International Institute for Applied Systems Analysis
Schlossplatz 1 • A-2361 Laxenburg • Austria
Telephone: (+43 2236) 807 342 • Fax: (+43 2236) 71313
E-mail: publications@iiasa.ac.at • Internet: www.iiasa.ac.at

Interim Report **IR-00-059**

Press-imistic Futures? — Science Based Concepts and Models to Assess the Long-term Competitiveness of Paper Products in the Information Age

Michael Obersteiner (oberstei@iiasa.ac.at; oberstei@ihs.ac.at)
Sten Nilsson (nilsson@iiasa.ac.at)

Approved by

Arne Jernelöv
Acting Director, IIASA

9 November 2000

Contents

Abstract

Traditional forest sector models used for demand forecasts only predict some “average future” based on extrapolation of the past. However, innovation driven dynamic systems are likely to lead to technological equilibria that are far from this “average future”. Thus, traditional models are incapable of assessing the full range of risks and opportunities in the market. Today, decision-makers need tools to explore and understand the system they operate in to be able to act as a pro-active market mover supported by rehearsed ex-ante strategies. In this paper we develop a simple scenario model to visualize possible future developments of information papers. Scenario forecasts are based on trajectories of population and economic growth, changes in life and work styles, substitution behavior, and technological change for individual population cohorts. Cohorts are split according to educational attainment, age, and gender. We also provide a theoretical background on the positive and negative feedback economies due to innovation and knowledge that are crucially determining the dynamics of the system. In a case study, we apply the model for one scenario of newsprint consumption in the USA. In addition, we present the methodology to plot the consumption pattern in a geographically explicit form using the concept of ‘Paperscapes’.

About the Authors

Michael Obersteiner is a research scholar in the Forestry Project at IIASA as well as at the Institute for Advanced Studies, Vienna. Sten Nilsson is Counselor to the Director and Leader of IIASA's Forestry Project.

Press-imistic Futures? — Science Based Concepts and Models to Assess the Long-term Competitiveness of Paper Products in the Information Age

Michael Obersteiner and Sten Nilsson

Background

The economics of the new information economy require a change in the strategic focus and demand for new methods of decision support and theory building. Traditional models are essentially based on the extrapolation of past or current processes, which fail to single out meaningful force factors of future development. Methods of strategy building, based on such models, have proved to be inadequate in an uncertain environment with rapid technological change. Thus, in an innovation driven environment forecasting strategies must be less about establishing and then defending a well-researched position within and of an industry. It is more about describing portfolios of options that allow decision-makers to change course or pursue unanticipated opportunities as they emerge. Adaptation to changes, regardless of whether they are continuous or discrete in nature, will be successful only if a number of possible futures are rehearsed and interactively built in the minds of individuals and entire organizations. Scenario building, as outlined in this paper, appears as the appropriate tool for such strategy planning. Scenarios provide the analytical framework to quantify options in an uncertain and highly dynamic environment, where predictions as such turn out to be increasingly meaningless, as they must be consistent with the past. Scenarios also prove to be useful in asking new important questions when scenario plots are scrutinized and disputed in a forum of interacting stakeholders and thus, by iterative feedback loops, the total uncertainty range is more likely to be researched. It appears to be indispensable to assess the full range of opportunities and threats in a quantitative and qualitative way. Strategies and tactics of survival, avoidance, and reachability of (un-)desirable equilibria have to be worked out ex-ante.

The role of research must also be changed in this new context. Research should be less about the development of indisputable and scientifically correct forecasting models, and more on providing a scientifically sound framework to identify drivers and their points of incidence leading to particular equilibria, providing a decent topology of the possible equilibria, and assess the likelihood of scenario plots.

The ultimate goal of scenario building is not to convince people that one scenario based on one ‘scientifically proven’ superior class of models is most likely to happen, but to provide people with the insight that a number of radically different scenarios are possible. And, more importantly, design the scenario tool in such an open manner that stakeholders can interactively assess and discuss quantitative scenarios. Decision-makers in the industry need to prepare today for a portfolio of futures in order to benefit from a first mover advantage later when rehearsed scenarios take real shape. On the market level the goal of using a scenario model is to devise strategies to increase total utilization for consumers through increased product diversity, higher quality and lower prices.

The challenges for meaningful scenario building are twofold. The first is that a sector study, as presented in this paper, must be highly integrative, both in terms of geographic and thematic cover. The second challenge concerns the way in which different stakeholders interact in order to build scenarios. Despite and because of the complexity of the system, scenario building must be transparent and participatory to guarantee maximum integration of codified and tacit knowledge across all of the participants involved in scenario building.

IIASA has a long history in living up to both challenges. For this particular study, IIASA is in the unique position of being able to build on an existing infrastructure of a number of crucial databases and scenarios, such as detailed population projections covering cohorts by age, education and gender for all countries of the world. In addition, IIASA can tap the existing in-house infrastructure for multidisciplinary research and is embedded in an extensive research network with its member countries that have been established over the years. IIASA’s Forestry (FOR) project has a long record of cooperation with the international forest industry and has made high-impact independent academic research.

Model Description

In this paper we develop a model that allows the user to explore future consumption scenarios. A simple dynamic system is used to describe the demand scenarios. Starting from an initial state of consumption we use index functions of a number of interacting drivers to describe future states of the system (see Figure 1). The population of consumers is divided into a number of different consumer cohorts, which are characterized by educational attainment, age and gender. The index functions are different for each cohort or sets of cohorts in order to capture the varying consumption trajectories of these cohorts.

Past, current and future states of the system are presented in two different ways: (1) Aggregate forecast, and (2) Paperscapes. The scenario representation in the form of aggregate output forecasts shows the scenario plot(s) in a diagram of the expected value trajectory and its lower and upper probability limits. These limits are not required to be symmetric relative to the expected value allowing for approximations of skewed probability distributions. The skewedness reflects the scenario builders’ belief that the probabilities for over-(under-)estimation are different. So, for example, in our scenario for newsprint consumption under the ‘press-imistic’ scenario (equilibrium dominated by electronic reading devices) we give more likelihood to the overestimation of the expected value than for the likelihood of underestimation. The second way to present the scenarios is through a series of Paperscapes, which plot the consumption information in real geographic space. Paperscapes are either computed directly with disaggregate data of consumption and its drivers using also geographically differing index functions (agent based models; bottom-up approach) or Paperscapes are computed by distributing the aggregated results using geo-referenced population characteristics and the geography of per capita consumption (top-down approach). Paperscapes are not only able to capture information on the current levels of consumption, but also their dynamics. Thus, Paperscapes describes the main features of the full dynamic system in one geographic map.

Establishing the Base Year

In the following section we describe the model using newsprint consumption as an example. Total aggregate consumption of newsprint is defined by the product of the consumption intensity of a representative newspaper reader of a particular population cohort (ϕ) (kg paper per capita), the total size of the population (p) consisting of a number of population cohorts, and the share of people reading the printed version of a newspaper(s) (r) (see analytical expression in Box 1). In order to assess the distribution of consumption according to population cohorts for the base year the intensity of consumption (ϕ) of each cohort is determined by decomposing aggregate statistics of apparent consumption (Figure 1). The Apparent Consumption Statistics (ACS) of particular paper grades are taken from various national and international sources (e.g., MPA, NNA, APPA, CEPI, FAO, PPI). The ACS's are then decomposed according to population cohorts along three dimensions: age, sex, and education. Decomposition is based on market research reports, which usually split consumption along these three dimensions. In the absence of such market reports, independent expert judgment and other information sources are used.

Building Scenarios

In the scenario calculation all of the three factors of our aggregate consumption function are allowed to change over time and depend *ea ipsa* on a number of underlying force factors (equation in Box 1). If we would allow all the force factors to change individually for all subscripts, then the number of manual changes of individual parameters would be counted in four-digit numbers. Of course, it is unrealistic to handle such a large amount of parameters in a meaningful way. We thus, very quickly faced a decision problem on the optimal size of the model (amount of parameters to be determined) that still made maximum use of the additional insights of working with disaggregated information. Scenario models on demand forecasts are only useful if the scenarios themselves can be built in a few minutes.

Scenario building is ideally a social process of interacting 'visioneers'. Resources should ideally be devoted to visioning and understanding the interesting consumption worlds rather than devoted to the selection and parameterization of complicated exclusively data-driven models, which are anyhow incapable of producing one correct prediction. We believe that for visioning our human brains still possess a competitive advantage and the visioning should ideally be a group exercise of interacting stakeholders of a particular market. With respect to the understanding part, we will increasingly work with analogous theories and existing models from economics, physics and biology in order to qualitatively understand the full dynamics of the sub-components of the system. All that the scenario model *per se* should then provide is a formal overview structure to organize the problem as such and make fast computations that our brains cannot do at a comparative speed.

