Delft Cluster

Title:	**Structural economic effects of large scale inundation: A simulation of the Krimpen dike breakage**		
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Abstract

The paper's main concern is to establish the general methodology for total economic loss estimation as a result of a large-scale flooding. The issue of economic loss definition is raised in the attempt to unify the scattered definitions met in the disaster literature as well as to provide clear implementation implications for the definition established. Total effect, as defined in the paper, includes the direct loss to households and government, and production interruption as well as the indirect costs caused by the 'ripple' effect. Input-output model is chosen as a framework approach in evaluation of the indirect costs. The necessary adaptations are brought into the model to account for such important asymmetric shock aspects as 'production bottlenecks' and substitution effect; the time dimension of the model is 2-year period. Bi-regional input-output table is utilised for this purpose to trace the inter-regional ties within the country as well as to elaborate on the disaster-induced changes of the economic structure.
The example of case study of a dike breakage in the South Holland province in the Netherlands is examined serving a fruitful playground for vast economic consequence modelling. Two basic models are compared. Given the same level of business disruption the maximum damage evaluation overestimates the economic loss, whereas the alternative adapted model provides for more moderate (though still significant) total damage estimate.

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Executive Summary

Research of the University of Twente is directed at the design of a methodology to compute the cost to society of large-scale floods. It is a peculiar observation that for the Netherlands after the inundation of 1953 there are very few investigations on the consequences of flooding for Dutch society. There is research on the damage to households and to firms, but there is no theoretical, let alone empirical research on the consequences for and changes in the structure of the economy. This paper aims at filling this gap. It will provide a methodology to handle the concept of direct and indirect economic effects of large-scale disasters and it will simulate a large-scale flood for part of the Province of South-Holland and compute the consequences for economy of the Netherlands. It has to be noted that the research is work in progress; the computations are thus merely an illustration of the methodology.

In order to explore the changes in the structure of the Dutch economy we have to classify economic damage. It is a second peculiar observation that there is no unified classification in defining damage. This lack of coherence is due to the fact that:

- There is no agreement on the economic points of departure. Financial appraisals are mixed up with cost-benefit analyses (CBA). In the latter the usual concept is economic costs, which relates to opportunity costs in welfare economics, whereas a financial appraisal is a base for investigating the sum of money to be recovered from insurance companies.
- There is confusion on time and spatial scales: Financial appraisal limits itself to a single organisation, whereas CBA requires well-defined borders, like a nation, or the European Union.
- Stock concepts are confused with flow concepts.
- The borderline between direct and indirect costs is not settled.

We concentrate on a Cost-Benefit framework and on national state boundaries.

Direct costs relate to:

- Physical damage to capital assets, including buildings, infrastructure, industrial plants, and inventories of finished, intermediate and raw materials destroyed or damaged by the actual impact of a disaster.
    1. Property owned by households and government is measured as changes in stocks;
    2. Damage to firms should be measured by a change in stock value or by a change in the flow of added value that result from the damage to the stock, or by a reasoned combination of the two. Business interruption as a disruption of the flow of added value is thus part of direct damage.
- Non-monetary impacts on households.

Indirect economic effects are defined as “a result of dislocations suffered by economic sectors not sustaining direct damage. Activities that are either forward-linked (rely on regional markets for their output) or backward-linked (rely on regional sources of supply) could experience interruptions in their operations”.

The total effect of a flood thus includes the direct loss to households, firms and government as well as the indirect costs caused by a ‘ripple’ effect. Bi-regional Input-output analysis is chosen as a framework for the evaluation of this ripple effect.

In modelling indirect economic effects of a large-scale flood in the province of South Holland is viewed as an asymmetric shock to the economy of South Holland. Apart from this shock, major effects on lifelines like infrastructure, cable and electricity networks have to be counted. Finally, substitution effects within the Dutch economy have to be anticipated. In this report we will not deal with effects on lifelines. Allowing for an initial shock and for substitution with the Dutch economy several scenarios can be developed:

1. Production disruption is translated into a change in final demand without changing the technology structure of the economy. A change in final demand then results in ripple effects in the Dutch economy.
2. Production disruption is translated into a change in final demand, but the input-output structure is adjusted for initial disruption of production (mostly absorbed by import substitution) and later for the production shift to the rest of the country.
3. Production disruption is translated into a change in final demand, but the input-output structure is adjusted for the so-called “bottlenecks” in production, resulting in restriction of overall production in the South Holland province; and later for the production shift to the rest of the country.

The three scenarios and assumptions on levels of substitution lead to different possible final outcomes of the indirect economic effects of a large-scale flood in the Province of South Holland.

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1 Introduction

Tsunamis, floods, droughts, hurricanes and earthquakes are a constant threat to society. In the past decades there is a growing awareness of the devastating effects of these natural disasters on the economies of developing and developed countries. The World Bank, United Nations and the EU have published numerous reports on this problem, *inter alia* (Kreimer and Arnold 2000) (Freeman, Martin et al. 2002) (ECLAC 1991) (ISDR 2002) (Colombo and Vetere Arellano 2002). Parallel to this policy awareness is an interest by economists in the methodology of estimating the economic consequences of disasters on welfare and an interest in the effects of recovery plans for the economy. There is a substantial literature for earthquakes, flooding and hurricanes.

In our research we are interested in the economic consequences of flooding. Specifically, we are concerned about the effects of large scale flooding in the Netherlands. Sea level rise and an increased probability of flooding of polders along the Dutch rivers ask for a quick and permanent solution. It is, however, a peculiar observation that there is hardly any report on the consequences for Dutch society of large scale flooding. There are several publications on small-scale floodings, but there is no experience with the societal and economic effects of major floods (van der Veen, Groenendijk and Mol, 2001). In the broader international literature it can also be noticed that the vast majority of academic work dealing with floods mostly focuses on relatively small-scale disasters. This means that the authors are more concentrating on the micro-level effects of the events, producing cost – benefit analysis for at most regional level. Large–scale floodings are thus not covered on an explicitly detailed way.

However, American authors open a wider perspective on disaster analysis. They raise the issue of large-scale earthquakes, which is more characteristic for the country. Generally American authors discuss the matter of flooding in the separate county-to-state scale. These are though usually not countrywide disasters, as the country itself is relatively big. Nevertheless the mode of analysis is very close to the large-scale disaster in a small country, therefore it can be easily projected for the case we examine in the Netherlands. Thus it is concluded that we can turn to the earthquake literature to borrow the necessary concepts and apply those for the case of floods

In this report we will translate the lack of Dutch experience into an empirical analysis of the structural economic consequences for the Netherlands of a dike breakage near Krimpen. The consequence of this dike breakage is a massive flooding of major parts of the Randstad.

In order to be able to deal with the economic consequences of this major flood we firstly need to establish an accepted definition of damage, which can be fed into an economic model of the Netherlands. In Chapter 2 we discuss general concepts of damage and we shall present a consistent system of definitions. In Chapter 3 we introduce the methodology we follow to simulate a shock to an economy, whereas in Chapter 4 we discuss the general principles how to describe the structure of an economy and how a major shock should be incorporated. In Chapters 5 and 6 we present the case of the Krimpen dike breakage: we discuss the data and theoretical implications of the model. In Chapter 7 we proceed with building of economic models for the affected area (the Province of South Holland), present the possibilities for an economy to adapt to such a shock via alteration of business and household behaviour and via shifts in the production system and discuss the results of our computations, whereas in Chapter 8 we formulate our conclusions and recommendations for future research.

2 Damage

In van der Veen, Groenendijk and Mol (2001) we mainly surveyed the Dutch literature on the methodology of estimating damage and we concluded that there is no agreed methodology, let alone a settled definition of damage. This conclusion is due to the fact that 1) there is no agreement on the economic points of departure. Financial appraisals are mixed up with cost-benefit analyses (CBA). In the latter the usual concept is economic costs, which relates to opportunity costs in welfare economics. CBA is a helpful means to weigh alternative measures against flooding, whereas a financial appraisal is often a base for investigating the sum of money to be recovered from insurance companies. 2) there is confusion on time and spatial scales: Financial appraisal limits itself to a single organisation, whereas CBA requires well-defined borders, like a nation, or the European Union. 3) stock concepts are confused with flow concepts. 4) the borderline between direct and indirect costs is not well defined.

In the following we will concentrate on the latter two points: stocks versus flows and the demarcation between direct and indirect costs. We will do so by reviewing the international literature. Our point of departure is a national Cost-Benefit Analysis.

2.1 Basic concepts for damage estimation

Twenty years ago Ellson, Milliman and Roberts (1984, p. 559) concluded on the basis of their literature survey that "most of the economic impact literature fails to make proper distinctions between measurement of losses and measurement of long run patterns of personal income, employment, and population growth. Much of the research has confused stock and flow concepts in the estimation of losses. Double counting is often involved, and the losses are not estimated in present value term".

Moreover, in MAFF (2000) it is stated that:

When identifying and valuing the different streams of benefits and costs, it is helpful to think in terms of stocks and flows. It is very easy to make the mistake of including the same benefit or cost twice because of a failure to distinguish sufficiently between the stock of some asset and the flow of resources, or consumption, which that stock generates. Typically, stocks give rise to some flow of consumption or resource so that the current capital value of the stock is determined by the discounted value of the future benefits, which flow from it. In some cases the flow diminishes the value of the stock value (e.g. mining coal necessarily diminishes the stock of coal) whereas in other cases it does not (e.g. catching fish at below the rate of replacement). An appraisal can include either the stock value of a resource or the sum of all the flows that it yields but not both.

The issue of double counting is important in assessing the value of properties. Before we start elaborating on this issue we need to find a definition of both concepts that allows us to make an appropriate distinction between both concepts. We follow Parker, Green and Thompson (1987, p. 36): "*Stocks* are the capital equipment, consumer durables and other physical objects damaged or destroyed by flooding. The *flows* are the flows of national income, which would have been produced by the damaged stocks but are lost after a flood".

The main thrust of the discussion in the literature is to assess the value of the loss, one can measure its value by either taking the stock value or the flow value. It is argued that these values, in theory, represent the same loss. So, when analysing damage that results from floorings, an assessment can be made on both the stock and the flow value of properties. Of course, this is especially relevant in the manufacturing sector.

As a result, in (Parker, Green and Thompson 1987) there is a demarcation between direct costs and primary and secondary indirect costs along this differentiation: Direct costs relate to loss of land, capital and machinery, thus to stocks, and primary indirect costs to business interruption, which means a flow. Moreover, secondary indirect effects relate to multipliers in the economy. The authors warn that it is not allowed to sum the first two categories (i.e. direct and primary indirect costs) unless production is lost to foreign countries.

Rose (2002) argues along the same lines. The stock of capital and machinery gives rise to a flow of production and income in the future, which means that business interruptions and capital stock affected measure the same thing. He consequently defines business interruption as a direct cost instead of an indirect one. Rose states that, for several reasons, an estimate based on flows may result in a better estimate than estimating damage based on stocks, or property damage. His reasons are the following:

1. First, an estimate based on flows makes up a better proxy of the lost value since it also accounts for damage due to business disruptions.
2. Second, flow measures are more compatible with macro-economic parameters, with respect to this Rose states that a stock based concept may result in an over-exaggeration of damage since only a portion of the property value may translate into service flows in any time.
3. Third, estimates based on a flow concept are more compatible and more consistent with the distinction between direct and indirect damage.
4. Fourth, flow measures have an explicit time dimension, which makes modelling better to do.

The main point of Rose's view is that when we estimate economic damage, stock-based damage models are related to a different time-period compared to flow-based damage models. The stock-based damage models do not reflect the true cost to society. When taking the stock value of the loss, this stock value does not take account of the fact that there are also flows produced with the stock outside the time span of the flood. The criticism on using the stock value to measure economic costs comes down to the idea that the effective disruption period (comprising of both the duration of the flood and the time necessary to turn back to normal) of the flood is a shorter time period than the depreciation period of the stock. It is only in the disruption period that society is faced with the loss of consumption due to a production disruption, given that resiliency or transfer of production does not take place.

Cochrane (1997) extends the definition of direct costs by not only including the physical damage to land, plants and houses, but also induced physical effects, which are the consequence of the disaster.

Finally, in the flooding literature there is a long lasting tradition to include also non-monetary impacts on households (MAFF 2000). To households, impacts of flooding such as increased stress, health damage and loss of memorabilia can be far more important than the direct material damage to homes and their content. Finally, there are approaches to include recreational and environmental benefits in flood and coastal defence schemes. In a CBA these benefits show up as avoided losses.

We may conclude that for direct costs there are differences of opinion: Cochrane has a wide definition by also including induced physical damage, which makes sense. Parker, Green and Thompson differentiate between direct and primary indirect costs along the distinction between stocks and flows, and then warn for not summing up direct and primary indirect costs. Rose simply states that direct costs can be measured either by stocks or by flows. We will come back to this conclusion in the next section.

2.2 Indirect effects in an economy

Whereas Parker, Green and Thompson (1987) defined indirect costs as business interruptions and multiplier effects in the economy, Cochrane (1997, p. 225) defines indirect economic effects more precise as "*a result of dislocations suffered by economic sectors not sustaining direct damage. Activities that are either forward-linked (rely on regional markets for their output) or backward-linked (rely on regional sources of supply) could experience interruptions in their operations*". He thus refrains from business interruptions.

In our view by applying the two concepts of Cochrane and Rose will solve the confusion of defining direct and indirect costs: Using a flow-based measurement of economic cost enables the analyst to make a clear the distinction between direct and indirect damage. If damage is valued according to a stock-based concept, one is forced to name property damage as direct damage and to name damage due to business disruptions as indirect damage. This is not an unambiguous distinction since it may introduce double-counting in the analysis. Expressing damage in a flow-based concept makes up an unobtrusive proxy; it enables us to better model indirect damage.

