A Microeconomic Model to Assess the Economic Impacts of the EU's New Chemicals Policy

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Executive Summary

To assess the economic impact of the new chemicals policy, DG Enterprise has developed a calibrated microeconomic model of the chemicals industry. The model is calibrated on 1998 data for the chemicals industry disaggregated into five sectors using the Eurostat Structural Business Statistics database (see Eurostat, 2000). The analysis in this paper aims at assessing the economic costs of the initial registration phase of the new chemicals policy. It does not cover the potential impacts of the subsequent evaluation and authorisation phases, nor their associated potential benefits for human health and the environment.

The theoretical basis of the model is the widely used Dixit and Stiglitz (1977) model of monopolistic competition with differentiated products and economies of scale. The model assumes that the products of individual firms in the chemicals industry are close, but not exact substitutes. It is possible therefore for downstream users to change between different substances, but at a cost that is determined by the "elasticity of substitution" between products. The number of products available is assumed to be directly proportionate to the number of firms. The production of chemicals exhibits economies of scale: i.e. the more that is produced, the lower the average cost of production[2]. Chemicals firms maximise their profits, taking into account both their own costs and the likely reactions of their close competitors. The model is solved assuming free entry to and exit from the market. Hence, a shortfall of over all profits will result in firms ceasing the production of their chemicals products. The remaining firms will then be able to increase their prices and production in order to restore their profitability. However, with less firms in the industry, downstream users of substances will face higher prices and fewer available products on the market. Downstream user costs will therefore be increased.

The implementation of chemicals policy effectively represents an increase in the overhead costs of chemicals firms. Testing costs can be seen as an investment, required by firms in order to be able to continue marketing their products. Higher testing and other direct costs (such as those for registration, authorisation etc.) need to be offset by either higher prices or a reduction in the number of firms allowing more scope for economies of scale. Part of the increase in testing and

[2] This results from the fact that chemicals firms generally face high initial fixed costs of production (largely capital costs and overheads), whilst the cost of producing an additional unit (the marginal cost) is relatively low and constant.

registration costs will be passed through in the form of higher prices to downstream users. However, some of the adjustment to the new chemicals policy will be reflected in a reduction in the number of firms and products in the market. Hence, the costs for downstream users are raised through two mechanisms: an increase in the overall price of chemicals and a higher cost for downstream users from the need to substitute alternatives for those chemicals taken out of production.

The exact size of the additional costs to downstream industries depends crucially on two factors. First, the extent to which the withdrawal of chemical substances has an effect on the chemicals supply-chain, resulting in an increase in substitution costs and a reduction in the efficiency of chemical products. Secondly, it depends on the time frame of any such disruption or temporary increase in market power.

Two scenarios for the costs of REACH to downstream users have been investigated: a "normal expectations" scenario and a "higher substitution costs" scenario. Both scenarios are based upon estimated testing and registration costs of € 2.3 billion. In each case a lower and upper estimate of the costs are derived for two time periods: 11 years (the time to register all substances currently on the EU market) and 15 years (to allow for a longer adjustment period).

The "normal expectation" case examines the impact of the introduction of REACH, where the implications for downstream users come solely from the pass-through of testing and registration costs and the effects of the withdrawal of chemical substances on individual downstream users.

A "higher substitution costs" scenario illustrates the effects where the withdrawal of substances further increases the costs of substitution, through the cumulative effects of the withdrawal of substances in terms of adaptation to the whole of the chemicals supply chain. In this case, it has been assumed that the efficiency of the chemicals industry is reduced marginally in proportion with the withdrawal of chemical substances. It also results in some increase in the market power of the suppliers of substitution substances. In this case, higher downstream user costs would be expected.

	Lower estimate (11 years)	Upper estimate (15 years)
Normal expectation	€ 2.8 billion	€ 3.6 billion
Higher substitution cost	€ 4.0 billion	€ 5.2 billion

Table: Alternative present value estimates of costs to downstream users

The table presents the results of the two scenarios. In either case, the use of the microeconomic model suggests that only some 0.5% of the overall value of chemical substances, approximately 1-2% of all substances[3], will be withdrawn from the market as a result of REACH.