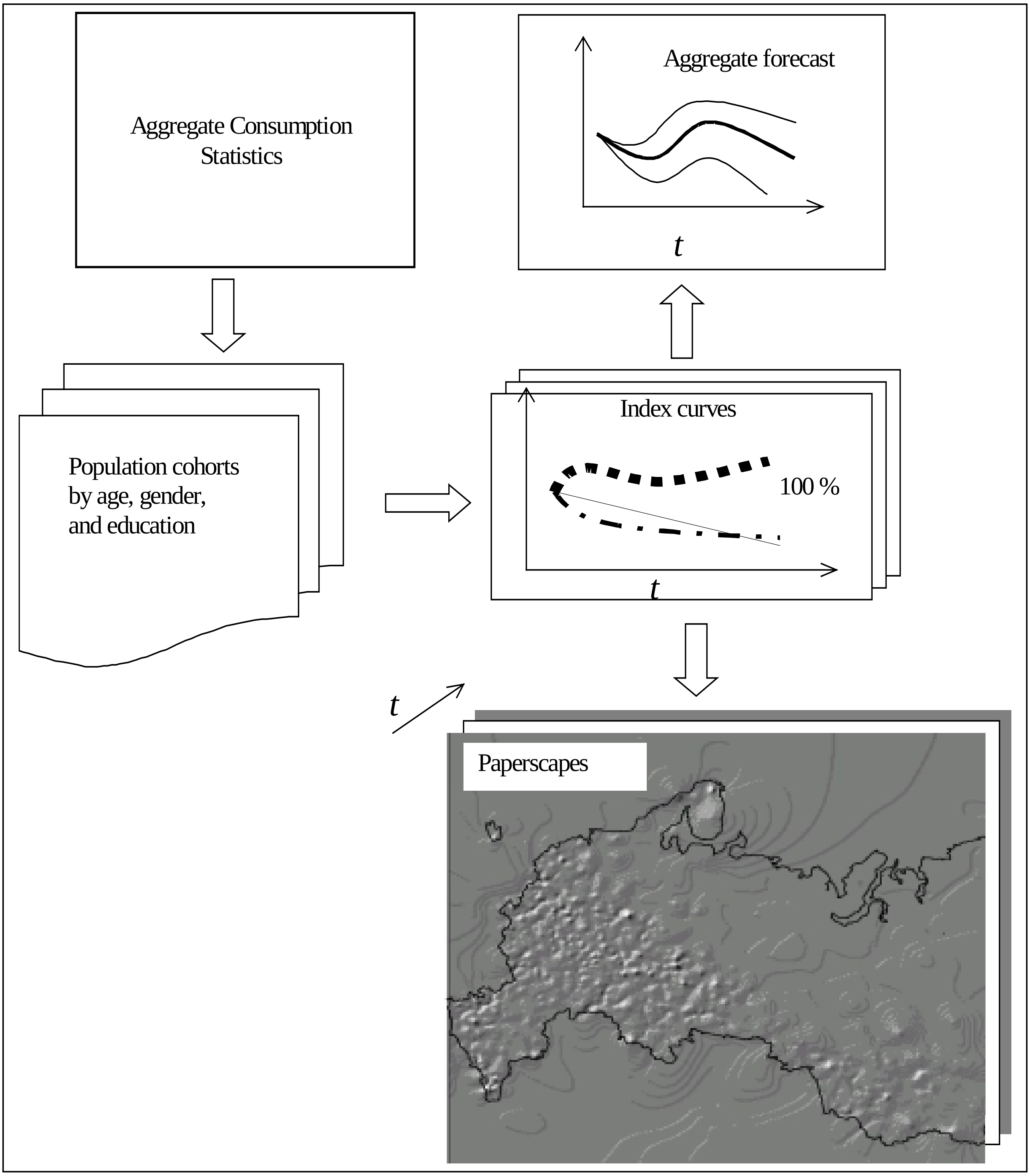

Figure 1: Scheme of the forecasting model.

We therefore work with simple index curves, pinning down the transition function of the first and second moment of vectors and matrices of the parameters underlying each force factor departing from the base year (see second line in the consumption function in Box 1). Here, assume that the index curves describe the path of the state variables of the consumption system, based on the understanding and description of the sub-models featuring each component.

Box 1: Analytical description of the scenario model

$$c_t = \sum_i \sum_j \sum_k \{\phi_{ijkt} \, p_{ijt}\} r_{ijkt} =$$

$$= \sum_i \sum_j \underbrace{\left(\omega_{edu_{jt}} edu_{jt} * \omega_{i_{it}} i_{it} * \omega_{e_{it}} e_{it} * s_t * g_t\right)}_{\phi_{ijt}} p_{ijt} * r_{it}$$

Reading intensity (ϕ)

- Reading intensity by educational class *(edu).*
- Reading intensity by age class *(i).*
- Economic wealth (income) *(e).*
- Reading intensity in terms of number of pages, size, and average number of editions per reader *(s).*
- Grammage of newsprint in use *(g).*
- Elasticity of consumption with respect to force factor (ω).

Population cohorts (*p*)

- Demographic development by age, gender and education *(p).*

Probability of reading a printed newspaper (*P(r)*)

- Readership rate of electronic and paper based newspapers by age class *(R).*
  - Readership of the paper copy *(r).*

Indexes

i Number of age class.
j Number of educational class.
k Number of gender class.
t Index of time.

Reading intensity (ϕ)

As already mentioned, current reading intensity levels in the base year are computed from aggregate statistics, which are decomposed into individual cohorts according to educational attainment, gender and age. The initial consumption level of each cohort is up- or down-graded by the number of the scenario indexes of individual force factors that drive the consumption of each cohort.

The reading intensity index describes the relative difference in the reading intensity across population cohorts with respect to the base year average. If we ignore that the education effect is influenced by age or gender (see subscript *j*), then ${}^{2000}edu_{H,\,2010}$ = 180% would mean that in 2010 a high education cohort would consume newspaper information at the 180% level compared to the average consumer (100%) in the base year 2000. In this way, the structural change with respect to changes in the educational composition of the total population is reflected. However, in the model reading intensity does not only change with changes in the structure of education attainments of the population, but also with changes in the demographic profile with respect to age classes. This allows us to trace population cohorts through time by picking up cohort effects like people tending to stick to consumption patterns and reading technology they experience in their youth. Many other behavioral patterns that change through time as young generations shift to more senior age classes can be modeled using the parameter *i*. More generally, it reflects changes in reading intensity of news due to structural changes in the way population cohorts typically work and live. The force factor, *e*, helps to model the income effect with respect to paper consumption. More generally two things can happen if income increases: (1) reading a newspaper becomes relatively cheaper and consumers can afford to buy more newspapers, and (2) with increasing income consumers will also be able to invest more in computer technology, robots, portable gadgets and internet services, which will increase reading intensity but, at the same time, result in substitution. The latter effect, however, is captured by the substitution parameter *r*. The ω reflects the ‘elasticity’ of the change of the respective parameter with respect to newspaper reading. In other words, ω determines the magnitude of the potential impact of a change in a force factor on the intensity of reading.

Whereas the above-mentioned factors influence total reading intensity and thus describe demand-sided factors, *s* and *g* reflect supply-sided factors. *s* reflects changes in the amount of newsprint needed to produce a newspaper and is related to the amount of editorial and advertisement content, which is expressed by the number and size of the pages needed to produce a paper copy of a newspaper. *s*, thus, reflects the ‘internal’ type of substitution between the electronic and the paper version of the same newspaper. *g* captures changes in the pure physical dimension of a newsprint used by reflecting changes in the grammature of newsprint.

Population (p)

Almost all state-of-the-art readership surveys are based on gender, age, income and education categories. This gives us reason to believe that the future development will also largely be driven along these demographic factors. In addition, it allows us to follow the development of a rather stable and as such more predictable development — people, who grow older. However, at least in the available literature, detailed demographic development is not explicitly modeled in demand projections. IIASA’s

Population project currently produces global population developments on a country by country basis (for some larger countries regional forecasts are developed, e.g., China) and we use these projections as the basis for our demand projections. For example, Figure 2 shows the demographics of the ‘central’ scenario according to age, sex and educational attainment levels for Egypt in 2045, with a projected total population of 127 million.

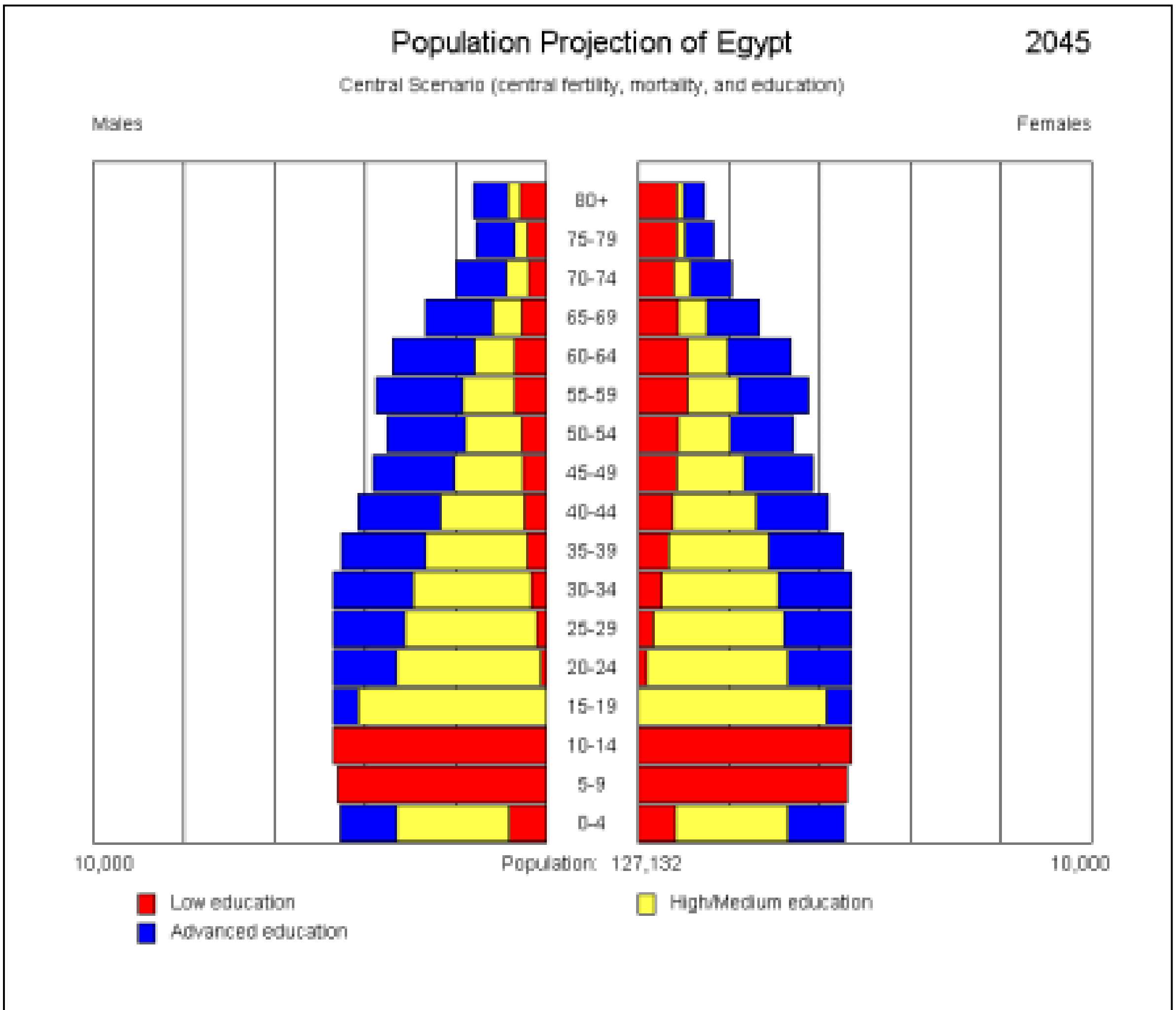

Figure 2: Age, education, and gender structure for Egypt in 2045 according to the central population scenario.