Indirect economic effects are due to relations within an economy. If part of the factories of type B is damaged by a disaster the production of sectors A and C is affected, but also the production of final products (consumption, investment, export and consumption of government) might be hit. From Figure 2 it can be seen that other factories of type B in non-flooded areas may take over the production of the damaged factory B.

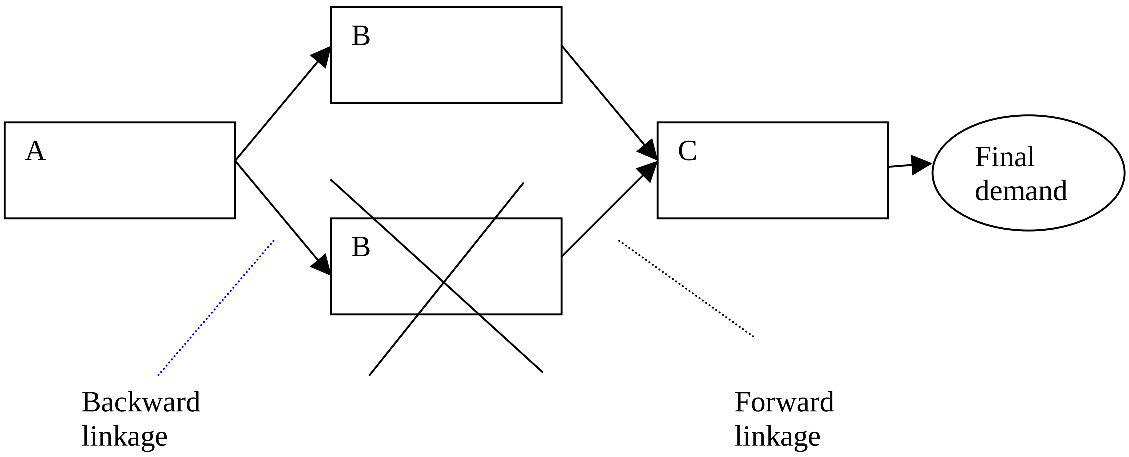

Figure 1 Forward and Backward Linkages in an Economy, when Factory B is Damaged

The magnitude of these indirect effects depend on:

1. The availability of alternative sources of supply and demand,
2. The duration of the disruption
3. The possibility to extend production

In general it is very difficult to assess whether alternative sources are available and whether elsewhere production can be extended. Detailed market information should be inserted in the model.

2.3 Damage: towards a consistent set of definitions for direct and indirect costs

To avoid the inconsistencies found in the literature on definitions for direct and indirect costs provided by various institutions involved in damage assessment[1] we make the following decisions for the classification of damage:

Firstly, we decide not to follow the approach by the World Bank. It seems to us that by introducing secondary effects as a classification the World Bank aims at modelling the recovery phase of an economy after a disaster. For the moment we skip this topic. In a later stage of this research we will elaborate on this issue.

Secondly, for firms we follow a flow concept to estimate business interruption[2]. For households and governments we apply a stock concept. This means that in our view direct costs relate to:

[1] Inter alia the World Bank, the UN, IIASA, Swiss Re. See for reference ECLAC (1999 and 1991), Benson (2000), Freeman (2002)
[2] We are aware that this choice is not unambiguous;

- Physical damage to capital assets, including buildings, infrastructure, industrial plants, and inventories of finished, intermediate and raw materials destroyed or damaged by the actual impact of a disaster.
    - Property owned by households and government is measured as changes in stocks;
    - Business interruption is estimated as a flow for the duration of the flood.
- Non-monetary impacts on households

Thirdly, in order to estimate indirect economic effects we apply the concept of Cochrane of forward and backward linkages.

Finally, in order to assess total damage an estimate is required for the excess capacity in production in the non-flooded areas and for changes in economic behaviour of firms and households.

3 Consequences of a Shock to an Economy

The literature on disaster analysis provides us with numerous approaches for the problem of how to look upon the economic costs of a vast devastating event. However, there is still no single unified method available to deal with the consequences of a large-scale disaster. Also, there exists no agreement on the exact definitions of major concepts. Given the large choice of model variants, we shall first outline the features we would like to see included into our ‘ideal model’, looking at the post-disaster situation through an economist’s eyes.

3.1 Asymmetric shock

As the water starts to flow into the region, we will see a large number of factories affected. In the case of a large catastrophe we can safely conclude that production in the flooded area will be totally lost for at least a year and will hardly be recovered during the next year. Therefore, no special theoretical assumptions are needed for the evaluation of direct output losses in the affected area: 100% of production will be gone. Nevertheless we have to take account of the fact that the factories flooded will belong to different branches of industry and they will be of different size and production capacity. Therefore, aggregating the losses of each production facility and bringing it to the industry level results in, as what is known as the paradigm of asymmetric shock. That is, different industries within the province (and hence the country) suffer different level of total output failure.

3.2 Lifelines

A significant source of additional production disruption mentioned explicitly in the literature is so called ‘lifelines’. These include infrastructure facilities (roads, railroads, air transport), utilities (electricity, gas and water supply) and communication services. Eventually many authors have emphasized their prominent role in contributing to losses[3]. There exists chain causality between natural disasters, lifelines and the operation of the economic system. Most economic transactions depend directly on physical lifeline systems – for example, purchases of power and water by businesses and households, the trucking of goods between the industrial areas and to markets, the flow of information within and beyond the region. Even in cases when a disaster has a limited direct impact on a region under effect, the indirect medium-term impacts might be much more devastating across the local economy, including areas outside the affected region.

3.3 Production bottlenecks

Lifeline disruptions can lead to so-called ‘production bottlenecks’. These bottlenecks can also be caused by the uneven loss of production to different sectors of an economy throughout the region (especially crucial in the case when e.g. a small industry is heavily damaged, but it used to be a highly important source of input for other industries), as well as due to imports limitations, payment lags, etc. As literature suggests (Cochrane, Benavides et al 1998), existence of such bottlenecks can substantially raise economic loss expectations.

[3] We can observe special stress put on them in Cole [1992] and Shinozuka et al [1996].

3.4 People

At the same time as the flood expands and covers a certain area, also people are affected: people just loose their jobs and become unemployed. This causes on the one hand decrease of welfare for those people, and on the other hand additional government expenditures for unemployed. This goes beyond the 'human' face of the story. People need to be evacuated from the flooded area and be settled in other places[4], which also will give rise to the government expenditures, not to say about the social and psychological impacts.

3.5 Substitution effects

There are several options of the possible response to the initial shock by producers. The key notion here is substitution. Each industry may have a number of choices for production and/or consumption substitution. First of all, as a result of a major flood in the province of South Holland a certain amount of production will be gone. Disrupted production substitution might come through imports. This in effect means that domestically produced goods are substituted for the ones produced abroad. Secondly, due to possible excess production capacities in the rest of the country, i.e. in the areas (provinces) outside the flood-affected region, part of the lost output can be overtaken. Thus an inter-regional shift of production will be observed (see also Figure 1).

The final demand structure might also change; for example, the consumption of domestic goods abroad can be reduced as a result of the reduced outputs. Also, exports might shrink. And finally there might appear some 'priority sectors', which are by some reason especially favoured to keep operation on a highest possible level. These may well for instance be communication, transportation, banking industry, which are naturally or by some institutional order restored and kept functioning to lessen the possible further losses and/or to secure faster recovery.

3.6 Time

Finally, we have to consider the time aspect of the analysis. First, we witness vast disruptions taking place in the flooded area, spreading also to the rest of the country. Then we observe adjustments of the economy to the new conditions. Eventually, recovery programmes take place to restore the flooded area, to reconstruct vital lifelines and thus favour economic activity. This time dimension is not always taken into account, although in real situations it plays an important role in a coherent economic development.

The outlined features as we have just portrayed stem from the logics of a disaster event. They also correspond to the concepts found in the literature concerning the estimation of indirect economic costs of natural disasters5. Nevertheless no single model includes all of these for overall economic cost calculation. This is explained by the limitations of the methodologies used for the analysis. Still, we consider it a challenge to construct a general model, which would be capable of including most of the aspects we consider important for establishing the end result of the large-scale flood: total economic loss. In the next chapters we shall make a step further for the generalization and implementation of this challenge.

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[4] Which in fact poses a considerable problem for the government. Taken the designated disaster is of large-scale factor, it will provide with an enormous amount of 'refugees'. On the other hand, the density of population in the Netherlands is the highest in Europe, which gives the solution of the problem a dimensional aspect.
Victims will also be an inevitable part of the disaster. This, though, is discussed in a paper specifically devoted to the issue.

[5](S.Cole, E.Pantoja and V.Razak (NCEER, 1992), M.Shinozuka, A.Rose and R.T.Eguchi (MCEER 1998), B.G.Jones et al (NCEER, 1997), Y.Okuyama, G.Hewings and M.Sonis (2002)

Methodological innovations are the prime focus of this research. Essentially, we shall try to bring additional consistency to existing modelling. As suggested by established literature, input output modelling makes it possible to look at the inside of the complex inter-industrial linkages within an economic system. Due to those considerations, we have accepted the input-output framework as a solid basis here for a more thorough examination and synthesis of the issue.

4 Description of an Economic Structure: the Input-Output Model

Whilst direct losses are about 'going to the site' and evaluating the lost assets, and seem quite straightforward, of course assuming the due level of expertise in this field, indirect losses are far not that easy to grasp by a fast look. It demands a sort of an 'implicit' analysis. It has been recognised that the techniques of input-output modelling (and/or their extensions – Social Accounting Matrices) have dominated the literature on indirect loss estimation. As outlined in Shinozuka et al (1998, p.128), "social accounting models have a particular advantage that <…> the supply and demand side of the economy can be described as a network that can be mapped into its physical and social counterparts. Because the nodes in the input-output tables represent localised production and consumption activities and the links show the flow of goods and services, such tables are especially appropriate for representing production, exchange and consumption activities." This is necessary to describe and evaluate the consequences of specific types of damage in a useful fashion, as well as to introduce fairly complex disaster and reconstruction scenarios, taking account of changes in the internal structure of the economy and its external links.

To put it in more precise frames, an input-output table has a matrix representation. Equal amount of rows and columns stands for branches of industry operating in an economy. Conventionally, incomes or receipts are given in the rows of the table while expenditures or outlays are shown in the columns. In other words, the rows of the matrix register the sales of each production sector to other sectors or to consumers of the final product. The columns inform us about the purchases of each sector from other sectors or from the providers of the so-called primary inputs. Since each figure in any row simultaneously is a figure in a column, each output is an input into some production process. The double-entry bookkeeping of the input-output table reveals the fabrics of an economy, connected together by the flows of trade, ultimately linking each sector of economy to all others. Input-output tables follow the fundamental law of economics, which states that their corresponding row and column totals, i.e. income and expenditure for each account, must be equal. Thus, observing such a table one is capturing the production processes in the whole of the economy, as the table reveals the quantified interrelationships or transactions among various sectors of a complex economic system.

4.1 The Standard Input-Output

The basic unit of the table is the transaction between its constituent parties (firms, sectors, industries, consumers, governmental agencies, and so on). The set of transactions consists of two parts, intermediate and final deliveries. If a delivery is intermediate, it means that it is an input in some (other) production process and, hence, is processed further. A delivery is final if it is bought without any intention of further processing. Let us consider now the intermediate purchases of a sector j (i.e. the sales of all sectors to this sector *j*). As mentioned, in I-O analysis a column vector is used to represent these purchases. The elements of this vector then register both the origin and the magnitudes of sector's j inputs. If we denote the observed (monetary) value of the flow from sector *i* to sector *j* by the symbol z_{ij}, we get the (column) vector:

$$\begin{bmatrix} z_{1j} \\ \vdots \\ z_{ij} \\ \vdots \\ z_{nj} \end{bmatrix} \qquad [4.1.1.]$$

Returning to the I-O table, the rows of the z_{ij}'s record where the *intermediate* output of each sector end up. If there is no final demand, total output (X_i) can be written as:

$$X_i = z_{i1} + z_{i2} + \dots + z_{ij} + \dots + z_{in} \qquad [4.1.2.]$$

The set of all linear equations expressing the balances for each commodity being produced or used in the course of one (static version of the model) or several periods of time (dynamic version) completely describes the interdependence among the sectors of the given economy. Sector *j*'s demand for inputs from the other sectors during the year in this way will be related to the amount of goods produced by the same sector *j* over the same period. Applying this to the *n* sectors, we obtain the mathematical structure of an input-output system, see Table 1 below.

		Purchasing sector					
		Z_1	…	Z_k	…	Z_n	Total
Selling sector	Z_1	z_{11}	…	z_{1k}	…	z_{1n}	$X_1 = \sum_{j=1\ldots n} z_{1j}$
	…	…	…	…	…	…	…
	Z_k	z_{k1}	…	z_{kk}	…	z_{kn}	$X_k = \sum_{j=1\ldots n} z_{kj}$
	…	…	…	…	…	…	…
	Z_n	z_{n1}	…	z_{nk}	…	z_{nn}	$X_n = \sum_{j=1\ldots n} z_{nj}$
	Total	$\sum_{i=1\ldots n} z_{i1}$	…	$\sum_{i=1\ldots n} z_{ik}$	…	$\sum_{i=1\ldots n} z_{in}$	$X = \sum_{j=1\ldots n}^{i=1\ldots n} z_{ij}$

Table 1 General Form of an Input-Output Matrix.

