distribution, environmental impact of chain activities, distribution of power or the impact barriers to entry. Many methodologies are found in scientific papers by screening scientific databases, but no overview of the use of different tools has been done until now.

This paper proposes an overview of methodologies related to value chain analysis in the context of environment and trade. Four major fields of methodologies applied in empirical studies were identified: Accounting of flows, equilibrium modeling, econometrics, and global commodity chain analysis. Accounting of flows includes different physical (e.g. life cycle assessment, material flow accounting) and monetary (e.g. input-output analysis, social accounting matrix) accounting frameworks provide the foundation for programming equilibrium modeling and econometric analysis. Value chain equilibrium models are a meaningful instrument to evaluate complex relationships between actors and the environment including risk assessment and game theoretical approaches. Econometrical value chain analysis is widespread in microeconomic value chain impact assessment. It includes treatment effect and gravity models to assess the impact of food, social, and environmental standards as well as transaction costs on the income of households or countries. Global commodity chain analysis aims to identify and measure the balance of power between the participating actors.

The presented methods deal with different objectives; hence, simple valuing of the models is impossible. Every method has its own field of application. Limitations of value chain analysis are usually the availability of data. If primary data are needed, the data complexity is restricted to time and labor. The need of a comprehensive data collection (primary and secondary data) during the phase of accounting is a major obstacle. Especially for life cycle analysis because not only direct input-output flows have to be taken into account but also indirect flows, which leads to the enhancement of the previously defined production system.

Other limitations of value chain accounting are the static and linear character of the underlying basic input-output flows. Here, equilibrium models with dynamic programming are an alternative, although it requires sufficient knowledge in programming. Modeling value chains is a very complex approach. Multifaceted environment and uncertainty related to future aspects have to be taken into account. However, once a model is developed, it serves as a comprehensive decision tool.

Especially, reducing risks and costs are two major points, which enterprises have to attend in their operational and strategic decision processes. Thus, a major field of application is the logistical part in supply chains and the environmental impact of wastes and emissions

Value chains and their changes over time are rarely analyzed. Comparisons of the same value chain in the present compared to the past and its conception of causal relation have not been done so far. At this moment, this is only done for gravity equations having access to panel data.

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Appendix

Table A 1: Overview on value chain manuals

Authors	Title	Focus	Key elements
McCormick and Schmitz (2001)	Manual for value chain research on homeworkers in the garment industry	Practical oriented handbook with indications on conducting questionnaires and interviews	– Focus on the garment value chain with attention on homeworkers – Gender Analysis in the framework of VCA – Methodology: Mapping the chain, collecting data, identifying relationships – Analyzing the actors (manufactures, homeworkers) – Indications for developing and applying participatory approach for successful value chains
Kaplinsky and Morris (2002)	A handbook for value chain research	Theoretical background of value chain analysis	– Differentiation between value chain analysis as a heuristic and an analytical tool – Value Chain Analysis from the point of view of competitiveness, efficient production, and globalization trends – Involvement of small enterprises into global value chain – Barriers to entry in the chain & governance – Upgrading & innovations for developing successful value chains
Mayoux (2003)	Participatory Value Chains Analysis for Pro-poor Enterprise Development	Value chain analysis as a part of participatory assessment process for strategic learning	– Discussing, of participatory value chains analysis and its usefulness – Participatory analysis to empowering processes
Roduner (2004)	Analysis of existing theories, methodologies and discussions of value chain approaches within the development cooperation sector	Theoretical background of value chain analysis	– Background on the value chain approach – Discussion on key factors o Barriers to entry and rents o Concept of governance o Upgrading – Measurement of value – Approaches of bilateral donor agencies
GTZ (2004)	Info-Cadena – Instruments to foster value chains	Guide for technical assistance in projects, policies and public programs	– Support of local economic development in rural areas with the aim of linking small rural producers to formal markets (domestic and international). – Market potential as a starting point – Way of proceeding: o Initial analysis o Support strategy for cluster development o Support strategy supply chain development o Monitoring and Evaluation

Schmitz (2005)	Value Chain Analysis for Policy-Makers and Practitioners	How can Value chain analysis be used for giving policy recommendations at different levels of government, institutions	– Value chain analysis for policy-makers to make balanced economic and social decisions – Gaining market access, upgrading enterprise's capabilities, improving employment practices and working conditions. – Indications of limitations of the value chain approach (e.g. upgrading, ensuring employment standards) – Improving and encouraging donor coordination
Bernet, Thiele, Zschocke (2006)	Participatory Market Chain Approach (PMCA) – User Guide	PCMA as an instrument / method fostering broad participation in existing or new value chains	– PCMA concentrates on solving two limiting factors: o The lack of market-oriented participatory method expertise of R&D institutions o The lack of methods that effectively integrate the different market chain actors – Application of PCMA and challenges
GTZ (2007)	'ValueLinks' Manual	Action-oriented methodology of value chain promotion and developing projects by public agencies	– Orientation on integration of the poor in economic activities in value chains – Manual consists of 12 modules organized according to the project cycle o Identification of value chains to promote o Value chain analysis o Formulation of chain upgrading strategy o Know How of facilitators o Implementation of projects, services, and the business environment including standards o Monitoring impacts and managing for developing results
FIAS (2007)	Moving towards Competitiveness: A value chain approach	VCA as an empirical tool in identifying binding constraints to industry growth and competitiveness	– Key elements of value chain analysis – Measuring of performance and establishing benchmarks – Developing policy recommendations