Readership (r)

The readership parameter is used to model ‘external’ substitution. This is the type of substitution resulting from changes of the readership base due to in- and out-flows to or from competing media (e.g., TV, pure internet content, music, magazines) or activities (e.g., sports, number crunching, commuting). The readership rate is the share of newspaper readers in the total population. Readership, however, does not give us information whether a reader reads 0.5 or 3 newspapers per day. This information is expressed in the intensity figure ϕ. Readership changes with gender, age and educational attainment categories. In probabilistic terms, bearing consumer surveys in mind, the readership rate is the probability of identifying a person in a particular gender-age-education category as a reader of a newspaper. The readership rate of the paper version of a newspaper is thus the product of the probability of being a reader of the paper version assuming that the person is a newspaper reader, i.e., $P(r) = P(pc)P(R)$ where *P(pc)* symbolizes the conditional probability of reading the paper copy assuming the person is a newspaper reader. *P(pc)* is the key parameter to model substitution from paper reading to reading newspaper content using electronic devices. It can, thus, be thought of as the prime parameter to proxy the competitive profile with respect to readership of print with respect to Internet publications of the same or similar content. *R,* on the other hand, stands for the competitive profile of newspaper content on the readership level against all other media, such as TV, radio, computer etc., and consumers' time in general. The latter point reflects behavioral patterns, such as how people spend their work and leisure time in general. Both types of external substitution are regularly surveyed by media analysts. Substitution on the intensity level are less frequently surveyed but can be derived from circulation and apparent consumption data. Our intensity indexes *edu, i, e* account for this type of substitution.

Dynamic Interaction of Drivers

The equation in Box 1 considers consumption as the state variable of a dynamic physico-economic system. However, this physico-economic system can also be described by its own dynamic properties in determining the system's evolutionary development. The dynamic interaction of the variables driving the system is considered in the following section. The use of dynamic models has the advantage of reducing the number of parameters to be manually determined for the computation of the state variables entering the consumption function. In addition, a formal model might also offer insights into the functioning of the system to be analyzed that would otherwise not have been possible. The disadvantage, however, is that most parameters cannot empirically be determined. Neither can the validity of the underlying theory be tested, despite the fact that the current economic discourse is dominated by such modeling approaches.

The yellow regions in Table 1 indicate positive relationships between mutually re-enforcing drivers, which could, if the interaction links are strong enough, lead to considerable positive feedback. For example, positive feedback between *e* and *s* is mainly due to the non-rivalry property of published information. The new growth theory is more explicit in how non-rivalrous information (knowledge) — if we take on a wider interpretation of *A* in Box 2 we can link it to our parameters *s* and *i* — and economic performance (*e*) interact.

Table 1: Interaction matrix of drivers.

	positive feedback				exogenous		
	edu	**i**	**e**	**s**	**p**	**r**	**R**
edu		+	+	+	±	±	+
i			+	+	±	±	+
e				+	±	±	+
s					±	±	+
p						±	±
r						±	±
R							±

The strength of the link between economic performance and information (knowledge) will also have a strong impact on the speed of diffusion of new information technologies. There is empirical evidence that the economies of industrialized countries have become more information intensive and that related new information technologies and communication technologies diffused at an unprecedented pace (OECD, 2000). The parameters of the logistic diffusion function are, thus, a function of the strength of the link between economic performance and information (i.e., the diffusion process: $diff = f(\sigma)$). The parameters r and R capture the diffusion of knowledge via newspapers.

The more traditional models of economic growth are based on a mechanism of factor accumulation of physical (K) and human (H) capital. The latter is related to education, training, or work experience acquired by individuals that corresponds to the parameter *edu* in our model. The production function becomes $Y = AF(K,H,L)$ and economic growth (e) can be modeled by the extended Solow decomposition:

$$e = \frac{\Delta A}{A} + \alpha \frac{\Delta K}{K} + \beta \frac{\Delta H}{H} + \gamma \frac{\Delta L}{L}.$$

Another factor to be discussed is population growth. In current economic literature there is a lot of debate on the question whether or not population growth is required to achieve economic growth. In our consumption-forecasting model we treat population growth as exogenous and do not assume a relationship between the developments of the other factors. However, market size plays an important role in almost all economic growth models as shown in Box 2. We acknowledge the empirical relationship between population growth and the level of economic performance, information and education. Similarly, the question related to the interaction of readership of the printed version of a newspaper also depends more on the levels of the other parameters.

Box 2: The positive feedback economics of output and knowledge

According to Jones (1999) the most general new growth model would look like the following:

Suppose a CES (Constant Elasticity of Substitution) aggregate consumption function of a composite of a variety of goods is:

$$C = \left(\int_0^B Y_i^{1/\theta} di \right)^{\theta}$$

where B measures the variety of goods available. Each variety is produced according to the following production relations:

$$Y = A^{\sigma} L_Y$$
$$\dot{A} = \delta L_A A^{\phi}$$

where A stands for the stock of ideas or non-rival information in general and L_Y is labor, the only competitive input to produce Y. There are only constant returns in the rivalrous input and increasing returns from labor and ideas together, where the degrees of increasing returns are measured by the parameter $\sigma > 0$. Thus, due to the non-rivalrous property of public information, there are positive feedbacks created through increasing returns to scale in the use of public information.

New ideas or public information are produced according to the production function in the second line, where L_A is the labor used to produce economical active information. A narrow interpretation of A, as used by the growth theorists would be scientific ideas, inventions and designs, but also a wider interpretation of A would fit into the model such as reaching from the weather forecasts in the daily newspaper to international policy analysis in magazines and advertisements. The stock of knowledge A manifests itself in massive piles of printed-paper, which can be regarded in a quantitative way as the major soft- and hardware of the total knowledge base.

Finally, one needs to explain how B, the total variety of consumption goods, which in an increasingly information based society are information goods involving directly or indirectly the use of paper, evolves over time. It is assumed that

$$B = L^{\beta}.$$

Taking these assumptions into consideration it follows that the rate of per capita output (consumption) (e_C) becomes

$$e_C = \theta\beta n + \sigma\delta s \frac{L^{1-\beta}}{A^{1-\phi}}$$

where, within this model, θ relates to the elasticity of substitution between products, β is the elasticity of the variety of products a population produces, n is the rate of population growth, σ is the parameter that relates the stock of knowledge to economic output, δ is the productivity parameter of knowledge production, s is the share of information workers, and ϕ is the parameter of returns to scale in the production of new knowledge.

Positive feedback economies and technological competitive advantage

The dynamics of the diffusion pattern of new reading technologies crucially depends on the occurrence of increasing returns to adoption and the path-dependency of the innovation.[1] Increasing returns to adoption give rise to self-reinforcing mechanisms. In the case of reading technologies, self-reinforcing effects stem from decreasing transaction costs to acquire, process, store and retrieve useful information achieved by the superiority of the features of new reading technologies. One important way to decrease transaction costs is by expanding the network within which individuals' actions conform to behavioral standards and norms (e.g., the use of e-mail; network effects from using a standard industry-wide software for eBooks to download eNewspapers[2]). Indeed, there are advantages in following what other economic agents are doing because of coordination effects so that, for example, a technology often offers advantages to keeping up with the other adopters; that is, to belong to a 'network' of users communicating in the same technological language. In this way, the domination of a certain technology can be explained by the occurrence of fashions or aggressive market campaigns and, to a lesser extent, by technological superiority. Thus, the dynamics are affected by the resulting (local) positive feedback of the ever-increasing user community and bring about an accumulated economic advantage. This is an important insight for assessing the future market potential of paper products. Market managers will have to watch the user base and the development of all competing technologies, even if the current user base is still small. We will increasingly learn that, once the user base reaches a critical load, the market share of the competing product might start to explode (at least within certain population cohorts). For example, newspaper article based discussions are not only discussed based on the article itself, but are increasingly based on and with the associated chat rooms.

Positive feedback need not only be of a local nature, but can also be of a more global nature, whenever an innovation leads to an adaptation of the local system it affects its environment. In our case, this means that adaptive changes arising from new information technology drive the structure and metabolism of society which, in turn, are altered by adaptive changes (Figure 3). The simplest illustration of this feedback is the fact that "information technology is significantly affecting the economy, the growth and structure of output, occupations and employment and how people use their time" (OECD, 2000). Innovation triggered changes in society lead, in turn, to new demands for improved or even brand new technologies resulting in a co-evoluting pathway of mutual reinforcement.

Ideally, technological change is driven by new and adapting demands of society, but new information technology also creates new demands. Competition is, thus, not only about delivering solutions to better and more cheaply satisfy existing demands, but is also about creating new demands. Competitive advantage of a new technology can be best understood by using the theory of adaptive dynamics as used for biological systems (see, e.g., IIASA's Adaptive Dynamics Network project). Taking the analog of an organism's fitness for the competitive advantage of a new technology we can develop

---

[1] In our context, technology must be interpreted in a wider sense relating more to the know-how, know-why, know-who, know-what, know-where, and know-when of distributed knowledge.
[2] The establishment of such standards and many other support activities guiding the market are administered through IFRA (www.ifra.com) and WAP (www.wap.asso.fr).

an adaptive theory of technological change that will help us to understand the role of new information technology with respect to the use of paper products. From Figure 3 we see that the competitiveness of an innovation can only be evaluated relative to the 'environment' — state of the information society — in which a paper-based or non-paper-based innovation is going to act. The environment helps to put the technological advance into a societal or economic context by defining the utility of the innovation to society (usually the utility is expressed in terms of the current and expected economic value of the innovation). In our context, the relevant environmental variables defining the state variables of the information society are described in Box 1. These range explicitly or implicitly from socioeconomic all the way to cultural variables. To assess the competitiveness of a technological innovation we must specify the relative advantage of the innovation compared to the existing technology given the environmental parameters of the entire market system.

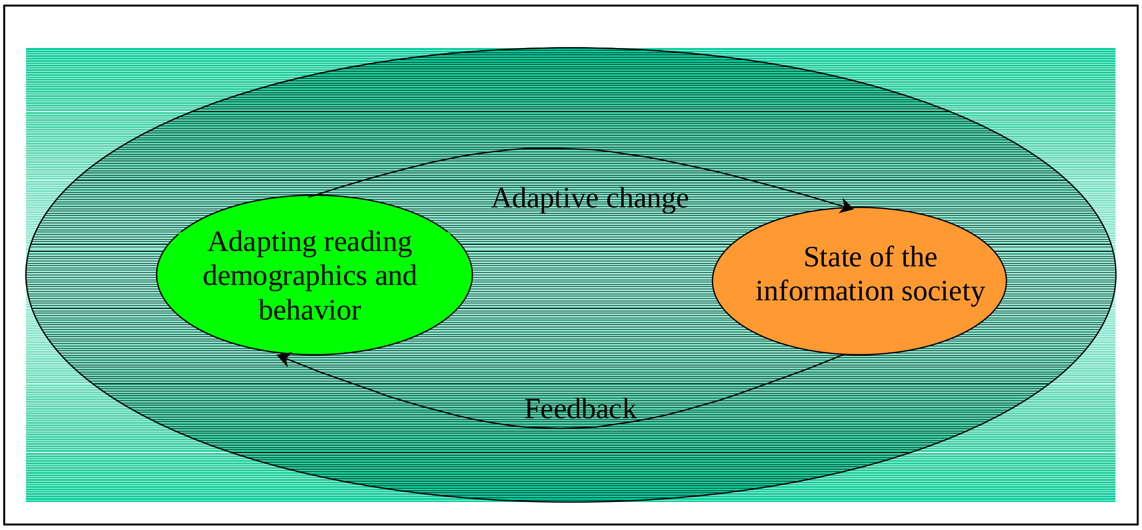

Figure 3: Positive global feedback between new information technology and society.