The fundamental law of economic equilibrium ensures that the corresponding row and columns totals of an input-output table must be equal. That is, the following equality should hold:

$$\sum_{i=1\ldots n} z_{ik} = \sum_{j=1\ldots n} z_{kj} \,. \qquad [4.1.3.]$$

This logically leads to another equality, stating that the sums of all columns should equal the sums of all rows:

$$\sum_{j=1\ldots n}^{i=1\ldots n} z_{ij} = \sum_{k=1\ldots n} \sum_{i=1\ldots n} z_{ik} = \sum_{k=1\ldots n} \sum_{j=1\ldots n} z_{kj} \,. \qquad [4.1.4.]$$

The entries in the table by convention are denominated in money terms but, following Leontief, these can easily be transformed into production (or technical) coefficients. If we denote them as *a*'s, these are obtained by dividing the entry in each cell by the total sum of the respective column:

$$a_{ij} = z_{ij} \Big/ \sum_{i=1\ldots n} z_{ij} = z_{ij} \Big/ X_j \qquad [4.1.5.]$$

It is usual to assemble all *a*'s into a single matrix denoted by A, (where A has dimension *n* x *n*). For its typical element a_{ij} we then have $z_{ij} = a_{ij} X_j$. This matrix of technical input-output coefficients accordingly represents the technical structure of the whole system. Thus, production coefficients show in the essence the production technology visible by columns, as here we see the structure of purchases of each sector, which are later used as production inputs. On the other hand row-wise we observe sales structure of each industry as the row entries reveal sales of each sector's products to other sectors.

In addition to the intermediate deliveries, we should distinguish sales to purchasers whose decisions are external (or exogenous) to the (decisions of the) industrial (i.e. producing) sectors - for example, households, governmental agencies and foreign trade. The demands of these units – and hence the size of their purchases from the industrial sectors – are generally the outcome of considerations outside the domain of the producing units. Therefore, the demand of these external units is generally referred to as final demand, basically being exogenously given.

Denoting by F_i the final demand for sector's i production, we can add it to the existing intermediary output and obtain the total or gross output for sector i:

$$X_i = z_{i1} + z_{i2} + \dots + z_{ij} + \dots + z_{in} + F_i \qquad [4.1.6.]$$

We now may substitute the above derived production coefficients for the z's. this will result in an expression for the total outputs in matrix notation. This expression is the basic equation for the input-output analysis:

$$X = A\,\underline{X} + F \qquad [4.1.7.]$$

Where $\underline{X}$ denotes the diagonal matrix with the X_i on its main diagonal.
We remark that the final demand category: is usually subdivided in several categories such as domestic final demand and foreign final demand. Domestic final demand again may consist of household consumption (C), government expenditures (G), investments (I) and other elements; foreign final demand is referred to as exports (E). Thus, total output in an economy adds up to the well-known equation:

$$X = A\,\underline{X} + C + G + I + E \qquad [4.1.8.]$$

Alternatively, being engaged in a production process, each sector not only has to pay for the inputs it obtains from all other sectors (including itself), but also has to pay for other types of inputs, such as labour (W) and capital (N). Together with certain other categories, such as imports (M), these form the 'value-added' part (V) of sector j. These items together are known as the 'payments' sector or primary cost categories. Incorporating them all into a formula for total expenditures, we obtain:

$$X = i'A\,\underline{X} + W + N + M \qquad [4.1.9.]$$

We now can express the whole system in the following way:

		Processing sectors (purchases)	Final demand				Total output
		1 … *j* … *n*					
Processing sectors (sales)	1 … *i* … *n*	**A**	C	G	I	E	X_i
Payments sector	Value added	W_i	W_C	W_G	W_I	W_E	W
		N_i	N_C	N_G	N_I	N_E	N
	Imports	M_i	M_C	M_G	M_I	M_E	M
Total outlays		X_j	C	G	I	E	**X**

Table 2 Expanded Flow Input-Output Table

So, let us elaborate more on the formula $X = A\,X + F$. We may straightforwardly transform it to have X as a function of F. In matrix notation we obtain:

$$I\,X = A\,X + F\,, \qquad [4.1.10.]$$

where I stands for an identity matrix. Thus:

$$(I - A)X = F, \qquad [4.1.11.]$$

or,

$$X = (I - A)^{-1} F \qquad [4.1.12.]$$

The matrix $(I - A)^{-1}$ is usually referred to as Leontief inverse. Denoting its elements by the symbol α_{ij}, we thus can write the equations [4.1.5.] and [4.1.6.] we have derived above as

$$X_i = \alpha_{i1}F_1 + \alpha_{i2}F_2 + \ldots + \alpha_{ij}F_j + \ldots + \alpha_{in}F_n \qquad [4.1.13.]$$

This shows in a direct way the dependence of gross output on the F_i's. In fact, looking at the α_{ij}'s in this context, we notice that we have $\alpha_{ij} = \partial X_i / \partial F_j$. Verbally, the α_{ij}'s (or multipliers) represent the amount by which gross output would change given a unit change in final demand. This property can be utilised to obtain a simple model:

$$\Delta X = (I - A)^{-1} \Delta F \qquad [4.1.14.]$$

Surprisingly, the multipliers of the famous $[I - A]^{-1}$ Leontief inverse matrix account for the total effect that incorporates direct and indirect effect of the exogenous impact (which is as discussed above is the change in final demand)[6]. The direct effect of changed final demand for the product of sector j is that this sector needs to increase its production by the amount of the expanded demand. The indirect effects reflect the responses of other industries (as well as sector j itself[7]) to this increased final demand – these sectors will have to produce more of their products to supply sector j with the inputs necessary to produce the extra goods or services needed. Therefore, in a general mathematical formula, sector's j multiplier $\alpha_{\cdot j}$ can be presented as a sum of all multipliers in column j:

$$\alpha_{\bullet j} = \sum_{i=1}^{n} \alpha_{ij} \qquad [4.1.15.]$$

4.2 Bi-regional input-output analysis

In bi-regional input-output analysis, the economic system is described not only in terms of interdependent industries, but also in terms of two interrelated regions. Like in the basic model, the output of each region is defined as a combination of the outputs of economic activities within its geographical borders; its input accordingly consists of the direct inputs of these industries and the goods and services absorbed directly by the final demand sectors of that region. The interdependence between two regions is modelled in terms of the interdependence between the industries located within their respective boundaries. In our case we can observe only direct linkages – standing for the extent in which commodities and services produced in one region are absorbed by the industries or the final demand sectors in the rest of the country8. The flow of commodities or services from one region to another obviously reflects the existence of a direct (input-output) relationship between the industries or an industry and the final demand sector located within the corresponding administrative borders.

Incorporating a region into the whole economic system asks for a number of changes in the construction of the input-output table. Here it is important to note that in the simple one-region model,

[6] In the literature devoted to the topic of input-output modelling the type of multipliers just described is being referred to as *simple* multipliers. These are distinguished from *total* multipliers, which are found via elements of the Leontief inverse of a model that is closed with respect to households. In this paper only *simple* multipliers are considered following this notation computed for the open model (refer to Miller and Blair, 1985, p.102).

[7] thus, it incorporates both inter-industry and intra-industry connections.

[8] Indirect interdependence that appears in a multi-regional framework in turn would mean that the connection between inputs and outputs is established through industries located in certain other regions.

which was outlined in the beginning, exports was included as one of the components of final demand F_i. Now, in the two-region I-O model representation, that part of final demand category which represented the sales of sector's *i* product to the productive sectors[9] in the other region (here, in the rest of the country) - but was included into the exports category as sales to outside of the chosen area - is removed from the final demand category and specified explicitly. The bi-regional table now provides an extended input-output matrix, divided into four quadrants. Two of these represent the intra-regional structure of region ZH, and 'the rest of the country'. The two remaining quadrants represent the industrial relations between the two regions: in the upper right corner of the table ZH region's industries appear as a sellers; in the lower left corner these are the receivers. Thus, the latter quadrants reveal the pattern of interregional trade flows. The following matrix notation may shed more light on the structure of such a table (using the basic notation of the previous sections):

$$Z = \begin{bmatrix} Z^{ZH.ZH} & Z^{ZH.N} \\ Z^{N.ZH} & Z^{N.N} \end{bmatrix} \qquad [4.2.1.]$$

Regarding the mathematical notation, let us assume that the underlying region is represented by the superscript *ZH*, whereas notions attributed the rest of the country will be represented by the superscript *N* (to provide the association with the Netherlands as will follow from the examples hereafter). Then, $z_{ij}^{ZH.ZH}$ (the element of the corresponding submatrix $Z^{ZH.ZH}$) stands for the money flow of goods from sector *i* in region ZH to sector *j* in the same region ZH. Similarly, $z_{ij}^{ZH.N}$ represents the money worth of inputs from sector *i* located in the region ZH to sector *j* in the rest of the nation (i.e., outside region ZH)[10]. Bearing this in mind and denoting final demand for the region ZH as F^{ZH}, the gross output of sector *i* in region ZH can be expressed as

$$X_i^{ZH} = z_{i1}^{ZH.ZH} + ... + z_{in}^{ZH.ZH} + z_{i1}^{ZH.N} ... + z_{in}^{ZH.N} + F^{ZH} \qquad [4.2.2.]$$

If the data is completed on the z_{ij}^{ZH} 's for all sectors in the regional economy ($i, j = 1, \ldots, n$) and also the data on gross outputs of each sector in the region, X_j^{ZH} ($i, j = 1, \ldots, n$), the set of regional input coefficients can be derived as:

$$a_{ij}^{ZH.ZH} = \frac{z_{ij}^{ZH.ZH}}{X_j^{ZH}} \qquad [4.2.3.]$$

Employing a similar notation for the matrix of the intra-regional flows $Z^{ZH.ZH}$ (n x n in dimension), and with $\underline{X}^{ZH}$ a diagonal matrix of regional outputs of the same dimension, the matrix of regional input coefficients can be defined as:

$$A^{ZH.ZH} = Z^{ZH.ZH} (\underline{X}^{ZH})^{-1} \qquad [4.2.4.]$$

By the same token trade coefficients for the flow of commodities between the two regions (which shows the money worth of input *i* produced by firms in the region ZH used per money unit worth of output of sector *j* in rest of the country) can be computed as:

$$a_{ij}^{ZH.N} = \frac{z_{ij}^{ZH.N}}{X_j^{ZH}} \qquad [4.2.5.]$$

These are also known as the inter-regional input coefficients. The corresponding matrix entailing these coefficients is:

---

[9] It should be noted that the final demand items associated with household and government consumption in other regions of the country (which were previously included in the exports category), are in the bi-regional setting not any more a part of exports, but are also allocated to the appropriate category of the respective consumption in the rest of the country.

[10] In order to facilitate the interpretation of the superscripts, one can think of these in a way analogous to the subscripts, interpreted as "from-to" with respect to sectors; the order of superscripts then indicates the "from-to" relation with respect to geographic location.

$A^{ZH.N} = Z^{ZH.N} (\underline{X}^{ZH})^{-1}$ [4.2.6.]

In the same way and following the same logic one can obtain the expressions for the matrix notations and the coefficient calculations for the intra-regional relations inside the 'rest of the country' and the inputs supplied by the region ZH to the rest of national economy.

Having established the relations among all inputs, outputs and final demands in each of the elements of the bi-regional table, we can substitute the z's in the equation [4.2.2.] by regional input and trade coefficients and restate the equality as

$$X_i^{\text{ZH}} = a_{i1}^{\text{ZH.ZH}} X_1^{\text{ZH}} + \ldots + a_{in}^{\text{ZH.ZH}} X_n^{\text{ZH}} + a_{i1}^{\text{ZH.}N} X_1^{N} + \ldots + a_{in}^{\text{ZH.}N} X_n^{N} + F_i^{\text{ZH}} \quad [4.2.7.]$$

Iterating the same procedure for obtaining equations for all gross outputs as in region ZH and the rest of the economy, X_i^R's and X_i^N's , and isolating the final demand categories in order to keep all X's on one side, the following equalities are obtained:

$(I - A^{ZH.ZH})X^{ZH} - A^{ZH.N}X^N = F^{ZH}$ [4.2.8.]

$- A^{N.ZH}X^{ZH} + (I - A^{NN})X^N = F^N$ [4.2.9.]

We now define the complete coefficient matrix for a two-region interregional model as consisting of the four submatrices

$$A = \begin{bmatrix} A^{\text{ZH.ZH}} & A^{\text{ZH.}N} \\ A^{N.\text{ZH}} & A^{N.N} \end{bmatrix} \quad [4.2.10.]$$

Also we define the total output and final demand vectors as consisting of the two subvectors of the respective economic areas of the country:

$$X = \begin{bmatrix} X^{\text{ZH}} \\ X^{N} \end{bmatrix} \quad \text{and} \quad F = \begin{bmatrix} F^{\text{ZH}} \\ F^{N} \end{bmatrix}.$$

We recognize here the extended version of the general formula employed in input-output modelling, i.e. [$X = (I - A)^{-1} F$]:

$$\begin{bmatrix} X^{\text{ZH}} \\ X^{N} \end{bmatrix} = \left\{ \begin{bmatrix} I & 0 \\ 0 & I \end{bmatrix} - \begin{bmatrix} A^{\text{ZH.ZH}} & A^{\text{ZH.}N} \\ A^{N.\text{ZH}} & A^{N.N} \end{bmatrix} \right\}^{-1} \begin{bmatrix} F^{\text{ZH}} \\ F^{N} \end{bmatrix} \quad [4.2.11.]$$

The advantage of such a bi-regional model (also applicable to multi-regional settings) is that it captures the magnitude of effects on each sector in each region; interregional linkages are made specific by sector in the supplying region and in the receiving region.

For a multi-regional and bi-regional input-output model a wide variety of multipliers measures may be obtained.