Source: own compilation

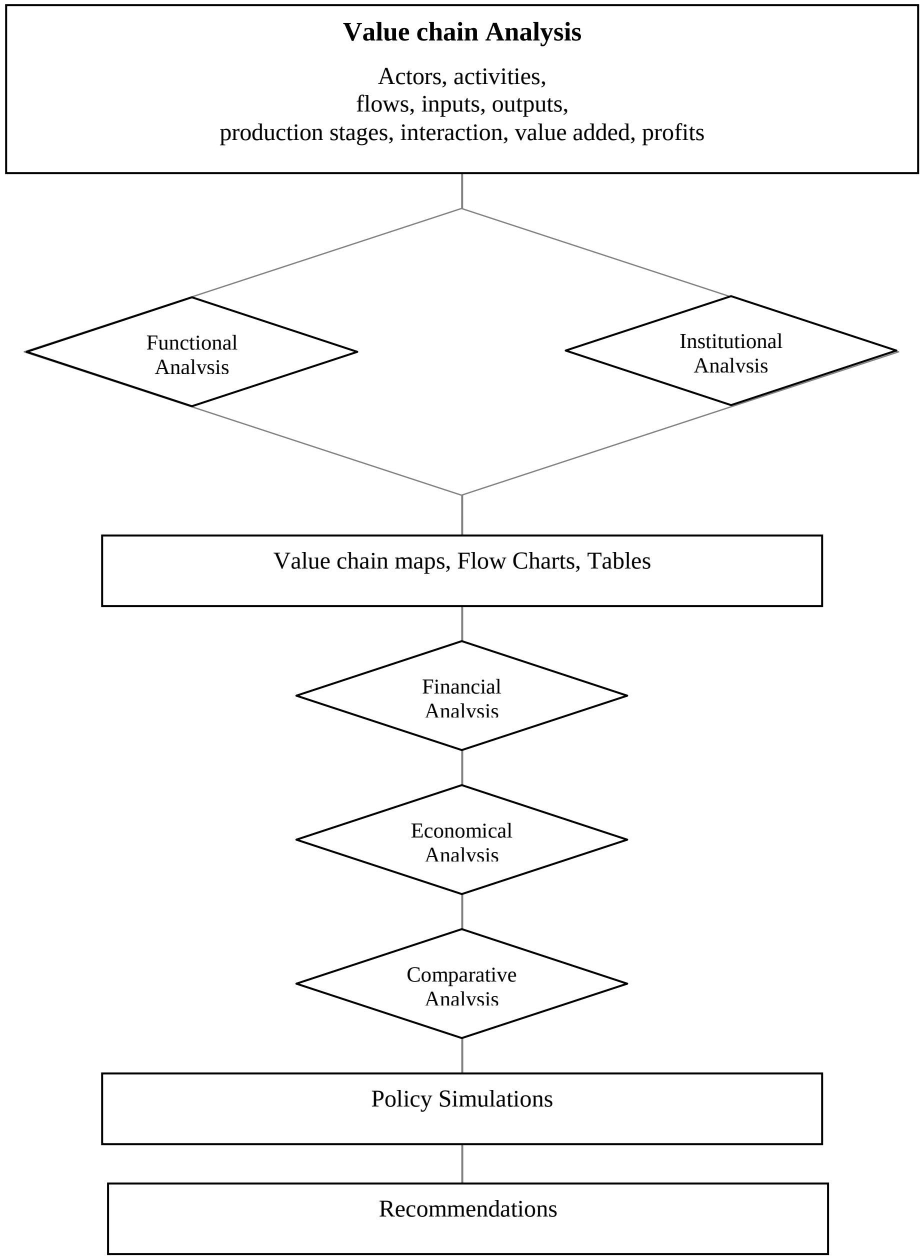

Figure A 2: Commodity chain framework developed by the FAO

Source: Adapted from FAO (2004a)