In our application and in real life, however, we need to understand that society consists of heterogeneous groups with respect to their adaptability to new information technologies. For simplicity, let us distinguish three different types of adapters: conservatives, techno-freaks, and market followers (Figure 4). The latter are described by a behavioral pattern that is guided by the rationale of trying to benefit from network externalities by adopting the technology of the majority of current or expected users. Figure 4 endeavors to illustrate the possible interactions among market participants and possible market share trajectories. We start from the right, taking an initial (continuous) distribution of two types — conservatives and techno-freaks. A market dominated by conservatives, who are skeptical about the benefits of adopting the new technology will, after initial trails to adopt, converge back to 100% use of the existing old technology (area above the four-point star). If, however, the types are more mixed (area between the four-point star and the sun) two different equilibria are reached. The market might:

(a) converge to the paper dominated reading technology (symbolized by the paper role), or
(b) converge to a state of a dominating rule of electronic reading technology (symbolized by the five-point star).

The fourth equilibrium comes about if the user community is dominated by techno-freaks (e.g., young age groups which no longer communicate by p-letters, or newspaper content is read to readers by a digital agent from the web in cars).

The position of the four-point star, the sun, the dividing line between the paper and electronic dominated equilibria (the straight dashed line), and the equilibria *per se* are determined by the technological distance (superior utility delivered) between competing technologies, the (expected) growth of innovation and their benefits, the distribution of behavioral types and their societal and institutional environment.

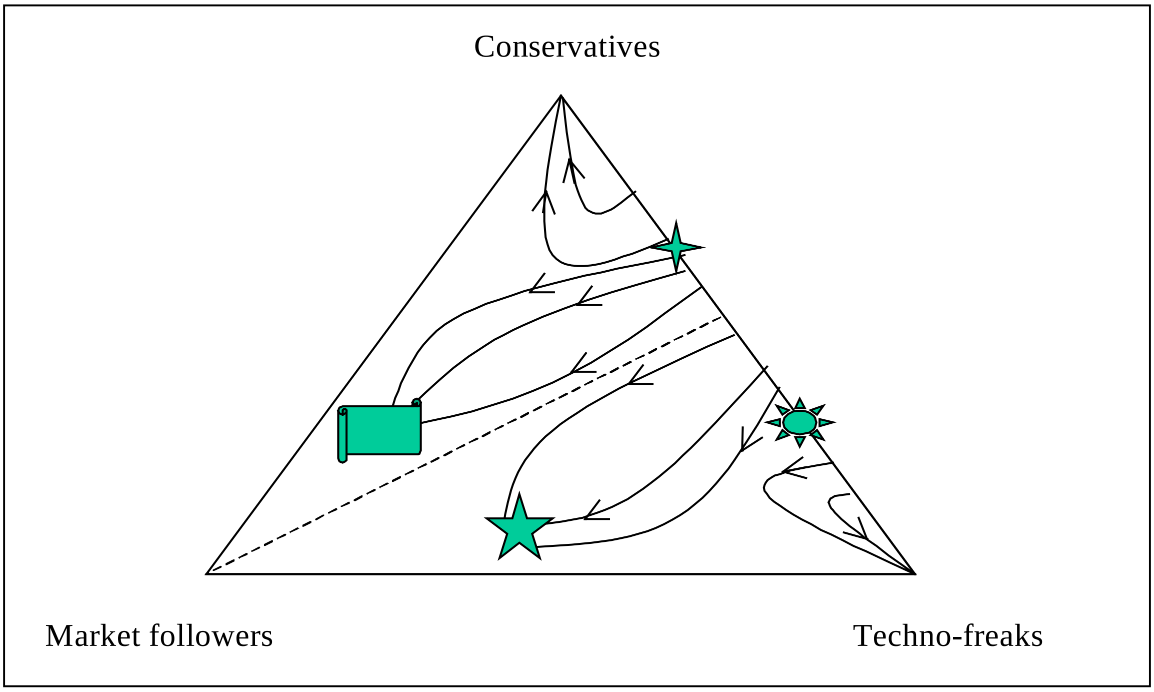

Figure 4: Trajectories of the use of reading technology according to population types.

Figure 4 graphically describes possible long-term equilibria for competing reading technologies. However, in reality these equilibria will never be reached due to continuous technological change induced by innovations that can again radically change the entire contexts of the existing technological constellations.[3] Thus, the path of innovation is of utmost importance. The expected rate of innovation of a certain reading technology can be described by a differential equation similar to the canonical equation describing evolutionary change in an adaptive biological environment (see, e.g., Dieckman and Doebeli, 1999):

---

[3] The insight that the future is not predictable gives us reason to conduct scenario analysis of the market of information papers, because information of ex-ante risks need to be included in current decision making to guarantee optimal adaptation to innovation triggered changes in the future. The current practice to conduct long-term forecasts based on econometric analysis of past data, i.e., predict future consumption based on a historical log-linear relationship with GDP and price, will certainly not contribute to optimal decision making in a world of changing risks.

$$\frac{\partial s}{\partial t} = \frac{1}{2}\mu\sigma^2 n(s) \left.\frac{\partial f(s,s')}{\partial s'}\right|_{s'=s}$$

where *s* is the adapting characteristic of the established technology, μ is the probability of innovation, σ is the average step size of the innovation, *n(s)* is the size of the economy measured in population size using the current technology with the characteristics *s*[4], and *f(s,s')* is the relative competitive advantage of the technological characteristics of the innovation *s'* in the current population *s*. *f(s,s')* is the 'per capita' growth rate of the innovated product. The crucial quantity to determine the evolutionary dynamics of the new technology is $\left.\frac{\partial f(s,s')}{\partial s'}\right|_{s'=s}$. It basically reflects a selection mechanism according to which technological advance increases utility to society. *f(s,s')* itself is subject to changes of the characteristics describing the state of the information society (Figure 3), which define the utility received by the consumption or use of certain information technologies. This term, however, also captures the effect of factors that make the system stickier, such as market imperfections and risk averse behavior.

Following this type of thinking we can explain that product differentiation or even new products, as well as the improvement of existing products, lead to increases in total societal utility and economic growth. On the product level, on the other hand, we can find all sorts of competition driven interaction between electronic- and paper-based reading technologies as illustrated in Figure 5.

From Figure 5 we can derive the following major types of interaction:

1. Substitution without an effect on total reading quantity (dotted line);
   1.1 Substitution with an effect on total reading quantity,
      1.1.1 Less total reading and less paper reading (south eastern border of the area limited by the dashed line).
      1.1.2 More total reading, but less paper reading (all possible lines between the dotted and the dotted-dashed line).
2. Neutrality (dotted-dashed line).
3. Mutual re-enforcement (north-western area limited by the dotted-dashed and dashed line).

Figure 5 is compatible with Figure 4 in the sense that we can find all possible types of interaction between two technologies in this graphical representation. The mixed equilibria are indicated by the same symbols as in Figure 4. The set of paper-dominated equilibria is symbolized by the thick full-line. If, as in this paper-based case, technologies prevail depending on the type of competitive interaction of the two technologies the equilibrium points can be found along this thick line. In the north-west of the diagram we plotted the probability density function (p.d.f.) for the paper dominated (full line) and the electronic reading technology dominated user distribution (dashed line). Depending on the environmental parameters and the technological state, either the full or the dashed p.d.f. describe the competitive interaction better. Multi-modal distributions are likewise possible. The equilibrium of pure paper-based reading

[4] Note that in this context we distinguish only two types of market participants — users and non-users.

can be found in the north-east corner of the diagram, whereas the pure electronic equilibrium is located in the south-western corner. From the previous discussion, we find that multiple equilibria are possible (line of equilibria and multi-modal p.d.f.s). We also find that symmetric market outcome, as drawn by the solid diagonal line, is unlikely (low probability). The diagonal line can, thus, be interpreted as a saddle point that needs to be climbed before moving then very quickly into the new equilibrium valley.