		Processing sectors (purchases)		Final demand									Total output
				Region ZH				Rest of economy, N				Total	
		Region ZH	Rest of count-ry, N	C^{ZH}	G^{ZH}	I^{ZH}	E^{ZH}	C^{N}	G^{N}	I^{N}	E^{N}	**F**	
Process-ing sectors (sales)	Region ZH	$A^{ZH.ZH}$	$A^{ZH.N}$	$C^{ZH.ZH}$	$G^{ZH.ZH}$	$I^{ZH.ZH}$	$E^{ZH.ZH}$	$C^{ZH.N}$	$G^{ZH.N}$	$I^{ZH.N}$	$E^{ZH.N}$	F^{ZH}	X_i^{ZH}
	Rest of country, N	$A^{N.ZH}$	$A^{N.N}$	$C^{N.ZH}$	$G^{N.ZH}$	$I^{N.ZH}$	$E^{N.ZH}$	C^{NN}	G^{NN}	I^{NN}	E^{NN}	F^{N}	X_i^{N}
Payments sector	Value added	W_i^{ZH}	W_i^{N}	W_C^{ZH}	W_G^{ZH}	W_I^{ZH}	W_E^{ZH}	W_C^{N}	W_G^{N}	W_I^{N}	W_E^{N}	W^{F}	W
		N_i^{ZH}	N_i^{N}	N_C^{ZH}	N_G^{ZH}	N_I^{ZH}	N_E^{ZH}	N_C^{N}	N_G^{N}	N_I^{N}	N_E^{N}	N^{F}	N
	Imports	M_i^{ZH}	M_i^{N}	M_C^{ZH}	M_G^{ZH}	M_I^{ZH}	M_E^{ZH}	M_C^{N}	M_G^{N}	M_I^{N}	M_E^{N}	M^{F}	M
Total outlays		X_i^{ZH}	X_i^{N}	C^{ZH}	G^{ZH}	I^{ZH}	E^{ZH}	C^{N}	G^{N}	I^{N}	E^{N}	F	**X**

Table 3 Expanded Flow Bi-regional Input-Output Table

4.2.1 Intra-regional effects

First come the *intra-regional effects*, denoted $\alpha^{ZH.ZH}$. These are found in the first quadrant (upper left one – $A^{ZH.ZH}$) of the Table 3 presented just above. They stand for the impact of exogenous changes in final demands for the selected region's goods on the outputs of sectors in this region. Column sums of all these multipliers through the area (we stay in the same quadrant) denote simple intra-regional output multipliers. These multipliers have the same interpretation as the multipliers in a simple one-region input-output table.

4.2.2 Inter-regional effects

Inter-regional effects provide more interest, as these appear exactly in the bi- or multi-regional tables. The essence of an interregional input-output model is that it informs us about the impacts in one region that are caused by changes in another region – these are often called the interregional spill-over effects. Let us now take a look at the lower left quadrant, AN.ZH, where the region ZH acts as a receiving region and the rest of the country as a supplier region. For any αijN.ZH the following interpretation should hold true: for each money unit worth of output by sector j in the region ZH, α cents worth of the output of the sector i in the rest of the country is used as an input. Thus in an interregional input-output model, one can calculate the simple interregional multipliers for each sector by column in the sub-matrix limits. These are output impacts that are transmitted across regional borders – in our case, from the rest of the country to the ZH - area.

4.2.3 National effects

From the regionally expanded I-O table it is possible to obtain the national effects, by aggregating the impacts to the national level. Let us assume, for example, that there are exogenous decreases in the final demand categories for the region ZH due to a deteriorating effect that flooding has produced there; hence the output level is being negatively affected11. This also implies reflections on the national level; thus, the national effects are obtained as the column sums in both sub-matrices AZH.ZH and AN.ZH. This means that the national effects for the respective sectors in region ZH and in the rest of the country can be obtained as

[11] In this case a two-way causality may be observed, i.e. impact coming from changes in the final demand or in the level of output of an industry that is being directly affected by a disaster. But let us abstain for a moment from these considerations and just allow the simplified assumptions as they are.

$$\alpha^{ZH} = \alpha_{.j}^{ZH.ZH} + \alpha_{.j}^{N.ZH} \qquad [4.2.3.1.]$$

$$\alpha^{N} = \alpha_{.j}^{ZH.N} + \alpha_{.j}^{N.N} \qquad [4.2.3.2.]$$

We now have an overall national effect vector

$$\alpha = [\alpha^{ZH} \mid \alpha^{N}], \qquad [4.2.3.3.]$$

4.3 Backward and Forward Linkages in Disaster Analysis

Taking a closer look at the presented model, one discovers the possibility of using 'sector interdependence' analysis to generate more the information on the most vulnerable sectors. These are the sectors that on the event of being hit by the natural disaster have a severe impact on other sectors. The basis is the insight into the sectoral structure of sales in the economy will serve as a guideline for the modelling effort.

Let us start with the analogy with the fundamental relationship of the standard I-O model. This concerns the matrix of transactions between sectors, Z, and the vector of final demand, F. From these the total gross outputs, X are found as $\alpha_{ij} = z_{ij}/X_{ij}$. The matrix of these coefficients, A, is $A = Z(X)^{-1}$ – each element in the j^{th} column of Z is divided by the gross output for the final sector, X_j. Therefore, as was already described in the previous section, the resulting relationship is given by $X = (I - A)^{-1}F$. Then, given A matrix for an economy, the necessary new output, X^{new}, needed to satisfy some exogenously determined new final demand, F^{new}, is found as $X^{new} = (I – A)^{-1} F^{new}$. In this sense, the standard input-output model is said to be a demand-side or demand-driven model. Once a set of demands is established, the model assumes that all necessary inputs to satisfy the needs for production to meet that demand will be supplied.

In other words, in the standard input-output model, the Leontief inverse relates the sectoral gross outputs to the amount of final product – that is to the units leaving the interindustry system at the end of the process. This in effect implies that supply is considered totally flexible, able to adjust to any changes in the final demand. In other words, production serves consumption needs. In a standard Supply – Demand framework this means that supply curve takes the shape of a horizontal line: for any given price level producers are willing to provide any amount of goods and services at the first order from the consumer side for a given price. The totally flat supply curve provides an indication of an assumption of perfect competition present in the market. Demand curve in turn, is considered vertical, i.e. treated in a short run, implying consumers are able to absorb the desired amount of goods at any price. Hence the equilibrium in such a system is being established as shown in the Figure 2 below.

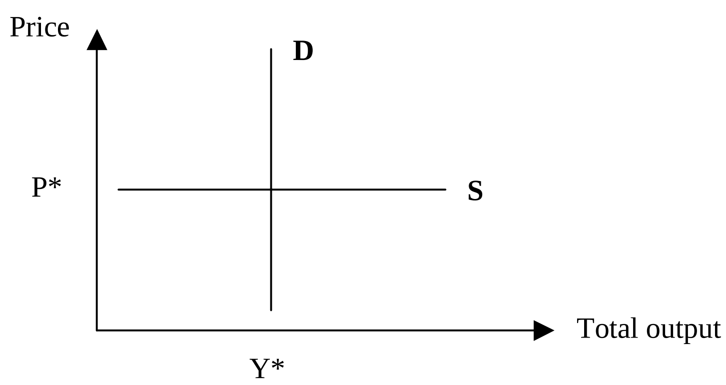


Figure 2 Supply – Demand System in Leontief Interpretation

However, several authors – for example, Ghosh (1958) – have suggested that an alternative point of view can be taken with the basic input-output data. This alternative interpretation relates sectoral gross production to the *primary* inputs, - that is, to the units entering the interindustry system as primary inputs. This approach is operationalised by shifting the point of view from a vertical (column-wise) one to a horizontal (row-wise) one. Instead of dividing each column of Z_j by the gross output of the sector associated with that column, we now divide each row of Z_j by the gross output of the sector associated with that row. Some authors use the notation $A^{->}$ to denote the latter direct-output coefficients matrix thus reflecting the nature of this transformation. However, in most of the literature one finds a notation involving the symbol '*B*' for this matrix. For the sake of simplicity and consistent notation, let us stick to the commonly used *B* denomination.

The motivation of this set of coefficients is as follows. From the basic flow table it follows that gross outputs can be calculated not only as row sums (interindustry sales plus sales to final demands), but also as column sums, provided that all elements in the payment sector are included. Now L_j[12] will be used to stand for the sum of all elements in the payment column for sector *j* (a value-added section; for example, labour inputs to sector *j*, imports used by sector *j*, government services paid for in taxes, capital paid for in interest, rental payments for land, entrepreneurship profits, etc.[13]). Algebraically this looks as follows:

$$[X_1\ X_2 \dots X_n] = i'Z + [L_1\ \ L_2\ \dots\ \ L_n] \qquad [4.3.1.]$$

Now the total gross output is presented as a row vector, which suggests that its elements are found via a summation down the columns of Z_j, after which V_n was added to the respective column sum. In matrix form we have: $X' = i'Z + V$.

Clearly, the parallel form in the demand-side model was $X = Zi + F$. Here X has been transposed; the vector of payments sector elements, *V*, is simply defined as a row vector. Now, using

$$z_{ij}/X_i = b_{ij}, \qquad [4.3.2.]$$

or

$$Z = X\,B \qquad [4.3.3.]$$

And, from the previous equations [2.2.1.] and [2.2.3.],

$$X' = i'XB + L \qquad [4.3.4.]$$

Since

$$i'X = X', \qquad [4.3.5.]$$

this becomes

$$X'\,(I - B) = L, \qquad [4.3.6.]$$

which is being reorganised to reap the resulting formula for the model (where $(I - B)^{-1}$ is also usually referred to as Ghosh inverse):

$$X' = L\,(I - B)^{-1}. \qquad [4.3.7.]$$

Given exogenously determined values for changes in the value added, say, wages due to trade union demands - ΔV, it becomes easy to find the associated values of $\Delta X'$ as

$$\Delta X' = \Delta L\,(I - B)^{-1}. \qquad [4.3.8.]$$

[12] Usually in the literature *V* is chosen to denominate the value added part of the input-output table, but here we shall stick to *L*-notation, to avoid the confusion with *V* variable that are to be introduced in the later chapter dealing with *vulnerability* analysis.

[13] For the numerical calculations provided hereafter in this chapter, the data for the Netherlands provided the value-added section with the following entries: Imports from extra-territorial sector; Imports from abroad; Trade margins; General taxes and subsidies; Product-related taxes and subsidies; Salaries and wages; Social security payments and Other income.

Thus the basic assumption of the supply-side approach is that stability is provided by the output distribution patterns. That is, if the output of sector *i* increases by 10%, then one should expect that the sales from *i* will also grow by 10%. That is, instead of fixed input coefficients, one assumes fixed output coefficients in the supply-side model. If we again refer to the Supply-Demand framework, this is translated into a graphical representation as the opposite to the Leontief demand-driven model. Here it is being assumed that in the short run demand is absorbing any amount of goods additionally produced at a given price: demand curve is horizontal. On the other hand, supply is limited at the level Y* (see Figure 3), and produces this amount of output at any price following welfare optimisation principle (setting the total output at a certain level): supply curve is vertical. As far as demand side has to adjust with respect to quantity, this type of model is considered supply-driven.

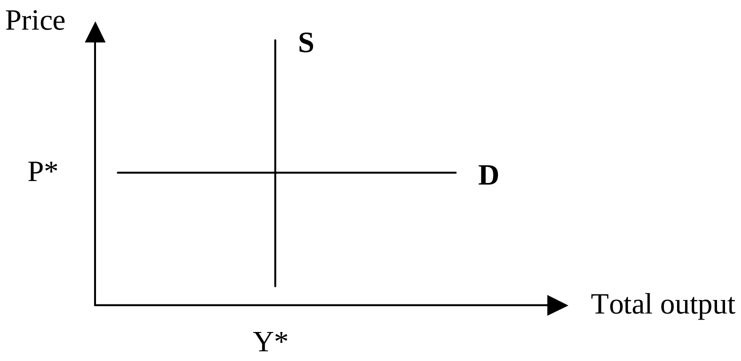


Figure 3 Supply – Demand system in Ghosh Interpretation

Let us consider the model specification in more detail. Denote the elements of $(I - B)^{-1}$ by β_{ij}. This is sometimes referred to as the output inverse, in contrast to the usual Leontief inverse, $(I - A)^{-1}$, which is also known as the input inverse. Then, for the *n*-sector case we have:

$$[X_1,...,X_n] = [L_1,...,L_n]\begin{bmatrix}\beta_{11} & ... & \beta_{1n} \\ ... & \beta_{ij} & ... \\ \beta_{n1} & ... & \beta_{nn}\end{bmatrix} \qquad [4.3.9.]$$

For sector *j* our model now gives:

$$X_j = L_1\beta_{1j} + L_2\beta_{2j} + \ldots + L_i\beta_{ij} + \ldots + L_n\beta_{nj} \qquad [4.3.10.]$$

Recall that the typical equation for the demand-driven model was:

$$X_i = \alpha_{i1}F_1 + \alpha_{i2}F_2 + \ldots + \alpha_{ij}F_j + \ldots + \alpha_{in}F_n \qquad [4.3.11.]$$

Therefore, looking at the typical solution of the supply-driven model, equation [4.3.7.], one can see that the effect of sector *j* output, ΔX_j of one unit (in money terms) change in the availability of primary inputs to sector *i* ($\Delta L_i = 1$) is given by β_{ij} which in continuous terms gives $\partial X_j/\partial L_i = \beta_{ij}$. It should be noted here that the order of subscripts in this case is the opposite of that for α_{ij} from the usual Leontief inverse.