In the "normal expectation" case, the costs to downstream users of the introduction of REACH is assessed to be in the range € 2.8 – 3.6 billion. These costs will occur in the form of higher chemical prices resulting from the passing through of testing and registration costs and as a result of the additional substitution costs for downstream users of chemicals in finding potentially higher cost or less-effective replacements for those substances removed from the market. In the "higher substitution cost" scenario, the costs to downstream users of the introduction of REACH is assessed to be in the range € 4.0 – 5.2 billion.

It is important to clarify the status of the estimate of the costs to downstream industry costs given in this paper. In particular, the estimate includes the majority of the testing and registration costs that have been passed through to downstream users. Hence the testing and registration costs should not be added to the downstream industry costs to give the overall costs of the REACH proposal. Moreover, while the principal economic mechanisms have been captured by the model

[3] Assuming that the withdrawal rate for substances below 100 tonnes is some 2 to 4 times higher than that for substances above 100 tonnes.

it should be understood that the model - nor indeed any other available model - does not and cannot encapsulate all of the economic mechanisms resulting from REACH proposal.

- Firstly, it should be emphasised that the estimated effects on downstream industries represent the immediate cost effects. The estimates therefore do not include any consequences on the international competitiveness of the downstream users of chemicals. .
- Secondly, the model does not quantify the impacts of REACH on innovation . For the moment, there is no readily-available technique for quantifying these effects. In general terms however, the introduction of REACH may in the short-run affect the resources available for R&D; whilst, in the longer-term however the modifications made to the R&D regime by REACH should give incentives for innovation.

1. Introduction

To assess the economic impact of the new chemicals policy (see box), DG Enterprise has developed a calibrated microeconomic model of the chemicals industry. The chemicals industry is disaggregated into five sectors: basic chemicals; pesticides and other agrochemicals products; paints, varnishes, and similar coatings; soap and detergents; and other chemicals. The model is calibrated on 1998 data for the chemicals industry from the Eurostat Structural Business Statistics database (see Eurostat, 2000). The analysis aims at assessing the economic costs of the initial registration phase of the new chemicals policy. It does not cover the potential effects of the subsequent evaluation and authorisation phases, nor their associated potential benefits for human health and the environment.

The theoretical basis of the model is the widely used Dixit and Stiglitz (1977) model of monopolistic competition with differentiated products and economies of scale[4]. The model assumes that the products of individual firms in the chemicals industry are close, but not exact substitutes. It is possible therefore for downstream users to change between different substances, but at a cost that is determined by the "elasticity of substitution" between products. The number of products available is assumed to be directly proportionate to the number of firms. The production of chemicals exhibits economies of scale: i.e. the more that is produced, the lower the average cost of production[5]. Chemicals firms maximise their profits, taking into account both their own costs and the likely reactions of their close competitors. The model is solved assuming free entry to and exit from the market. Hence, a shortfall of overall profits will result in firms ceasing the production of their chemicals products. The remaining firms will then be able to increase their prices and production in order to restore their profitability. However, with less firms in the industry, downstream users of substances will face higher prices and fewer available products on the market. Downstream user costs will therefore be increased.

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[4] Applications are common particularly in the evaluation of trade and industrial policy: examples include Smith and Venables (1988) and Allen et al. (1998).

[5] This results from the fact that chemicals firms generally face high initial fixed costs of production (largely capital costs and overheads), whilst the cost of producing an additional unit (the marginal cost) is relatively low and constant.