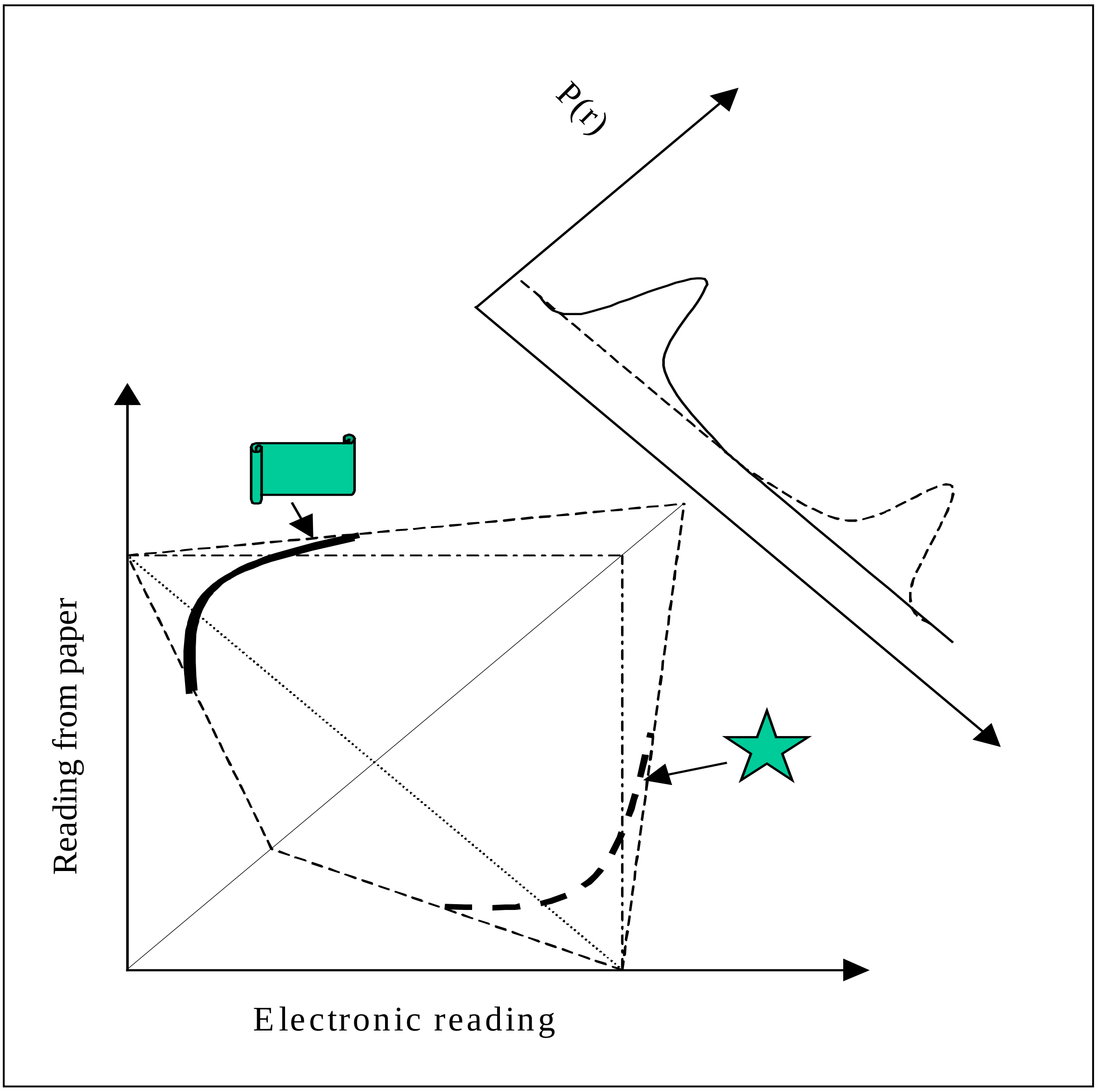

Figure 5: Typology of competitive interaction.

A typical paper dominated equilibrium with increasing total reading would be reading reports from A3/A4 cut paper and computer technology. In this example a rather quick jump (chaotic behavior) to the electronic reading technology dominated equilibrium can be expected if screen technology improves significantly and emerging electronic papers will produce higher consumer satisfaction. A typical example of an electronic dominated activity is writing and reading professional mail through email (SMS) and paper-based mail. A purely electronic equilibrium would be the trade of stocks, which no longer involves the exchange of paper-based stock ownership titles. A purely paper-based equilibrium is still the use of passports.

In the third case of mutual reinforcement or complementarity, network effects or network externalities are exploited. Complementarity is characterized by the fact that the complementary technologies have little or no value in isolation but generate value combined with others. In many cases, the component purchases of a system (compatibility of paper and printer, compatibility of software and hardware, etc.) are spread over time, which implies that buyers must form expectations about the availability of components they will be buying and using in the future. Switching technology is then always costly one way or the other. In this situation, the market follower type of consumer is expected to choose the more popular technology exactly for the reason that it is expected. This is crucial for understanding and predicting the diffusion of information technologies. Of course, such systems pose challenges for coordination among user groups and other organizations like firms and governments, but also coordination among technology providers is often extensive and explicit, including common ownership of various component suppliers, long-term contracts and industry-wide standard-setting bodies (Aliardi, 1998).

Figure 6 gives a graphical representation of how the newspaper business changed its technological and commercial character since the introduction of the Internet. The continual invasion of technological solutions to exchange information over the internet can cause technological branching that leads to a more intensive harvesting of the market if the necessary feedback from the market participants is strong enough, i.e., people and businesses adopt the new technology and begin using it more effectively through learning processes and continuous technological improvement. The economics of diffusion of a technology is closely tied to learning phenomena. In particular, the strategic decision to adopt a new information technology or stick to the existing technology strongly depends on the economics of knowledge building. We distinguish three types of learning processes:

1. Learning by doing,
2. Learning by using, and
3. Learning to learn.

There is a qualitative difference between the first two concepts. Learning-by-doing is a phenomenon due to which the cost of production decreases with accumulated knowledge, which is usually indirectly approximated by the volume of production. The other way of defining learning-by-doing, which is less frequent in the literature, is in terms of the effects of cumulated investment on current costs (Arrow, 1962). Given a certain volume of production, the cost of production also decreases the more a technology is used and the more users learn about it; that is, the technology improves because of leaning-by-using (Rosenberg, 1976). Learning effects involve a form of sunk cost and knowledge is the asset whose cost is sunk. This observation comes from the properties of knowledge or the knowledge to use a certain technology, which makes it a special commodity; unlike most commodities it decays if it is unused and grows with use; the more it is used the more durable it is, that is, the less likely it will be forgotten either by the individual using it or the entire user group of a certain information technology. In terms of using paper technology this means that paper has a long history itself and users usually look back on a history of using paper — they learned how to use it for many purposes to build and extend their knowledge and pleasure received from paper-based information. At the same time, we can observe how computers and electronic gadgets are becoming increasingly easier to use making learning processes very inexpensive. A web newspaper is easy to read even for the absolute computer illiterate, but also offers searchable archives and many other features that make the management of newspaper content a lot easier. This could lead to the effect that consumers dis-learn their traditional habits of using the classical newspaper (e.g., cut out articles and store them in personal paper-based archive for later use, but instead rely on the searchable electronic archive).

A piece of knowledge does not need to be produced more than once (if universal access is guaranteed as in the case of the internet), it can be used over and over again by many people, at any scale of operation. Thus, the production of knowledge is like a fixed cost in the production of goods and services (see formal description in Box 2). In our context, this means that the smaller the cost of learning how to e-live and e-work the less paper-based information products will be used. In other words, the more natural the human-machine interaction becomes the less paper we will consume and, as argued above, we will forget how to effectively use paper as we traditionally did before.

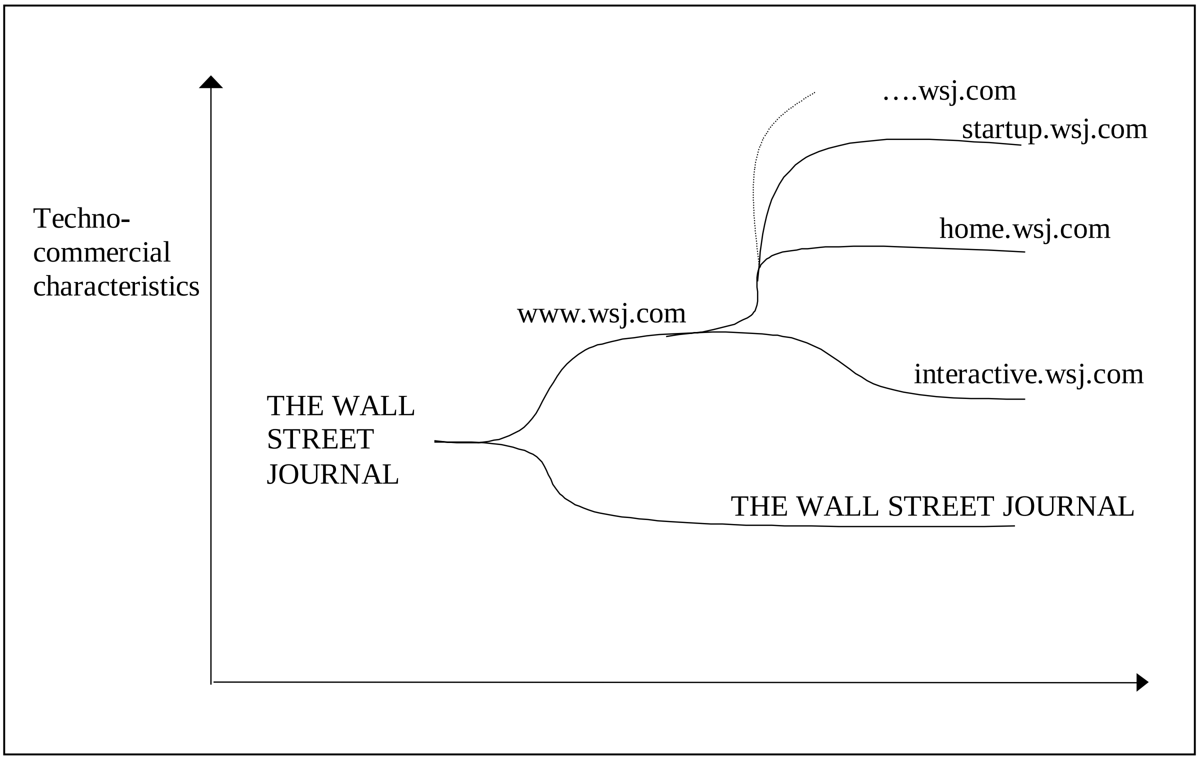

Figure 6: Evolutionary technological branching of the newpaper business illustrated by the Wall Street Journal.

Moreover, there can be increasing efficiency in the 'technology' of learning through the actual process of learning, the so-called learning-to-learn (Stiglitz, 1987). The presence of such learning possibilities implies not only an inter-temporal externality, but also dynamic economies of scale in production activities. Learning, therefore, manifests itself as irreversible in production possibilities and might help to explain the velocity and acceleration of diffusion processes of electronic information technologies. As a result, if a given person or organization enjoys some initial advantage over its rivals (in terms of initial skills of using an information technology), it can capitalize on this advantage in such a way that advantage accumulates over time and makes the rival incapable of offering effective competition in the long run. This basically means that the existence of such sunk costs or simply some initial advantage leads to one of the market equilibria as shown in Figure 5. Accumulation of advantage of a certain technology grows with the level of experience and adaptability of the users, rate and step-size of the innovation, and the number of users in relative and absolute terms. This accumulation can itself be used as a pre-emptive move on the part of the stakeholders in a particular information market benefiting from one technology to deter rival technologies from entering the market or, in the other circumstance, to make it even less profitable for rivals to remain in the existing market segment. This, in part, explains the branching of technologies, but also explains Schumpeterian creative destruction of existing technologies.