By ranking these output inverse matrix elements, β_{ij}'s, it is possible to determine where primary factor constraints would have the greatest potential for limiting aggregate economic output as a result of an external shock to the economy. Verbally this means looking down the *j*'th column of $(I - B)^{-1}$ matrix, which allows identify supply linkages that have potential for significant limiting the output of sector *j*.

Again, comparing to the output multipliers of the Leontief inverse, - these are concerned with the sensitivity of aggregate gross outputs throughout the economy to changes in the strength of (exogenous) final demands for outputs. Here, the input multipliers in a supply-side model provide one way of measuring the sensitivity of aggregate gross outputs to changes in the availability of (exogenous) scarce resource inputs. Such view on these coefficients of the supply-side model will be considered useful in the paper in the interregional setting for natural disaster consequence analysis, in particular taking into account that the assumptions behind this model are more plausible than they are at the national level.

Generally speaking, production by a particular sector has two kinds of effects on the other sectors of the economy. If sector *j* increases its output, this means there will be increased demands from sector *j* (as a purchaser) for the products of sectors whose products are used as inputs in *j*. This is the direction of causation in the usual demand-side model. The term *backward linkage* is used to indicate this kind of interconnection between a particular sector and the sectors from which it purchases inputs. On the other hand, increased output of sector *j* also means additional quantities of products *j* that are available to be used as inputs by other sectors for their own production. That is, there will be increased supplies from sector *j* (as a seller) for those sectors which use good *j* in their production. This is the direction of causation in the supply-side model. The term *forward linkage* is used to indicate this kind of interconnection of a particular sector to those sectors to which it sells its outputs.

Comparison of the strength of backward and forward linkages for the sectors in a single economy provides one mechanism for identifying "key" or "leading" sectors in that economy and for grouping sectors into spatial clusters. If a backward linkage of sector *i* is larger than that of sector *j*, one might conclude that a money unit's worth of expansion of sector *i* would be more beneficial for the economy than an equal expansion of sector's *j* output in terms of productive activity that would be generated by it. Similarly, if a forward linkage of sector *r* is larger than that of sector *s*, it could be said that a money unit's worth of expansion of the sector *r* is more essential to the economy than a similar expansion in the output of sector *s* from the point of view of the overall productive activity it could support. The same should hold true for the case of contraction of the "key" industry: a money unit of decay in the production of the "key" sector would have a more severe effect on the whole economic system compared to the same money unit contraction in any other sector.

4.4 Critique of the Standard Input Output Analysis

Now let's get back to the basic general formula of the input-output modelling (borrowing formulas from the sub-title 4.1.)

$$X = (I - A)^{-1} F \qquad [4.4.1.]$$

defining the relation between the input requirements and the final demand for the products, and its derivative

$$\Delta X = (I - A)^{-1} \Delta F \qquad [4.4.2.]$$

defining the relation between the changes in input requirements which are seen to be caused by the changes in the final demand stand. We noted above that the final demand categories are viewed as being determined exogenously. The above formula thus allows us to assess the effect on the economy of a change in F. For example, we may study the effect of a change in the investment level due to a switch in spending, as a consequence of a natural disaster. Such changes in investments now are translated via the respective Leontief inverse $(I - A)^{-1}$, representing production multipliers, into changes in outputs of the industrial sectors in the region. It is important to bear in mind here that the term 'impact-analysis' is used when the exogenous change is caused by one "impacting agent" (or a small number of such agents) and when the changes are expected to occur in the relatively short run (e.g. next period). This means that such an analysis suits well for a relatively simple small-scale, short-term economic shock examination when production coefficients are supposed (and assumed) to stay unchanged. These general considerations obtain additional interpretations in the interregional model framework. In this case not only stability of the regional input coefficients is required (i.e. the elements $A^{ZH.ZH}$ and $A^{N.N}$ from the Table 3), but also of the interregional intra- and interindustry trade coefficients. Thus, both the structure of production in each region and the trade patterns between regions are perceived as 'frozen' in the model. Verbally this means that for a given level of final demands in either of the two areas, the necessary gross outputs in both regions can be found following the established input-output mode of production and distribution.

Once we introduce a vast, large-scale shock (for example, as we intend to do for the case of a major flooding in the South Holland province of the Netherlands), a number of basic input-output modelling assumptions become contradictory to the event realm. The scale of the disaster plays the key role in determination of the shape of the model. The standard model exercise can no longer bear the large-scale shock analysis. This stems firstly from the complexity of the economic consequence scenario(s), and secondly from the time range while the economy is found under effect. Let's discuss first the nature of the event. In the definition of the model in Chapter 3 we have mentioned a number of elements we would like to see included into the final modelling framework. These cause a number of consequences, which are too important to be avoided and naturally inevitable to be skipped. It suggests that we are definitely dealing with the case of complex causality, which, provided also logical intuition, puts under the question mark the stability of the production coefficients. Putting it in simple words, the event is too big to leave the behaviour of production patterns unchanged. This reminds of the Lucas critique, which discusses the instability of structural parameters [here: production coefficients] as a result of change in exogenous variables. This means, that for our case the assumption of stable coefficients becomes invalid.

On the other hand, when longer-term effects and broader changes are examined, we are basically dealing with projections and forecasting. For example, we are dealing with regional forecasting if we project the levels of final demand for all sectors in a regional economy for the coming years. As the period of projection gets longer and the number of assumptions increases, the accuracy of such an exercise tends to decrease. On the one hand this is a consequence of a diminishing ability to forecast the new final demands (i.e. the elements of F) accurately. On the other hand, the accuracy of forecasts also decreases because the coefficients matrix (i.e. the elements of the A matrix, and hence also the $[I - A]^{-1}$ matrix) will tend to be outdated.

Furthermore, another basic assumption behind the traditional input-output model is going to be violated from the very outset. Now the substitution effects are meant here. As we outlined in the problem setting, both production and consumption substitution possibilities in dealing with the issue are considered. Leontief does not allow such options for the standard operation of the input-output. This leads us to the conclusion that the model should be addressed differently.

Therefore, looking at the requirements we put forward in the model, it becomes neither possible nor reasonable to incorporate standard exercise of final demand change for the complex analysis of a vast long-term disaster we have in hand. To be able to proceed, we need to employ another technique for reflections of estimated direct economic damage into the input-output table. This is what literature refers to as 'table decomposition' method. It is rather unexplored, but nevertheless attempted to be utilised means by some authors (see e.g. Cole et al. 1993). Virtually, the method presupposes dealing with changes of single entries of the input-output table, either in coefficient terms or in absolute numbers. We consider it here to be more reasonable to go down to the absolute table entries, as they exactly reveal the volumes of transactions between various industries. These are the ones, which form the basis for the coefficient calculations, thus we see them as a natural source to form the main 'playground' for alterations. There, simple 'event logics' can be employed more easily than on the production coefficients. Otherwise it becomes rather insecure to use the assumptions over the coefficient changes, as in fact that's what we are curious about in the end: are structural parameters changed and how much. Let us explain it in more detail how we suppose the method to work joining it together with the requirements we impose on the model.

5 The Case Of Krimpen: The Data

A number of challenges exist for the practical implementation of the described model. Therefore it is important to have a fair coupling of theory and reality. To do this we need to combine the effects of a hydrological model with an economic model. The literature on earthquake hazard modelling (French, 1998) suggests the use of a conceptual framework, which links physical damage to economic functions using the spatial relation both have in common. Translating this to the case of a large-scale flood, this means that we can design a conceptual model depicted in Figure 4.

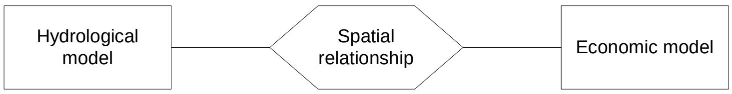


Figure 4 Conceptual model GIS-analysis (French 1998)

At our disposal we have a data-set which is applied in the HIS-SSM (Vrisou van Eck and Kok 1999, p. 4-5) damage model. The dataset is generated with the D&B Marketeer & Prospector. The Dun & Bradstreet data-set contains information on location, size (number of employees) and sort of economic activity (per 4 digit SIC-code) of any place in the Netherlands for the year 2002. This data-set is used as an explicit link between the spatial characteristics of both the hydrological and the economic model. The spatial element is a six-digit zipcode. Combining them results in a database in which we have, per zipcode, data and economic activities (sort of activity and size of activity). Besides this, we have a dataset of all zipcodes in the Netherlands.

Apart from this spatial data, we also need economic data to carry out the analysis. The data-requirements we face are basically the same as in (Rose, 2002) in which a regional transactions matrix is used to model the relations in an economy. We use a bi-regional transactions matrix in which the economy is modeled according to a bi-regional structure, for Zuid-Holland and the rest of the Netherlands. The transactions table was constructed according to a semi-survey method (Eding, Stelder et al. 1995), in which survey methods were combined with technical methods to construct the transactions table[14].

We have stated that a consistent measure of damage to households is the “stock” measure and that the measure for business activities is the “flow” measure. The damage to households is calculated by the HIS-SSM damage assessment program, damage to firms by our economic model, based on Input-output modelling. The latter will be presented in Section 6.

Damage to households refers to the value of replacement of the destroyed objects. In HIS-SSM we take the damage to <u>infrastructure, buildings and urban property</u>. The direct cost to households based on HIS-SSM mounts to 64 560 mln (Dutch Guilders). For details see Appendix 1.

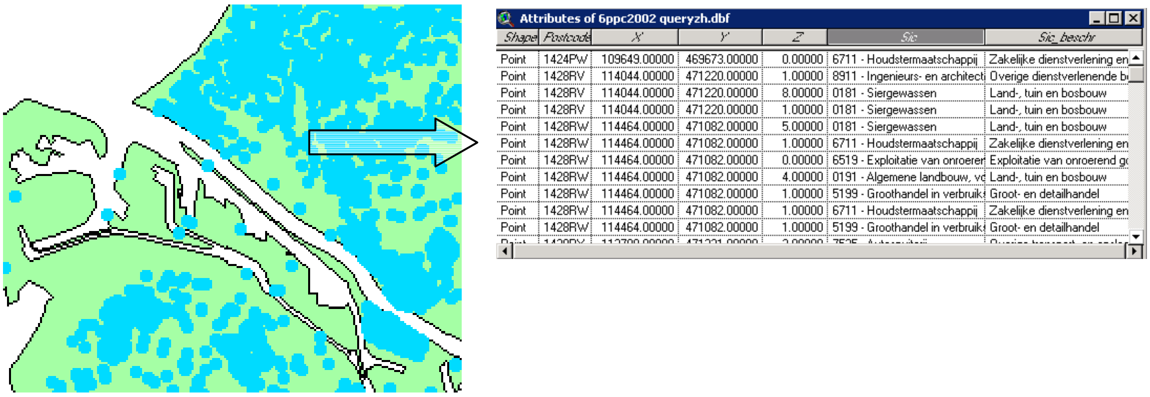
5.1 Geographic Information System

The effects of the hydrological model and the D&B data are downloaded into a GIS.

Figure 3 shows the operational implementation of the conceptual model of Figure 5. It shows how a link can be made between data on a micro-level and our data on a more aggregated sector level. Each entry in the table is of a disaggregated micro-level character. The blue dots represent the centres of this zipcode. The description of the zipcode is given in column two of the table, and the X and Y

[14] The table itself was set up with data in the time-period 1992-1997. This means that the precise data on the table may be somewhat outdated, however the literature (Eding, Stelder et al. 1995) suggests the main characteristics of the economic structure essentially remain unchanged.

coordinates are given in respectively column 3 and 4. Column 5 (Z) represents the number of employees and columns 6 and 7 describe the type of economic activity.



Attributes of 6ppc2002 queryzh.dbf

Shape	Postcode	X	Y	Z	Sic	Sic_beschr
Point	1424PW	109649.00000	469673.00000	0.00000	6711 - Houdstermaatschappij	Zakelijke dienstverlening en
Point	1428RV	114044.00000	471220.00000	1.00000	8911 - Ingenieurs- en architecti	Overige dienstverlenende b
Point	1428RV	114044.00000	471220.00000	8.00000	0181 - Siergewassen	Land-, tuin en bosbouw
Point	1428RV	114044.00000	471220.00000	1.00000	0181 - Siergewassen	Land-, tuin en bosbouw
Point	1428RW	114464.00000	471082.00000	5.00000	0181 - Siergewassen	Land-, tuin en bosbouw
Point	1428RW	114464.00000	471082.00000	1.00000	6711 - Houdstermaatschappij	Zakelijke dienstverlening en
Point	1428RW	114464.00000	471082.00000	0.00000	6519 - Exploitatie van onroerer	Exploitatie van onroerend g
Point	1428RW	114464.00000	471082.00000	4.00000	0191 - Algemene landbouw, v	Land-, tuin en bosbouw
Point	1428RW	114464.00000	471082.00000	1.00000	5199 - Groothandel in verbruik	Groot- en detailhandel
Point	1428RW	114464.00000	471082.00000	1.00000	6711 - Houdstermaatschappij	Zakelijke dienstverlening en
Point	1428RW	114464.00000	471082.00000	1.00000	5199 - Groothandel in verbruik	Groot- en detailhandel

Figure 5 The link between spatial and economic data

The data on a micro-level can thus be ordered according to the SBI-code, which is used in the transactions tables. This is performed by applying a reclassification schemes to transform SIC data into SBI data[15].

With the appropriate GIS software we now can make an overlay to select the zip codes, which are hit by the flood[16]. This in turn will provide us with the number of employees that are affected by the flood.