Table A 3: FAO modules for commodity chain analysis

Module	Title	Content
Module 43	Constructing the Commodity Chain: Functional Analysis and Flow Chart	– How to construct the commodity chain. – How to develop an institutional and functional analysis. – How to analyze the commodity flows (flow chart).
Module 44	Financial Analysis	– From the perspective of individual agents – Analysis includes: o Value added & gross profit o Production-trading account o consolidated account of the chain o Profitability of investments o Overall Efficiency of the chain
Module 45	Impact Analysis Using Market Prices	– How to analyze the impact of the commodity chain on the economy, using markets prices. – Three stages of calculation: o Directs effects, o indirect effects o total effects
Module 46	Impact Analysis Using Shadow Prices	– Constructing segments of the chain – Efficiency price analysis (export and import parity prices) o Parity prices for goods and services o Parity prices for factors of production o Shadow exchange rate – Constructing a Policy Analysis Matrix – Comparing economic policies
Module 73-75	A Software for Commodity Chain Analysis	– 73: Installation Note and Software Package – 74: Inserting and Managing Data – 75: Calculations Performed by the Software

Source: FAO, own compilation

Table A 4: Indicators for economic impact evaluation on the national economy

Impact on…	Indicator	Formula	Description
… economic growth	Contribution of the chain to GDP	VA_{Total}	Reflected by the amount of total value added by the entire chain.
	The Rate of integration within the economy	$\frac{VA_{Total}}{Y}$	To what extent the chain depends on domestic production, or its degree of linkage with the domestic economy. < 50% ➔ outward orientated > 70% ➔ good linkage with national economy > 90% ➔ depends on domestic resources
	Capital coefficient	$\frac{\sum Depreciation}{VA_{Total}}$	Importance of fixed capital consumed in the creation of value added by the entire chain
	Ratio of the total added GDP	$\frac{VA_{Total}}{GDP}$	Measures the importance of the chain to the GDP.
…foreign exchange	Net balance in foreign exchange	$Netimports = Y_{exported} - imports_{total}$	In the case of export chains, it is the net balance in foreign exchange rate, which measures the contribution of the chain to the balance of payments.
	Efficiency Ratio of Foreign Exchange Expenditures	$\frac{Y_{exported} - imports_{total}}{imports_{total}}$	Ratio < 0 ➔ chain is exporting none of its output, or that the portion exported is less than the overall foreign exchange cost of operation of the chain. Ratio > 0 ➔ gains from foreign exchange spending.
…income distribut-ion to agents	Impact on income distribution to the actors of the chain	Shares in the created wealth (value added)	See above (value added calculation)
…government budget	Impact of the chain flows on the state budget	$GB_{total} = T_{total} - S_{total} + P_{public.sector}$	Whether the chain is a deficit or a support to the government
	Direct Rate of Taxation/Subsidy (or the nominal rate of taxation)	$\frac{Government.Budget_{direct}}{VA_{direct}}$	Measures the nominal level of transfer (tax or subsidy content of the value added created: a positive rate indicates taxation, a negative rate, a subsidy)
	Effective Rate of Taxation/Subsidy	$\frac{Government.Budget_{total}}{VA_{direct}}$	The same like before, but the ratio includes indirect transfers between the government and economic agents.
	Real government cost coefficient	$\frac{Government.Budget_{total}}{\sum Subsidies_{direct}}$	Shows the real impact on the government's finances of each monetary unit given in direct subsidy to actors of the chain

VA = Vakue Added Y = monetary valued output GDP = Gross domestic product GB = Government Budget T = Taxes S = Subsidies P = Profits (This list is not intended to be exhaustive)

Source: FAO (2005b) and FAO (2005c)

Table A 5: Non-exhaustive list of industrial life cycle inventory data

Database name	Geographical scope	Managed by	Format	Further Information
Ecobalances of the European plastic industry	Europe	APME	Text format	www.apme.org
Environmental profile report for the European aluminium industry	Europe	European Aluminium Association	Hardcopy	www.aluminium.org
FEFCO European database for corrugated board-life cycle studies	Europe	FEFCO	Hardcopy or "spold"	www.fefco.org
Life cycle assessment of nickel products	International	Nickel Development Institute	Text format	www.nido.org
LCA of the steel industry	International	IISE	Hardcopy	www.worldsteel.org

Source: Rebitzer et al. (2004)

Table A 6: Proxies for hard and soft transaction costs

Hard / Soft	Categories	Proxy-Variables	Authors
Hard	**Transportation costs**	– Distance to the market – Transport costs (fuel, number of pickups) – Time, road conditions	Key et al., 2000 Lu (2005)
Soft	**Search / Information cost**	– Number of traders, visited before selling – Sources of access to market information – Time of price information (at time of sale or before)	Lu (2005) Maltsoglou / Tanyeri-Abur (2005)
Soft	**Negotiation costs**	– Number of visits / calls for reaching agreement of the selling price – Time span to waiting to sell produce in market	Lu (2005), Maltsoglou / Tanyeri-Abur (2005)
Soft	**Monitoring costs**	– Number of years that the farmer is engaged with the trader	Lu (2005)
Soft	**Enforcement costs**	– Difference between sale and agreed price – Times had to approach merchant to get paid – Confident level in the merchant – Level of fulfillment of the merchant	Maltsoglou / Tanyeri-Abur (2005)

Source: Own compilation