The (partial) combination of learning phenomena and network externalities determine the degree of increasing returns to adoption as already briefly described at the beginning of this section. The individual benefits from increasing returns to adoption, which change with the intensity of using a certain information technology and changes with the size or number of adopters. When increasing returns to adoption are present, history matters in the sense that the equilibrium outcome is path (history-) dependent: the resulting equilibria cannot be understood without knowing the pattern of adoption in earlier periods. In Figure 4, history is reflected in the initial distribution of conservatives and techno-freaks. The uncertainty of history dependency can be interpreted as an ex-post uncertainty, but there are also ex-ante uncertainties with respect to the expected adoption behavior of other market participants. If this analogy is correct (some more analysis will have to be made on this topic), a co-existence of ex-ante and ex-post risk in the total risk perception of market participants can lead to strong risk-aversion even in cases of linear utility functions (see, Ermoliev *et al*., 2000). Situations of slow diffusion of new information technology and early lock-in cause and result in inefficiencies and decreasing technological diversity. In the framework of the model discussed in Figure 4, such a type of risk aversion can be interpreted as some kind of increasingly difficult hill climbing over the saddle point between the paper and electronic dominated reading technology. Counter-acting strategies to make hill climbing easier can only be achieved by the incorporation of suitable ex-ante scenarios in today's decision making thereby reducing total risk perception.

Summarizing the above arguments we can state that when competing technologies possess positive feedback economies, the following properties are likely to arise (see, Arthur, 1988a,b; 1994 and Ermoliev *et al*., 2000):

Multiple equilibria: In the competing technologies case, if self-reinforcing forces are not off-set by countervailing forces, implies that quite different asymptotic market share solutions are possible so that the outcome is indeterminate and unpredictable, i.e., even the equilibrium regions described in Figure 5 can shift all over the place.

Lock-in: Once an equilibrium is reached (the dominance of the Microsoft Office Package) repellent forces are too weak to exit this equilibrium causing structural and dynamic rigidity and inflexibility.

Possible inefficiency: If a technology is unsuccessful in attracting early adopters, yet it is superior in its technology (Microsoft versus Apple), leads to a lock-in in the inferior technology.

Path-dependency: The dynamics are affected by ‘initial conditions’ as well as by the expectations so that early history or current visions can determine which solutions will prevail in the end.

Uncertainty of the Aggregate Forecast

Scenario building not only involves casting various futures and their quantification, but also involves the judgment of how probable the envisaged scenarios are. Thus, the resulting forecast is complete only when accompanied by a quantitative statement of its subjective uncertainty of the forecaster’s vision. This is the reason why we also introduce uncertainties concerning the parameters of the model. In our analysis we allow for asymmetric errors. This means that the true distribution function is allowed to be skewed. For simplicity, however, we assume a left-sided and a right-sided error term of symmetric distributions as illustrated in Figure 7. This should help to mimic the uncertainty estimations of drivers, which in the most extreme case can only be under- or overestimated. The upper- or lower-sided errors are aggregated separately in the analysis. These asymmetric errors should then give an indication of the skewedness of the combined distribution. For simplicity, we will approximate the combined summarized distribution by two uniform distributions. This allows us to give a first order quantitative measure of the probability distribution of the upper and lower limit of the given confidence interval. Notice, however, that the two halves cannot be connected and that we thus face discontinuity at the expected value. For example, in Figure 7 the approximation of the expected value from the upper side is smaller than the approximation from the lower side.

According to the law of propagation of uncertainty the combined uncertainty or in common parlance the “root-sum-of-squares” (RSS) (Taylor and Kuyatt, 1994) of consumption u_c can be computed based on the uncertainty estimates (judgments) of its individual components.

$$u_C = \sqrt{\left(\frac{\partial C}{\partial \phi}\right)^2 u_\phi^2 + \left(\frac{\partial C}{\partial x_2}\right)^2 u_p^2 + \left(\frac{\partial C}{\partial x_3}\right)^2 u_r^2 + 2\left\{\left(\frac{\partial C}{\partial \phi}\right)\left(\frac{\partial C}{\partial p}\right)u_\phi u_p + \left(\frac{\partial C}{\partial \phi}\right)\left(\frac{\partial C}{\partial r}\right)u_\phi u_r + \left(\frac{\partial C}{\partial p}\right)\left(\frac{\partial C}{\partial r}\right)u_p u_r\right\}}$$

In the case of forecasting based on our index-based scenarios correlations are *a priori* non-existent (i.e., $u_x u_y = 0$). In the event that scenarios of the consumption drivers are derived from a dynamic model correlations can be quantified and should be included in the computation of the combined uncertainty of consumption according to the above-mentioned law of propagation of uncertainty.

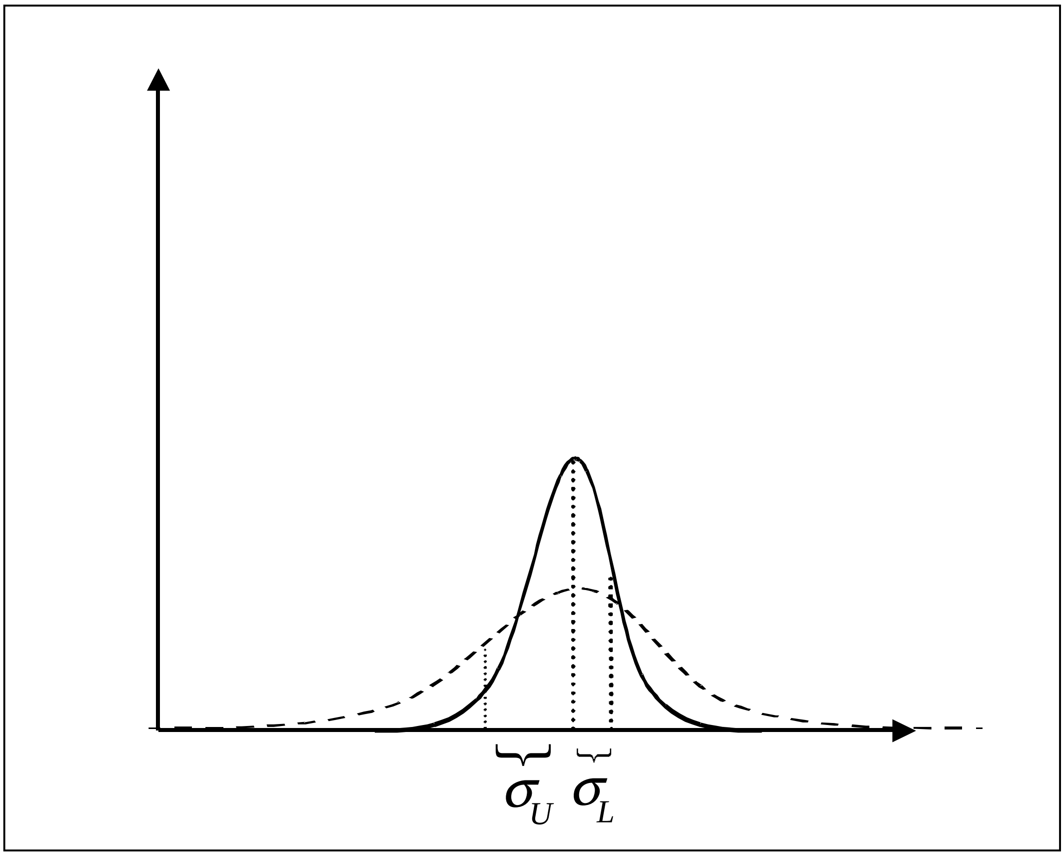

Figure 7: Illustration of the upper and lower normal error.

Uncertainty generally consists of several components, which for our purposes we divide into two groups:

1. Empirically evaluated by statistical methods, and
2. Evaluated by other means.

The first type of uncertainty only occurs in the evaluation of uncertainties of the determination of consumption along the different population cohorts. Here, we use estimates of uncertainty from surveys. In this case, the standard uncertainty is equal to the positive square root of the statistically estimated variance, and the associated number of degrees of freedom. In a similar manner, an uncertainty component of the second type may be considered an approximation to the corresponding standard deviation; it is equal to the positive square root of the corresponding variance of an assumed probability distribution based on the available information and comprehension of the visioneer (experimenter).

Uncertainty can be obtained from a number of different distributions.

Normal Distribution

Procedure: Model the input quantity in question by a normal probability distribution and estimate lower and upper limits a_- and a_+ such that the best estimated value of the input quantity is $(a_+ - a_-)/2$ (i.e., the center of the limits) and there is a 50% (67%, 99.73%) probability that the value of the quantity lies in the interval a_- to a_+. Then u_x is approximately 1.48 (1, 1/3) a, where $a = (a_+ - a_-)/2$ is the half-width of the interval. Let us call the multiplicator of a k, then for any random variable x the Chebyshev inequality states that

$$\Pr ob(\mu - ku \leq x \leq \mu + ku) \geq 1 - \frac{1}{k^2}.$$

Uniform (rectangular) Distribution

Procedure: Estimate lower and upper limits a_- and a_+ for the value of the input quantity in question such that the probability that the value lies in the interval a_- and a_+ is, for all practical purposes, 100%. Provided that there is no contradictory information, treat the quantity as if it is equally probable for its value to lie anywhere within the interval a_- to a_+; that is, model it by a uniform (i.e., rectangular) probability distribution. The best estimate of the value of the quantity is $u_x = \frac{(a_+ - a_-)^2}{12}$. If the distribution used to model the quantity is triangular rather than rectangular then $u_x = \frac{(a_+ - a_-)^2}{24}$.

Figure 8 schematically illustrates the three distributions described above: normal, rectangular, and triangular. In the figure, μ_t is the expectation or mean of the distribution, and the shaded areas represent ± one standard uncertainty σ_x about the mean. For a normal distribution, ± σ_x encompasses about 68% of the distribution; for a uniform distribution, ± σ_x encompasses about 68% of the distribution; and for a triangular distribution, ± σ_x encompasses about 65% of the distribution.

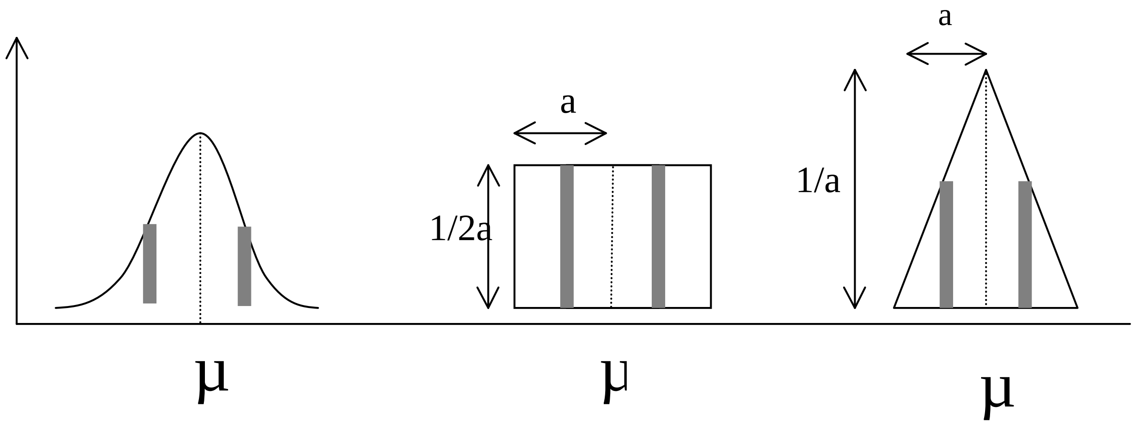

Figure 8: Expected value and variance of the normal, uniform and triangular probability distribution function.
(Source: http://physics.nist.gov/cuu/Uncertainty/index.html).