5.2 Coupling of GIS and IO databases

In the following an overview of our data is presented (see Figure 6). Several elements are worth mentioning. On top of the flowchart we find the four datasets, which are used in this study, whereas in rectangles the operations we apply to the data are represented. These are: a join between two datasets and an overlay between two spatial entities.

The *zipcode file* we use contains the centers of every zipcode in the Netherlands. We use 6 digit zicodes (like 7521 JL). It is the only georeferenced file at our disposal, which makes it one of the cornerstones of our analysis.

Employment per site is the fundament of the thematic data in our case. This data is generated by the Dun & Bradstreet marketing prospector (version 2002/1). It contains information on a breakdown of employment into activity per each 6-digit zipcode. Economic activity is ordered by a 4-digit SIC code (Standard Industrial Code). We judge this information on employment as not very reliable. Especially the data in Commercial Services (Zakelijke dienstverlening) proved to be wrong. We performed major adjustments.

The *hydrological model* data file is the result of a simulated flooding in the Province of Zuid-Holland following a dike breakage near Krimpen ad IJssel. The data was provided by WL Delft Hydraulics.

[15] SBI Standaard Bedrijven Indeling, a Dutch classification system for economic activities. Description of these schemes is available on the internet www.cbs.nl

[16] Arcview (http://www.esri.com/software/arcview/index.html)

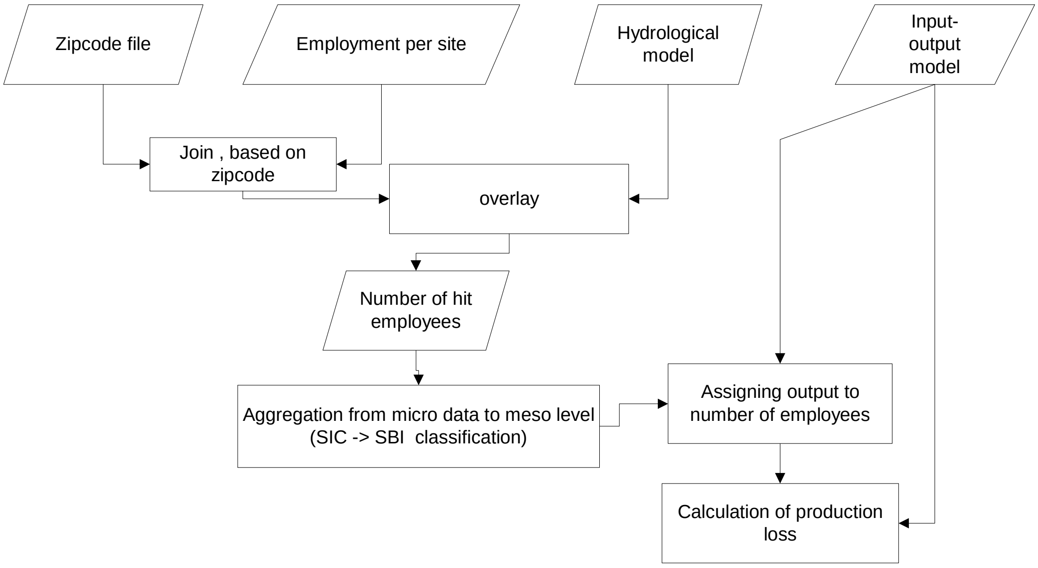
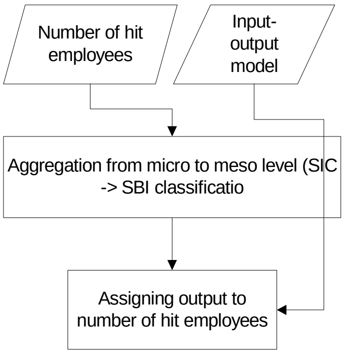


Figure 6 Flowchart of data and data manipulations

The input-output model we use is based on the transactions table that was constructed by Groningen University and the Central Bureau of Statistics. The table contains information on the 1992 transactions in a SBI format. With regard to the validity of the dataset and the use of the employment data for the year 2002, we assume (following Eding, Stelder et al. 1995) that economic structure remains constant in time. We acknowledge that this time-inconsistency of data sets might significantly undermine the accuracy of the obtained results.

6 Business Disruption And Indirect Effects



First of all we take the number of affected workers as our starting point, aggregated into SBI code and obtain the vector of lost employment by sector ε, where each coefficient is calculated by dividing the number of employees in a sector that are affected by the flood, by the total number of employees in a sector in the province.

$$\varepsilon_j^{ZH} = \frac{N_j^{affected}}{N_j^{ZH}} \quad [6.1.]$$

By doing so, we aggregate micro-data to a meso and a macro level. The result of this process is a proxy for business disruption that can be used as a starting point to estimate indirect damage.

6.1 Implication of the adapted models: asymmetric shock

There exist various methods for asymmetric shock implementation. A promising option is offered by Cole et al. (1993) offers a certain device to formalise the interference into the tables. He introduces what he calls an Event Accounting Matrix (EAM) to trace all the changes induced on the transactions matrix. It is meant to absorb the reflections of the changed situation in the production sector. Still the construction of EAM's is not clear enough.

Provided the uncertainty about the existing formal ways of dealing with the aims we have in mind, we proceed with building of our own model. The initial impulse should be imposed on the whole system, and we model it like Rose. Literature (Rose, 1998) suggests, that employment loss coefficients (presented in the previous section) can in principle be projected onto the change in output assuming that sectoral output is evenly distributed among employees. Therefore, the chain of causality in our modeling case goes as follows:

$$\Delta X_{direct} \rightarrow \Delta F \rightarrow \Delta X_{indirect}$$

Production changes are assumed to cause final demand changes. In this case output loss is only an underlying 'latent' variable, making us run into the problem of direction of causality. Here we make an assumption, which is actually in odds with the demand exogeneity assumption of the conventional input-output model. Nevertheless we relate the loss estimation data to the final demand dimension of the transactions table. This means that we can model our <u>initial impulse</u> as follows to assess the effects on production inside and outside the region.

$$\Delta F_j = \varepsilon_j^{ZH} \cdot (F_j^{ZH})_0 , \quad [6.1.1]$$

where ΔF_j is the final demand change for sector j;
$(F_j^{ZH})_0$ is the pre-disaster final demand level for sector j;
ε_j^{ZH} as defined by formula [6.1].

6.2 Implication of the adapted models: production 'bottlenecks'

Moreover, we have also mentioned the appearance of the so-called 'key industries'. Here the situation may evolve in at least two steps. First, most probably, those 'key industries' may appear to be the ones causing production 'bottlenecks', thus triggering over-proportional losses in other industries. Therefore, this is reflected in the tables as sharply reduced transactions between the industries mostly dependent on such key sectors[17]. Later, as the system adapts, those ‘bottlenecks’ are cured with finding new suppliers, new transportation routes and/or modes or even new inputs, thus restoring resiliency of the system.

6.3 Implication of the adapted models: lifeline system

One of the crucial assumptions should be made about the lifelines, as their partial disruption brings up larger negative effects than can be viewed directly from the input-output table[18]. As indicated in Tierney and Nigg (1995), “data on the business impacts of the 1993 floods indicate that lifeline service interruptions were widespread, were perceived by business owners as very disruptive, and were a much more significant source of business closure than actual physical flooding”.

As done by Eguchi et al [1997] ‘lifeline disruption effect’ functions can be estimated for each branch of industry of the type

$$y_{n(t+1)}=\beta\cdot y_{n(t)}\ , \qquad [6.3.1.]$$

where β stands for industry sensitivity for the loss of e.g. energy supply. Although it goes quite straightforward for the case of one lifeline breakdown, several lifeline element disruptions is not that easy task to reflect. The reason is non-linearity of those effects. Most probably, multiple effects are not additive, and this poses another question for a more thorough research and business surveying.

Alternatively, Okuyama et al [2003] offers to model lifeline collapse via the imposition of final demand drop impulse due to the interruption in lifeline services on the coefficient-adapted input-output table.

In our empirical example, although we recognise the importance of this factor and the vulnerability of the indirect loss estimation upon it, we are not yet able to evaluate lifeline disruption effects due to the lack of basic input information for at least the order of magnitude for its direct loss.

6.4 Implication of the adapted models: substitution effect

Another important assumption should be made about the substitution effects, both production and consumption. After the initial shock to the economy the system shall adjust and start to recover. The most vivid example of this behaviour is production substitution when the producers outside the flooded area overtake a part of lost production. This will obviously moderate the total loss figures as economic activity revives, though spatially shifted.

It should fairly be noticed here that production substitutability (or as sometimes referred to as transferability as in Parker, 1987) highly depends on the excess production capacities of the factories in the areas outside the affected region. This issue also needs additional attention before industry substitution coefficients are obtained.

Consumption shifts may be caused by twofold effect. First, the dropped production volume in the flooded area causes natural proportional drop in the exports. On the other hand, domestic producers may as well shift their sales from the foreign markets to the domestic markets to satisfy the appeared goods vacuum at home. The dimension of these shifts is not straightforward to forecast. Anyway, one can try to make ‘best guesses’ by starting from assumptions like exports are reduced proportional to the lost production and that in addition domestic producers shift away a part of their exports volumes to the home markets.

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[17] There has been no unanimity over the unified definition of a ‘key sector’ in the literature (see for example Beyers 1975, Hazari 1970). This therefore still provides enough space for free interpretation of the concept. As the first characteristics revealing the possibility for the existence of the ‘key sectors’ one should consider backwards and forwards effects. When a sector has the figure for both effects relatively high, there are grounds to conclude it’s an expected candidate for a ‘key industry’ nomination.

[18] As mentioned in Chapter 3 on p.6, lifelines are defined as a set of infrastructure, communication and utilities services.

6.5 Social Aspect

One of the complex sets of assumptions refers to the ‘social sphere’. In fact, a broader view over these characteristics one can extract from the extended version of an input-output table, the Social Accounting Matrix, SAM. Generally speaking, this table provides an insight into the way by which income is earned and spent in the private and public sector. So, one can gain en extended knowledge about the welfare distribution across the country for different population strata. Anyway, even in the input-output table one can see changes in the composition of the social layers. Especially, in the case when we would like to reflect the increased number of unemployed, resulting in government increased spending on the social benefits, as well as other costs associated with the flood. These may be costs of population evacuation, provision of extra (temporary) dwellings for the refugees, recovery programmes, etc. These measures, in fact, can provide a good ‘boost’ or a starting point for the economic recovery after the flood disastrous consequences. Nevertheless this might partially occur at the expense of the future generations of taxpayers, who will finance the government debt arising from (possibly outstanding) budget deficits[19].

[19] Basically, the financing of costs of direct damage will be split between the government and the private sector, represented by the insurance companies.

7 The Case Of Krimpen: Calculations

So far we have discussed both our conceptual vision of the economic cost estimation model and the technical means to provide the solution to that model. Now we have to join them together to have an operational model to work with.

For our empirical exercise we are forced to face a number of problems. One of the major ones: how to introduce the business disruption estimates into our table. We do not have information about the intensity of transactions between the flooded area, which stops producing, and the remaining province of South Holland. This in effect becomes the core issue of the adaptations to be performed during the 1st stage. There are a number of modelling possibilities in the attempt to overcome this difficulty.

As far as the business interruption damage is assessed and translated into the loss of flow of produced outputs, it is ready to serve as an input for input-output table transformations. There are two possibilities to assess the indirect loss: via the standard model multiplier or with the new adaptations of the input-output framework. The exercises on the latter model is of most interest here; nevertheless we will provide the estimation with the standard model formulation to check for the estimation differences. The standard indirect effects in the course of calculations are obtained with the help of the IRIOS programme20. Let us then describe how we implement the adapted table transformation mechanisms for the case of flooding in South Holland. After that the calculations on the case will be presented. While modelling we discriminate between 3 scenarios. Each case consists of 3 steps (and the last step in each scenario – of 4 alternatives). For all the cases we look at the loss as a result of 2 years of economic system adaption to the initial flood shock. Let us go through the whole process of indirect effect calculation by scenario. This will clearly mark the differences between the modelling options and expected results.

7.1 Scenario I [Standard exercise]

This scenario is presented as a 'point of departure' for the comparison of loss estimate results of various scenarios. It genuinely presents the procedure as it might be modelled using the (rigid) standard assumptions of the conventional input-output model.

Step 1. As production stops in the flooded area, it causes the decrease of output in the province (direct effect – production interruption). The estimate of direct production activity interruption is provided for each sector in terms of fraction of lost employment in the province of South Holland. This will be introduced into the change of final demand (as a consequence of output drop) and indirect multiplier effects will work out.

$$X^{St}_0 \rightarrow X^{St}_1: \qquad \Delta X_{indirect} = (I - A)^{-1}\, \Delta F_{direct} \qquad [7.1.1]$$

As a result decrease of intermediary output level in the South Holland province and in the rest of the country will be observed. Consequently, it will also get reflected in the decreased employment throughout the country and changed imports.

Step 2. Induced effects on the economy are caused by lifeline collapse, which imply extra output losses to the remaining activities. Additional depression of activity happens 'on top' of the initial shock during the first year after the start of the flood and is introduced in the model via the final demand decrease as a result of lifeline service interruption.

$$X^{St}_1 \rightarrow X^{St}_2: \qquad \Delta X_{induced} = (I - A)^{-1}\, \Delta F_{lifeline} \qquad [7.1.2]$$

The calculations for this stage demand additional information about the degree of dependability between the output produced and lifeline services. Unfortunately such information is far more limited

[20] The programme is developed at the University of Groningen, the Netherlands. Homepage in the Internet http://www.regroningen.nl/irios/irios.html

and thus the calculations for the additional loss induced by the lifeline system disruption will be omitted for the time being for all scenarios.