Approximation of the probability mass for under- and overestimation

If we face a situation where there is a difference in the probability for values to occur above or below the expected value, the probability density function is skewed. As discussed above, we are trying to take this asymmetry into account by computing normal upper and lower uncertainties separately and aggregate those using the law of error propagation. The summarized skewed distribution is then approximated by two corresponding uniform distributions (see, Figure 9, for the one σ confidence interval). The probablities for underestimation (*P*(C_U)) and for overestimation (*P*(C_L)) are then computed by $P(C_U) + P(C_L) = \frac{u_{C_U}}{u_{C_U} + u_{C_L}} + \frac{u_{C_L}}{u_{C_U} + u_{C_L}} = 1$. The ratio *P*($C_U$)/ *P*($C_L$) is then called the under/overestimation ratio of the given scenario plot. If this ratio is, for example, 10:90 we say that there is a 10% change that the expected value is underestimated and that the likelihood of overestimation is 90%, given a certain confidence interval of the original symetric normal distribution.

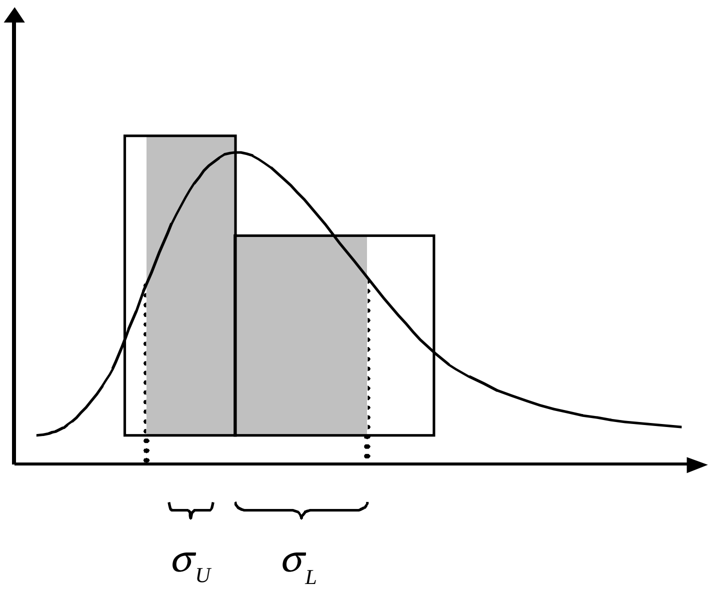

Figure 9: Skewed normal distribution and its approximation by two uniform distributions.

Paperscapes

One of our first examples of Paperscapes is illustrated in the bottom right corner of Figure 1 and shows the distribution of paper consumption for the European part of Russia and West Siberia. Paperscapes stands for a new modeling approach of the distribution of the consumption pattern of individual paper grades in real geographic space by using geo-referenced data on paper consumption as such and its underlying drivers for scenario-building as discussed above within a common GIS framework. The map took into account settlements larger than 2,000 inhabitants. Depending on population density and its distribution and the type of smoothing the surface level curves vary. We are still experimenting with the best representation of Paperscapes trying different smoothing techniques and representation methods (e.g., level curves, spikes, color representation).[5] The combination of representation techniques will allow us to pack more information of the system and its dynamics into one geographically explicit Paperscape. So, for example, level curves represent the state of the system in terms of current consumption levels in XY coordinates while, at the same time, colors of the consumption mountains and valleys indicate the speed and direction of change of consumption at XY. Oscillation within the limits of the skewed distribution of simple blurred borders of the level curves could be used to visualize uncertainty.

Through Paperscapes we are getting closer to agent based models, which will increasingly allow us a more detailed analysis of all the components of the paper cycle. More and more disaggregate information facilitates the calibration of demand models and improves forecastibility. At the same time, we have to realize that the root-sum-of-squares will increase the finer the resolution and the more comprehensive Paperscapes become (see, Obersteiner *et al.*, 2000, for a discussion of the properties of uncertainties and comprehensiveness of systems). In addition, Paperscapes establishes an interesting basis for sector analysis for all the stakeholders involved — from producers, distributors, marketers, consumers all the way to recyclers — due to easy-to-capture visual representation of complex data in Paperscapes. It will also allow a better understanding of the entire fiber-cycle by disaggregation in geographic space. Furthermore, any higher aggregations on a regional, up to continental, level are possible with a few keystrokes within such a framework.

Aggregate Forecast

The aggregate representation of the press-imistic scenario is given in Figure 10. Table 2 shows the development of readership of the press-imistic scenario (or electronic reading dominated equilibrium trajectory) as expressed in the number of readers purchasing the printed edition of newspapers *(*$\Re_{it}$*).* $\Re_{it}$ was calculated by

$$\Re_{it} = \omega_{edu_{jt}} edu_{jt} * \omega_{i_{it}} i_{it} * \omega_{e_{it}} e_{it} * r_{it} * p_{ijt} .$$

The underlying population forecast, provided by IIASA’s Population project, was performed along three different dimensions (age, education, and gender; see the example for Egypt in Figure 2). The population forecast used for the aggregate forecast of newsprint consumption in the USA refers to the ‘central’ population scenario. Additional scenario plots for the general economic development, the life- and work-style parameter of the information society, and the readership rate of the printed edition of newspapers were produced by the authors based on informal interviews that were conducted with various experts in the newsprint/newspaper business at DRUPA 2000 in Düsseldorf.

---

[5] The interested reader is recommended to visit IIASA’s FOR internet page (http://www.iiasa.ac.at/Research/FOR) for the latest representation techniques on paperscapes.

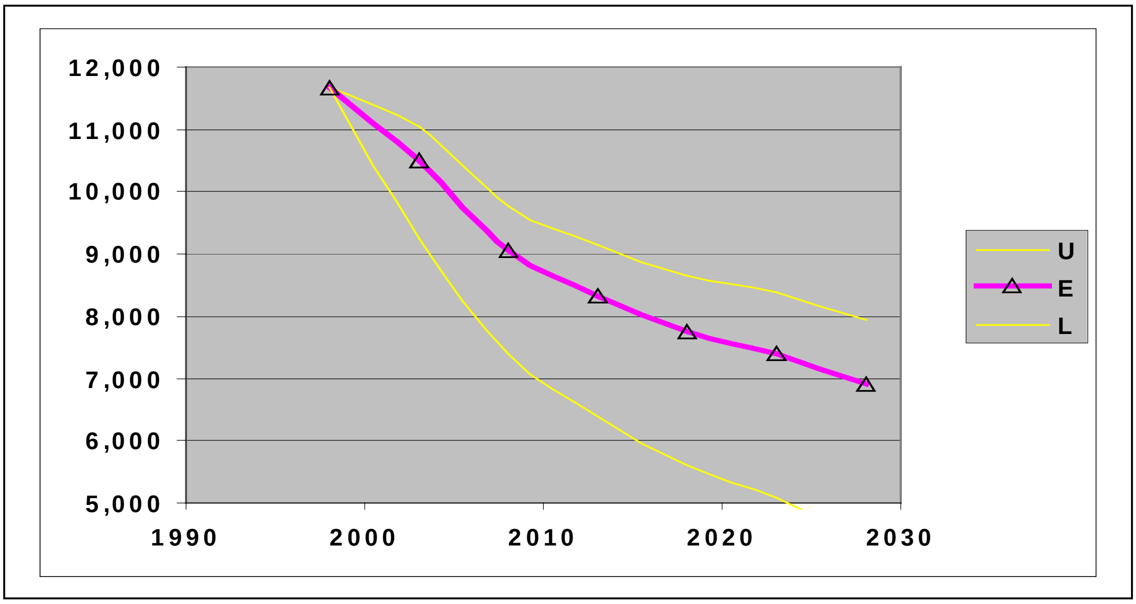

Figure 10: Apparent consumption of newsprint ('000'MT) according to the 'press-imistic' scenario assumptions for the USA (U = upper uncertainty limit; E = expected value; L = lower uncertainty limit).

Table 2 shows a dramatic decrease in readership of the younger age cohorts, whereas older cohorts actually increase readership of the printed version of newspapers in absolute numbers. The total expected number of total readers decreases only by some 13% in the press-imistic scenario.

Table 2: Readership development of paper-based newspapers by age group for the United States.

	Age 18–24	**Age 25–34**	**Age 35–44**	**Age 45–54**	**Age 55–64**	**Age 65+**	**Total**
1998	16169	30456	44054	38276	27508	41147	197609
2003	14883	27279	39747	41635	33116	42238	198899
2008	11987	23078	34462	41923	37050	45342	193843
2013	11674	21144	28914	41505	40449	47471	191158
2018	10915	20630	25388	33822	45068	51766	187590
2023	10379	19395	25559	27112	38588	62624	183657
2028	9164	18114	24487	26394	30342	63685	172187

Sources for 1998 data: MRI, Spring 1999; SRDS, Circulation 99 for the base year 1998 (http://www.naa.org/marketscope/databank/rpc1999.html).

The main factor explaining readership decline of the 'press-imistic' scenario in Table 2 is substitution. Out-substitution is modeled by changing the readership rate (r_{it}) as shown in Table 3. It is assumed that young cohorts are faster substituters, whereas people after retirement change their reading habits very slowly. Older people mostly stick to the type of reading they were used to just before retiring. It is assumed that substitution will be most virulent in the technological transition period up to the year 2008–2013. The counter-veiling forces to total readership decline are population growth in both quantitative and qualitative (education) terms, economic growth, and finally the fact that an increasing number of people will demand newspaper reading due to the informatization of the societal metabolism.

Table 3: Scenario assumptions on the readership rate along different age cohorts *(r_{it})*. The level in 1998 for each individual age group was set at 100%.