Step 3. In the second year after the flood production substitution is assumed to take place as a manifestation of economic resiliency. This means that lost production of goods in the South Holland during the first year after the flood is overtaken by the same industries found in the rest of the country during the next year. The degree of substitution depends mainly on the existing spare production capacities of factories, and the estimation of those capacities requires special surveying. Nevertheless we can make some assumptions concerning substitution and consequently a number of alternative outcomes. As far as the 'rest of the Netherlands' is quite highly aggregated to the industry level, such general assumptions look reasonable. We will compute the effect of production transfer for all sectors of 10%, 20%, 50% and 100% of the initial shock[21]. This means that the following change in final demand will occur: the respective percentage of lost final demand in the province of South Holland in stage 1 will now be regained in the rest of the country.

$$X^{St}_2 \rightarrow X^{St}_3: \qquad \Delta X_{substitution} = (I - A)^{-1} \Delta F_{substitution} \qquad [7.1.3]$$

Overall standard input-output model exercise is agreed to overestimate the loss estimation [see for example Rose and Lim 2002]. This stems from the unchanged multipliers, which might be assumed decreased as production drops and thus certain fraction of the transactions 'leaks out' of the economy. Another drawback of this scenario is the assumed rigidity of industry production functions. Here they stay constant after the flood for the producers both in South Holland and in the rest of the Netherlands. Alternative assumptions will be discussed in the proceeding two scenarios.

7.2 Scenario II [Adjusted model for economy resilience]

In order to keep the results of different scenarios comparable, the sequence of events is assumed the same as described in the standard exercise case. The difference will lay in the change (or rather relaxation) of some assumptions behind the standard input-output model.

Step 1. Production stops in the flooded area, thus causing the decrease of output in the province of South Holland (direct effect – production interruption in the affected area). As a result production functions in the province of South Holland change. In order to reflect a higher degree of resiliency of the system, the lost input purchases from the South Holland are compensated by imports. After this table adjustment the indirect multiplier effects will be obtained. Initial shock is again modelled via the projection of lost employment into the respective decrease of final demand for each sector the South Holland, as here final demand requirements are no more possible to fulfil as a result of production decay in the flooded region.

$$X^{A}_0 \rightarrow X^{A}_1: \qquad \Delta X_{indirect} = (I - A_{Ms})^{-1} \Delta F_{direct} \qquad [7.2.1]$$

It will have the following consequences: decreased intermediary production level in the South Holland province and in the rest of the country, decreased employment throughout the country, changed imports. Expectedly this figure should be smaller than that of step 1 in scenario I.

Step 2. The evolvement of the induced loss estimation would be the same as laid out in the standard modelling scenario, but as mentioned there we are not performing these calculations here for the lack of input information.

Step 3. Following the initial flood shock economy responses with production substitution and lost output in the South Holland is overtaken by the respective industries in the rest of the country during the second year. This shift implies a number of adjustments. Because we are found in the bi-regional input-output framework each input coefficient is split into two places of origin: South Holland and the rest of the country. Thus, in the after-flood situation, the increased input requirements in all other

[21] These in a sense simplified production substitution assumptions also will help in providing a comprehensive comparison between the modeling scenarios. By means of imposing the **same** initial shock and the **same** production transfer degree in each scenario one is able to clearly distinguish between the strength of the resulting effects for each one.

provinces cannot be proportionally obtained from the South Holland as the province should recover itself, but these additional inputs will rather come from producers in the rest of the country. Hence the change in production function reflected in the growth of the input coefficients obtained from the rest of the country relative to the inputs obtained from the flooded province. The assumed levels of production transfer are the same as in the previous scenario leading to 4 alternative outcomes.

At the same time the positive final demand impulse is given to the economy (with the new substitution-adjusted structure). Hence, final loss figure will be more moderate than the effect of the initial shock. This stage impact is calculated as follows:

$$\boldsymbol{X^A_2 \rightarrow X^A_3}: \qquad \Delta X_{substitution} = (I - A_{Ps})^{-1} \Delta F_{substitution} \qquad [7.2.2]$$

7.3 Scenario III [‘Bottleneck’ scenario]

Contrary to the previous scenario, this is the one for the ‘black day’ case where economic system is very restricted in response to the large negative shock. Following the similar steps as before we arrive at the subsequent calculation procedure:

Step 1. this scenario reflects a result of production drop as change in relationships between the economic actors. But in this case the response of the industries in the adjacent areas to the flood circle will be much more restricted: we assume here that all the industries in the South Holland will be restricted to the level of the sector mostly hit by the disaster. This might temporarily happen due to the limited access to the area, time lag needed to establish new contacts to replace lost suppliers and consumers, etc. Adjusted table becomes balanced through the built up inventory for the excess supplies as well as indebtedness for the increased imports to satisfy the final demand. Thus trading pattern between the flooded province and the rest of the Netherlands will change, while the production functions will remain constant. We will impose the final demand shock on the new adjusted table:

$$\boldsymbol{X^B_0 \rightarrow X^B_1}: \qquad \Delta X_{indirect} = (I - A_R)^{-1} \Delta F_{direct} \qquad [7.3.1]$$

Thereafter indirect multiplier effects will get obtained and expectedly the consequences on the categories of interest should be higher than in the previous ‘economy resilience’ scenario.

Step 2. idem scenario I.

Step 3. During the recovery phase of this scenario initially restricted economic system has more room for expansion. Firstly, the maximum loss clause can be relaxed now as after a year the remaining capacity of South Holland can be restored to the ‘natural’ distortion level, as well as the companies in the rest of the country will tend to increase output, thus creating ‘production transferability’ (this substitution effect will work as described in scenario II). These assumptions call for another adaptation of the economic structure. The balancing of the table will happen through the inventory and imports adjustments. The impulses of the increased final demand in the rest of the country will be imposed on the renewed table.

$$\boldsymbol{X^B_2 \rightarrow X^B_3}: \qquad \Delta X_{substitution} = (I - A_{Ps})^{-1} \Delta F_{substitution} \qquad [7.3.2]$$

It’s worth noting here that as far as the economy has more potential to restore it’s activity, the recovery pace might happen with a relatively higher speed.

It is important now to make a few notes. Taking into account the complexity of the tasks and assumptions made in the course of model development, one should be really cautious in interpretation given to numbers. In reality we are forced to observe the end result of an event, which actually consists of multiple effects produced by multiple causes. Therefore, in order to be able to keep a reasonable level of control over such complex situation, one should be as sure as the ‘best of the knowledge’ allows about the assumptions taken, and of course the mode of implementation of those assumptions. Alternatively in our example for the sake of tracing the ‘cause-consequence’ relationships we discriminate step by step between the kinds of consequences created by specified impact.

Another note attributes to the methodology implementation. In our case methodology maturation goes ahead of data. The calculations on our case can be improved by provision of the lacking gaps in our input data. In particular, it refers to the availability of employment loss estimation as opposed to the value-added estimate. Moreover, as mentioned before, this gap can be closed by the additional data on sectoral output dependence on lifeline services.

7.4 Discussion Of Results

The main reference category for our economic loss evaluation is a change in value added. This acts as a close proxy for a change in GDP, which is also expressed in value-added terms. Therefore changes in production are presented here for illustration purpose. For a reference to the obtained results consult Appendix 2-4. The tables there are given per scenario.

First of all let's discuss the order if magnitude for the estimated loss figures. Step one presents the figures of the impact brought by the shock initiated by the flood. Scenarios I and II suggest the initial total loss might overshoot -5%, and the model where South Holland province responses with a highly restricted output to the shock provides with the figure almost twice as that –9,7% measured in value added terms.

As another general observation one can at once notice that as expected scenario II portrays slightly lower loss figures than the ones obtained as a result of standard input-output model use. In turn, 'bottleneck' scenario presents really a more depressive picture.

As we zoom closer and explore first the recovery pace, the conclusion is: the value added in nominal terms happens to change for all scenarios for the respective step on approximately the same level. Only for the scenario I revival of activity occurs slower. Thus, if we look now at the final loss estimate (the value added change for step 3 for each alternative with respect to the initial pre-disaster value-added level), we can see that the results for scenarios I and II go very close together. The difference is measured in half-percent, which only might give an indication about the direction of difference, but is insignificant in nominal terms.

Virtually, the differences in final step results stem from the differentials between the scenarios in the 1st step, where the initial negative flood shock is modelled. This indeed gives a much lower loss for the bottleneck case – 9,7%, whereas standard estimate mounts to -5,77%, and the adjusted for the initial shock scenario –5,34%. Therefore, it can be concluded from our exercises that the final loss estimate depends mainly on the degree an economic system is able to adjust immediately as disaster outbreaks.

As for the recovery path: it is interesting to notice the effect of various levels of production overtaking by the industries in the rest of the country. Whereas 10% and 20% initial shock substitution does not bring much relief to the system for all scenarios, 50% and especially 100% substitution make a difference. Then, for the standard modelling case 50% substitution corrects initial disruption from –5,77% to –3,08% and 100% production transfer – down to –0,40%. Similar results are obtained for the adjusted scenario II. Only for the restricted 'bottleneck' model the initial loss estimate is substantially reduced in the occasion if the producers in the provinces outside the flooded region are flexible enough to overtake 100% of the lost output in South Holland. Still, even such extreme behaviour would result in –4,32% loss of value added compared to the pre-disaster level. In general, we can conclude so far that it is hard for an economy to recover if it operates at its full capacity level prior to a disaster. In this case there is no room for production substitution and expansion to take place. Thus, it might trigger the ability of the system to adjust.

Once again, the results presented in this section are still in a sense overestimated, as the important factor of lifeline disruption effect has not been included into the model. It would inevitably produce higher loss estimates. Nevertheless, the exercised example sheds light on the outcome of different system behaviour scenarios and resilience capacities of the economy.

Another interesting observation concerns the behaviour of production: it drops more relatively to the value-added only for the adjusted scenario in step 1, but mostly it goes ahead in recovery. It also looks more likely to reach faster the pre-disaster level than value added. This is especially true as we look at the 100% substitution case results throughout the models. In addition a more important conclusion to be drawn from the production changes is the economic activity redistribution in the country. As a result of the initial shock and after-phase system adaptations, the relative weight of output in the ‘rest of the country’ tends to grow relative to the weight of flood-affected South Holland production. This clearly suggests the evolvement of a new structure of the economic system of the whole country.

8 Conclusions

With regard to methodology development we made a step forward. Have we succeeded in the attempts of filling the gaps of the existing disaster modelling in the research? In this respect we have a number of preliminary conclusions. We would like to stress the following points:

1) The problem of double-counting poses a significant threat to overestimation of the overall damage. We expect this confusion to be resolved when one explicitly discriminates between stock and flow measurements. Direct damage based on flow estimation gives sound grounds for safe business interruption and indirect damage assessments.

2) Standard input-output model is given more flexibility: it is adapted for the modelling needs of a large-scale flooding disaster. Such crucial elements as ‘production bottlenecks’, substitution effects and time dimension are included into the analysis of the indirect effects in an economy.

3) Pivotal point of the adaptations performed: technology is assumed to change due to a vast devastating event of flood. On the later stages economy will tend to adjust, responding with production substitution.

4) Practical problems faced during the empirical estimation for the case of a large-scale flooding in the province of South Holland involve the joining of data between different data sets (geographically referenced GIS and bi-regional input-output table reflecting the structure of economic relations). Providing the employment data with the additional spatial dimension forms the core element of coupling different data sets in our research.

5) Empirical economic loss calculations for our case study were performed for the initial shock phase and recovery phase. Standard modelling is compared to two alternative input-output table transformation models. As a result it appeared that a significant difference between the final loss estimates depends substantially on the initial response of the economy to a shock, as well as on the transferability level within the system.

Further possibilities for methodology extensions and empirical applications should preferably involve software developments. More is to be done in the formalisation of the input-output table transformations. Next steps need to be based on additional information concerning induced lifeline disruption and production substitution possibilities. This will bring significant downwards corrections to the total economic loss estimates.