	Age 18–24	**Age 25–34**	**Age 35–44**	**Age 45–54**	**Age 55–64**	**Age 65+**
1998	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
2003	80.0%	90.0%	90.0%	90.0%	98.0%	100.0%
2008	60.0%	70.0%	80.0%	80.0%	88.0%	98.0%
2013	55.0%	57.5%	67.5%	77.5%	79.5%	88.0%
2018	50.0%	52.5%	55.0%	65.0%	77.0%	79.5%
2023	45.0%	47.5%	50.0%	52.5%	64.5%	77.0%
2028	40.0%	42.5%	45.0%	47.5%	52.0%	64.5%

The scenarios concerning the development of more technical factors were also adjusted based on expert opinions. The grammature of the newsprint used is assumed to decrease by only 3%. The size of the average printed version of a newspaper and the number of newspapers per capita is expected to decrease by 30% in a non-linear fashion. The first 20% decrease is expected in the period up to 2013, while the remaining 10% will become effective in the last 15 years. This mainly reflects a shift of advertisements to other media, changes in the editorial content, and other content to e-newspapers. It follows that substitution is modeled in two different ways — through readership and through reading intensity. Due to a lack of information on the initial distribution of reading intensity (kg/(p*r)) across educational and age groups, we assumed that the decrease in the intensity *(s)* would decline in a uniform manner across all population cohorts (Table 4).

Table 4: Development of the reading intensity *(s)* and grammature *(g)*, and development of apparent consumption.[6]

	Index (s*g)	**Kg/(p*r)**
1998	1.00	59.0
2003	0.90	52.9
2008	0.79	46.8
2013	0.74	43.6
2018	0.70	41.4
2023	0.68	40.3
2028	0.68	40.1

[6] Apparent consumption figure of newsprint was taken from http://www.naa.org (11,665,000 MT), whereas PPI (2000) reports some 12,243,000 MT (62.0 kg per (p*r)) for the year 1998.

Figure 10 shows the aggregate consumption path of newsprint according to the above mentioned scenario assumptions. It also gives information on the uncertainty of the press-imistic scenario. The uncertainty bands are asymmetric with a lower uncertainty of the upper-limit curve (15% uncertainty from the mean in 2028) and a higher uncertainty of the lower-limit curve (56% uncertainty from the mean in 2028). In other words, this means that within the drawn limits the ratio of the probability of under- to overestimation of the expected value is 21:79.

Evaluation of Scenario Dynamics

Consistency with Historical Evidence

There is no doubt that new technologies can aggressively replace existing technologies. However, when we cast future scenarios a very informative indicator on the 'credibility' of a scenario is the consistency with historical evidence of the trajectories of technologies. In other words, would it be possible to reconstruct a certain scenario with a dynamic systems model using historical data, i.e., reachability?

Comparison of the descriptive statistics (minimum, maximum, average, median, standard deviation) of the first and higher differences of consumption of the historical data of the same system (the actual time series of consumption of the particular paper grade) or some other reference system (e.g., number of cellular phones in a particular region) and the data generated by the scenario plot, i.e., for the first difference and the maximum:

$$I_C = \frac{\min \overset{\Delta t}{C}_{t^+}}{\min \overset{\Delta t}{C}_{t^-}}$$

where I_C is the index of consistency, $\overset{\Delta t}{C}_{t^-}$ is the first difference of past consumption (t^-) observations over some period(s) Δt, and $\overset{\Delta t}{C}_{t^+}$ is the first difference of forecasted consumption (t^+) over the same period(s) Δt. However, more research effort will have to be dedicated to develop indicators on these lines. For a five-year period ($\Delta t = 5$) I_C was 7.6 in the illustration of newsprint consumption for the USA. This means that the largest relative decline recorded in history (i.e., between 1980–1998) (–1.8%) was 7.6 times smaller than the largest decline of the expected value in the scenario forecast (–13.8%). Of course, history can only contingently be used as a benchmark for future consumption trajectories. So, the historical reduction in consumption was mainly due to a decreasing aggregate economic output (decline in *e*) rather than connected with substitution due to technological change of a competing product, which was the main driver in our scenario plots.

Gap Analysis

Another indicator would be the difference between the forecasted value gained from the application of a standard econometric forecasting method with the value gained by the scenario plot. However, for most paper grades short yearly time-series are available, which for most cases do not even allow for meaningful stationarity tests making any kind of application of time-series models at least spurious. The application of structural models to create a benchmark is equally problematic due to the lack of data on meaningful drivers and their projections leading to omitted variable biases.

Summarizing Discussion

The dynamic properties of new information technologies make it clear that traditional forecasts, which are based on extrapolation from the past, are becoming increasingly meaningless. However, projections into the (long-term) future are more important than ever before as technological change impacts the globe and the global society at an increasing pace of change. There are currently no models available that allow us to produce merely reasonable decisions in an environment of fast technological change. The traditional models' view is that the world is relatively certain and predictable ignoring that the technique to deal with long-term strategic planning under the type of uncertainty faced today is seriously flawed. Most organizations today are still structured around and function on this familiar logic, mainly because it has worked so well in the past. But we have to realize that under the new environment of the information age Pavlovian dogs will have difficulties to survive on the market. The traditional models of strategy building and forecasting were successfully applied for industrial based activities where cost efficiency, increased productivity, and economies of scale were of paramount importance. However, as discussed in this paper the world of today is becoming increasingly complex and interconnected, full of rapid discontinuous change and non-stationarity due to feedback economies. In the context of our topic we have to realize that there is no single right answer to 'how Paperscapes will look in thirty years from now'. At the same time, investors in the paper sector make multi-billion investment decisions based on their long-term expectations of future Paperscapes. The development of a methodology to derive sound long-term expectations was the core of this paper.

In this paper we established a simple computable scenario model that allows the user (group of users) to very quickly assign parameter values of the paper consumption system to generate interesting scenario plots. It further allows for an explicit probability measure of the considered scenarios. Probabilities are allowed to be skewed, reflecting a user's belief of differing probabilities for under- and overestimation of certain parameters. The scenario model is designed in a modular fashion so that scenario building can be implementable on all levels of detail both in terms of geographic and parameter space.

Scenario building is understood as a social process. The model provides a formal structure to combine the wetware, software, and hardware[7] associated with the social process in an effective way. At the same time, the model is designed in such a way that it can be used as an online scenario building tool as discussions are going on either in a physical or virtual discussion room with the purpose to visualize the quantified outcome

---

[7] According to Conceicao *et al.* (1998) wetware is defined as tacit knowledge stored in human brains (beliefs, talents, skills), software is codified knowledge (books, CDs, internet pages, blueprints, etc.), and hardware is all knowledge built in non-human material things (equipment, buildings, land).

of scenario building. Visualization can either be regarded as an end product of scenario building reflecting the systems insight of the scenario group or be regarded as an input for new or refined scenarios. Thus, visualization of results is of paramount importance for the validation of scenarios. We provide two types of visualization of the results: Paperscapes, which are geographically explicit, and the diagram of the dynamics of the aggregate results and its associated uncertainties. The idea that Paperscapes can comprise the full description of the dynamic system in one Paperscape will still require some more research on different representation tools. Paperscapes will in a later stage be coupled with Fiberscapes involving a global forest sector model.

There is still a lot to be done on theory building in order to understand which drivers operate in what way on the total consumption system. Visioning itself is a very beneficial process, but without proper supplementation of theory the quantified scenarios might consistently be very wrong. More theory is needed to understand the processes driving the frequency and step size of innovation. We will also have to put more effort into understanding the formation and properties of different technological equilibria. Of special interest should be the ‘chaordic’ fashion of hill climbing between two equilibria involving continuous innovation and creative destruction.

The scenario model is currently implemented as a simple spreadsheet model. However, we are currently working on an implementation that will allow us a more graphical representation of scenario assumptions that will significantly improve the transparency of modeling and also speed-up scenario building.

We are currently testing the model developed here in a *Future Exercise* with industry executives engaged in a course on “Managing Technology for Value Delivery” in cooperation with the University of British Columbia, Canada.

References

Aliardi, Elettra (1998). *Positive Feedback Economies*. MacMillan Press Ltd., London UK.

Arrow, Kenneth J. (1962). The Economic Implications of Learning by Doing. *Review of Economic Studies*, 29:155–73.

Arthur, W.B. (1988a). Competing Technologies: An Overview. In: G. Dosi, C. Freeman, R. Nelson, G. Silverberg and L. Soete (eds.), *Technical Change and Economic Theory*, Pinter, London.

Arthur, W.B. (1988b). Self-Reinforcing Mechanisms in Economics. In: P. Anderson, K. Arrow and D. Pines (eds.), *The Economy as an Evolving Complex System*, Addison-Wesely, Reading, MA.

Arthur, W.B. (1994). *Increasing Returns and Path Dependence in the Economy*. University of Michigan Press, Ann Arbor.

Conceicao, P., M.V. Heitor, D.V. Gibson and S.S. Shariq (1998). The Emerging Importance of Knowledge for Development: Implications for Technology Policy and Innovation. *Technological Forecasting and Social Change*, 58:181–202.

Dieckmann, U. and M. Doebeli (1999). On the Origin of Species by Sympatric Speciation. Interim Report IR-99-013. International Institute for Applied Systems Analysis, Laxenburg, Austria. Available on the Internet: http://www.iiasa.ac.at.

Ermoliev, Yuri M., Tatiana Y. Ermolieva, Gordon J. MacDonald and Vladimir I. Norkin (2000). Economic Growth Under Shocks. Interim Report. International Institute for Applied Systems Analysis, Laxenburg, Austria (forthcoming).

Jones, Charles I. (1999). Growth: With or Without Scale Effects. *American Economic Review*, Vol. 89, No. 2, May, pp. 139 ff.

Obersteiner, M., M. Jones, S. Nilsson, A. Shvidenko and M. Gluck (2000). If You Act Locally and Compute Globally What is the Optimal Comprehensiveness of the Reference Carbon System? Interim Report IR-00-65. International Institute for Applied Systems Analysis, Laxenburg, Austria. Available on the Internet: http://www.iiasa.ac.at.

OECD (2000). Information Technology Outlook 2000: ICTs, E-commerce and the Information Economy. Organization for Economic Cooperation and Development (OECD), Paris, France. Available at: http://electrade.gfi.fr/cgi-bin/OECDBookShop.storefront/1580433711/Product/View/932000011P1).

PPI (2000). International Price and Fact Book 2000. Pulp and Paper International (PPI), Brussels, Belgium.

Rosenberg, Nathan (1976). *Perspectives on Technology*. Cambridge University Press, Cambridge.

Stiglitz, Joseph E. (1987). Learning to Learn, Localized Learning and Technological Progress. In: P. Dasgupta and P. Stoneman (eds.), *Economic Policy and Technological Performance*, Cambridge University Press, Cambridge.

Taylor, B.N. and C.E. Kuyatt (1994). Guidelines for Evaluation and Expressing the Uncertainty of NIST Measurements. United States Department of Commerce, National Institute of Standards and Technology, Washington, DC, USA.