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Appendix 1 Direct damage to consumers (incl. government)*

Model : Standaardmethode
Dataset : SSM100NL
Scenario : Krimpen ad IJssel

Category	Damage (Mfl)	Number of affected units	
Urban property	191.78	81600000	[m2]
Airports	825.29	915000	[m2]
Highways	134.17	336000	[m]
Provincal roads	45.48	174000	[m]
Other roads	317.44	3580000	[m]
Railroads	50.63	153000	[m]
Trasnportation vehicles	3046.46	357000	[units]
Waterworks:			
Gemalen	17.61	132	[units]
Zuiveringsinstallaties	1.35	19	[units]
Buildings:			
Eengezinswoningen	27945.39	233000	[units]
Laagbouwwoningen	6267.95	54700	[units]
Hoogbouwwoningen	4980.16	55900	[units]
Middenbouwwoningen	5987.31	70500	[units]
Total	64560.84		

* in millions of guilders, basic prices of 1992. [1 Euro = 2.21 Guilders]

Appendix 2 Modelling results: Scenario I [Standard exercise]*

		Scenario 1					
			value before the impulse	Direct impulse	Indirect effect	Total effect of the impulse	value after the impulse
STEP 1: Initial shock to the economy after the flood		*Production (South Holland)*	*235341*	*-40679*	*-9037*	*-49716*	*186425*
		Production (rest of the country)	*790058*	*0*	*-8491*	*-8491*	*781567*
		Total production	1025399	-40679	-17528	-58207	967992
		% production change (w.r.t. pre-disaster output)					-5,60
		% prod. change during the step				-5,68	
		Total value added	**593216**			-34222	**558877**
		% value added change (w.r.t. pre-disaster v.a.)					**-5,77**
		% v.a. change during the step				-5,77	
STEP 3: Recovery (production substitution scenarios)	10%	*Production (South Holland)*	*186425*	*0*	*199*	*199*	*186624*
		Production (rest of the country)	*781567*	*4067*	*1531*	*5598*	*787165*
		Total production	967992	4067	1730	5797	973789
		% production change (w.r.t. pre-disaster output)					-5,03
		% prod. change during the step				0,60	
		Total value added	**558877**			3185	**562062**
		% value added change (w.r.t. pre-disaster v.a.)					**-5,23**
		% v.a. change during the step				0,57	
	20%	*Production (South Holland)*	*186425*	*0*	*401*	*401*	*186826*
		Production (rest of the country)	*781567*	*8140*	*3072*	*11212*	*792779*
		Total production	967992	8140	3469	11609	979605
		% production change (w.r.t. pre-disaster output)					-4,47
		% prod. change during the step				1,20	
		Total value added	**558877**			6376	**565253**
		% value added change (w.r.t. pre-disaster v.a.)					**-4,70**
		% v.a. change during the step				1,14	
	50%	*Production (South Holland)*	*186425*	*0*	*998*	*998*	*187423*
		Production (rest of the country)	*781567*	*20339*	*7674*	*28013*	*809580*
		Total production	967992	20339	8672	29011	997003
		% production change (w.r.t. pre-disaster output)					-2,77
		% prod. change during the step				3,00	
		Total value added	**558877**			15928	**574805**
		% value added change (w.r.t. pre-disaster v.a.)					**-3,08**
		% v.a. change during the step				2,85	
	100%	*Production (South Holland)*	*186425*	*0*	*1998*	*1998*	*188423*
		Production (rest of the country)	*781567*	*40679*	*15342*	*56021*	*837588*
		Total production	967992	40679	17340	58019	1026011
		% production change (w.r.t. pre-disaster output)					0,06
		% prod. change during the step				5,99	
		Total value added	**558877**			31858	**590735**
		% value added change (w.r.t. pre-disaster v.a.)					**-0,40**
		% v.a. change during the step				5,70	

* in millions of guilders, basic prices of 1992. [1 Euro = 2.21 Guilders]

Appendix 3 Modelling results: Scenario II [Adjusted model]*

		Scenario 2					
			value before the impulse	Direct impulse	Indirect effect	Total effect of the impulse	value after the impulse
STEP 1: Initial shock to the economy after the flood		*Production (South Holland)*	235341	-40679	-16599	-57278	178063
		Production (rest of the country)	790058	0	-8440	-8440	781618
		Total production	1025399	-40679	-25039	-65718	959681
		% production change (w.r.t. pre-disaster output)					-6,41
		% prod. change during the step				-6,41	
		Total value added	**593216**			-31774	**561442**
		% value added change (w.r.t. pre-disaster v.a.)					**-5,34**
		% v.a. change during the step				-5,36	
STEP 3: Recovery (production substitution scenarios)	10%	*Production (South Holland)*	178063	0	555	555	178618
		Production (rest of the country)	781618	4067	3295	7362	788980
		Total production	959681	4067	3855	7922	967598
		% production change (w.r.t. pre-disaster output)					-5,64
		% prod. change during the step				0,83	
		Total value added	**561442**			3179	**564621**
		% value added change (w.r.t. pre-disaster v.a.)					**-4,80**
		% v.a. change during the step				0,57	
	20%	*Production (South Holland)*	178063	0	757	757	178820
		Production (rest of the country)	781618	8140	6628	14768	796386
		Total production	959681	8140	7380	15520	975206
		% production change (w.r.t. pre-disaster output)					-4,89
		% prod. change during the step				1,62	
		Total value added	**561442**			6364	**567806**
		% value added change (w.r.t. pre-disaster v.a.)					**-4,26**
		% v.a. change during the step				1,13	
	50%	*Production (South Holland)*	178063	0	1333	1333	179396
		Production (rest of the country)	781618	20339	16779	37118	818736
		Total production	959681	20339	18119	38458	998132
		% production change (w.r.t. pre-disaster output)					-2,66
		% prod. change during the step				4,01	
		Total value added	**561442**			15915	**577357**
		% value added change (w.r.t. pre-disaster v.a.)					**-2,65**
		% v.a. change during the step				2,83	
	100%	*Production (South Holland)*	178063	0	2310	2310	180373
		Production (rest of the country)	781618	40679	34295	74974	856592
		Total production	959681	40679	36607	77286	1036965
		% production change (w.r.t. pre-disaster output)					1,13
		% prod. change during the step				8,05	
		Total value added	**561442**			31852	**593294**
		% value added change (w.r.t. pre-disaster v.a.)					**0,03**
		% v.a. change during the step				5,67	

* in millions of guilders, basic prices of 1992. [1 Euro = 2.21 Guilders]

Appendix 4 Modelling results: Scenario III ['Bottleneck' scenario]*

		Scenario 3	value before the impulse	Direct impulse	Indirect effect	Total effect of the impulse	value after the impulse
STEP 1: Initial shock to the economy after the flood		*Production (South Holland)*	*235341*	*-40679*	*-18530*	*-59209*	*176132*
		Production (rest of the country)	*790058*	*0*	*-20796*	*-20796*	*769262*
		Total production	1025399	-40679	-39326	-80005	945394
		% production change (w.r.t. pre-disaster output)					-7,80
		% prod. change during the step				-7,80	
		Total value added	**593216**			-57565	**535651**
		% value added change (w.r.t. pre-disaster v.a.)					**-9,70**
		% v.a. change during the step				-9,70	
STEP 3: Recovery (production substitution scenarios)		*Production (South Holland)*	*176132*	*0*	*503*	*503*	*176635*
		Production (rest of the country)	*769262*	*4067*	*3422*	*7489*	*776751*
		Total production	945394	4067	3925	7992	953386
		% production change (w.r.t. pre-disaster output)					-7,02
	10%	% prod. change during the step				0,85	
		Total value added	**535651**			3188	**538839**
		% value added change (w.r.t. pre-disaster v.a.)					**-9,17**
		% v.a. change during the step				0,60	
		Production (South Holland)	*177132*	*0*	*759*	*759*	*177891*
		Production (rest of the country)	*768262*	*8140*	*6712*	*14852*	*783114*
		Total production	945394	8140	7471	15611	961005
		% production change (w.r.t. pre-disaster output)					-6,28
	20%	% prod. change during the step				1,65	
		Total value added	**535651**			6385	**542036**
		% value added change (w.r.t. pre-disaster v.a.)					**-8,63**
		% v.a. change during the step				1,19	
		Production (South Holland)	*177132*	*0*	*1363*	*1363*	*178495*
		Production (rest of the country)	*768262*	*20339*	*16914*	*37253*	*805515*
		Total production	945394	20339	18277	38616	984010
		% production change (w.r.t. pre-disaster output)					-4,04
	50%	% prod. change during the step				4,08	
		Total value added	**535651**			15965	**551616**
		% value added change (w.r.t. pre-disaster v.a.)					**-7,01**
		% v.a. change during the step				2,98	
		Production (South Holland)	*177132*	*0*	*2499*	*2499*	*179631*
		Production (rest of the country)	*768262*	*40679*	*34372*	*75051*	*843313*
		Total production	945394	40679	36871	77550	1022944
		% production change (w.r.t. pre-disaster output)					-0,24
	100%	% prod. change during the step				8,20	
		Total value added	**535651**			31966	**567617**
		% value added change (w.r.t. pre-disaster v.a.)					**-4,32**
		% v.a. change during the step				5,97	

* in millions of guilders, basic prices of 1992. [1 Euro = 2.21 Guilders]

Appendix 5 Minutes Of the Workshop

"In search of a Common Methodology On Damage Estimation"

(Delft, 23 – 24 May 2003).

European Commission (Joint Research Centre Institute for the Protection and Security of the Citizen Technological and Economic Risk Management Unit Integration of Information for Risk and Emergency) and the University of Twente have organized and held a joint Workshop on the topic "In search of a Common Methodology On Damage Estimation" (Delft, 23 – 24 May 2003).

The workshop was split into 2 panels: on country experience in damage estimation and the panel of economic experts. Joint round table discussion closed the workshop, where conclusions of the sessions were made and paths of further methodological and practical damage estimation convergence were laid. Both panels numbered about 15 participants.

The workshop was chaired by ***Jean-Pierre Nordvik*** and ***Ana Lisa Vetere Arellano*** from European Commission, DG Joint Research Centre, Technological and Economic Risk Management Unit and ***Anne van der Veen***, Professor in Spatial economics, University of Twente.

The economic expert panels were represented by speakers from various institutions from Europe, Asia and USA in the attempt to bring together and discuss methodological abilities of various models in use. In particular, the following papers were presented:

Hal Cochrane (Colorado State University, USA), *Economic Loss; Myth And Measurement*

Colin Green (Flood Hazard Research Center, UK), *Evaluating Vulnerability And Resilience In Flood Management*

Marija Bochkarjova, Bert Seenge and ***Anne van der Veen*** (University of Twente), *Indirect Economic Effects Of Large Scale Flooding: The Case Of The Randstad, The Netherlands*

Sam Cole (University Of Buffalo, Usa), *An Insurance Matrix Approach For Social Accounting*

Mark Thissen (University Of Twente), *Al Qaeda In The Netherlands; Indirect Economic Effects Of Terrorist Attacks On Infrastructure*

Angelika Wirtz, (Munichre), *Damage Estimation From Insurer's Prospective.*

Yasuhide Okuyama (Regional Research Institute, West Virginia University, Usa), *Modelling Spatial Economic Impacts Of Disasters: Io Approaches*

Adam Rose (Department of energy, environmental and mineral economics, The Pennsylvania State University, USA), *Modelling Regional Economic Resilience To Disasters: A Cge Analysis Of Water Service Disruption*

Joanne Bayer And ***Anna Vari*** (Iiasa, Laxenburg, Austria), *Designing A Flood Insurance Program For Hungary: A Model Based Participatory Approach*

Fumiyaki Yoshimura (Asian Disaster Reduction Center, Japan), *Methodology Of Earth Quake Economic Damage Estimation In Japan: Case Of Tokai Earthquake*

Christiaan Logtmeijer and ***Anne van der Veen*** (University of Twente), *Economic Hotspots: Visualizing Vulnerability To Large Scale Flooding*

A number of general considerations have been admitted; in particular the concept definitions formed the cornerstone of all discussions. It has been concluded that it is yet premature to talk about a common damage estimation methodology before defining a concept. It is necessary to first build a common understanding and an agreed set of common definitions. This is the case because damage estimation methodology is often linked to the use of the estimate, and thus insurance specialists, government officials and economists have different ‘damage languages’. Moreover, the need of creation of a common structured archive – a disaster database for European countries has been highlighted to facilitate damage estimation and future damage projections.

As a result of worldwide-recognized economic experts presentations a number of valuable results were obtained. First of all, various damage calculations show that the common methodology does not exist and estimations provided by different sources sometime lead to confusion and not comparability of results. As it has been shown during the workshop, the use of various models to simulate the physical phenomena and economic consequences of the natural disasters provide useful insights in the processes, each focusing on different aspects of the event. Namely, whereas input-output models have an advantage of covering the technology, these are still rather rigid in assumptions, but nevertheless can be given additional flexibility when time dimension is added. General equilibrium models, on the other hand, provide the economic system with too much of flexibility, thus leading to underestimated damage figures. There are also macroeconomic models, which feature the dependability of the macro-variables on the disaster shock.

Second, it was established that a number of small-scale events do not produce the same consequence as a large-scale one because of to the non-linearity of costs involved in the processes.

Third, it was concluded that the complexity of the problem of disaster damage estimation needs multidimensional approach, including *inter alia* both social and economic loss assessments. It was also noted that social aspect of loss estimation does not practically exist and needs encouragement for portraying a fuller picture of disaster consequences.

Finally, the fact was established that is not possible to make correct damage and loss estimations immediately after disaster. Nevertheless this preliminary assessment might be useful for the practical purposes (rescue operations, insurance payments, restoration activities planning, decision making process for people support etc.).

The papers presented during the workshop will be available in *Proceedings: Joint NEDIES and University of Twente Workshop - In search of a common methodology for damage estimation* (editors: A. van der Veen, A.L. Vetere Arellano and J.-P. Nordvik, Report EUR XXXXX EN (2003), Office for Official Publications of the European Communities from September 2003).

General Appendix: Delft Cluster Research Programme Information

This publication is a result of the Delft Cluster research-program 1999-2002 (ICES-KIS-II), that consists of 7 research themes:
►Soil and structures, ►Risks due to flooding, ►Coast and river , ►Urban infrastructure, ►Subsurface management, ►Integrated water resources management, ►Knowledge management.

This publication is part of:

Research Theme	:	Risk of Flooding			
Baseproject name	:	Consequences of floods			
Project name	:	Consequences of floods			
Projectleader/Institute		Prof. A.C.W.M. Vrouwenvelder		TNO	
Project number	:	02.03.03			
Projectduration	:	01-04-2002	-	1-07-2003	
Financial sponsor(s)	:	Delft Cluster			
		Ministry of Public Works, Road and Water Management			
Projectparticipants	:	GeoDelft			
		WL|Delft Hydraulics			
		TNO			
		Delft University of Technology			
		Twente University			
		Alterra			
		CSO			
		Delphiro			
Total Project-budget	:	€ 450.000			
Number of involved PhD-students	:	2			
Number of involved PostDocs	:	0			

Delft Cluster is an open knowledge network of five Delft-based institutes for long-term fundamental strategic research focussed on the sustainable development of densely populated delta areas.

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Theme Managementteam: Ground and Construction

Name	**Organisation**
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