The implementation of chemicals policy effectively represents an increase in the overhead costs of chemicals firms. Testing costs can be seen as an investment, required by firms in order to be able to continue marketing their products. Higher testing and other direct costs (such as those for registration, authorisation etc.) need to be offset by either higher prices or a reduction in the number of firms allowing more scope for economies of scale. Part of the increase in testing and registration costs will be passed through in the form of higher prices to downstream users. However, some of the adjustment to the new chemicals policy will be reflected in a reduction in the number of firms and products in the market. Surviving chemicals firms are assumed to increase their production to compensate for the withdrawal of other chemical firms. Hence, the costs for downstream users are raised through two mechanisms: an increase in the overall price of chemicals and a higher cost for downstream users from the need to substitute alternatives for those chemicals taken out of production.

The plan of the paper is as follows. The next section introduces the microeconomic model used and demonstrates its general properties. The third section explains the data sources used and the procedure employed for calibration. The fourth section contains the empirical assessment of the impact of the new chemicals policy. Section five concludes.

The New Chemicals Policy

The need for a new chemicals strategy arose from a wide acceptance that the existing chemicals legislation was not capable of responding adequately to public concern in Europe about the potential impact of chemicals on health and the environment. The Commission published a White Paper in February 2001 (CEC, 2001) outlining a new strategy for the management of chemicals.

Following an extensive internet consultation, the Commission finally published on 29 October 2003 its proposals for a "Regulation concerning the Registration, Evaluation, Authorisation and Restrictions of Chemicals" (CEC, 2003a). The central features of the proposed new system, named REACH[6], are as follows:

- The registration by companies of substances produced over 1 tonne; this means that manufacturers and importers of substances must submit information to a new chemicals

[6] Registration, Evaluation, and Authorisation of CHemicals.

agency. In order to obtain the prescribed information, registrants may have to perform tests on the substances they manufacture or import. They will also be required to assess the use of substances, and to put in place or recommend appropriate risk management measures. The information required increases at tonnage thresholds 10, 100 and 1000 tonnes respectively. Deadlines for registration are established for existing or "phase-in" substances, starting with over 1000 tonnes, 3 years after the Regulation comes into force, and ending with over 1 tonne after 11 years.

- The evaluation of data provided by industry on registered substances would be automatic for any testing programme that is proposed by the registrant (required for substances above 100 tonnes), but optional for evaluation of other aspects of registration dossiers.

- The authorisation of certain categories of substances of very high concern, typically CMRs, namely carcinogens, mutagens, and reproductive toxicants, and substances with persistant, bioaccumulative and toxic (PBT) or very persistant and very bioaccumulative (VPVB) properties. The manufacturer, importer, or downstream user of such substances will have to demonstrate that the substance can be used safely or, failing that, that the socio-economic benefits of the use outweigh the risks. It is proposed that such authorisations will be granted by the EU Commission on the recommendation of the Agency.

Overall, it is anticipated that some 30,000 chemical substances will come within the scope of the REACH system. Estimates of the direct costs of the policy were published by the EU commission in the Extended Impact Assessment that accompanied the proposals (CEC 2003b).

2. A microeconomic model of the EU chemicals industry

2.1 The theoretical model

A key characteristic of the chemicals market is the wide variety of different or differentiated products that are currently available. Hence it would not be adequate to analyse the impact of this new policy using a model of perfect competition, in which all products are assumed to be identical.

For this reason, we have used a model of monopolistic competition with differentiated products[7]. In these models, we do not assume that all products are identical, but allow a horizontal differentiation between the products. This means that each firm, with a certain kind of product, satisfies one part of overall downstream-producers' demands. Downstream producers have different preferences and requirements: for instance, there are different particular characteristics of each product (Lancaster, 1966). Consequently, chemicals firms derive a limited amount of market power from these differences in demands.

In the model, the demands for chemicals products by downstream users are generated from a aggregate objective function. This function is assumed to have the property that it is possible to aggregate together all chemicals inputs into a single bundle of goods[8]. Within this bundle, it is nevertheless possible for downstream users to substitute between different individual products, although at a cost determined by a common indicator of the elasticity of substitution (•) [9].

To simplify the model, we have made the assumption that chemicals firms are identical and that the number of chemical product varieties is directly proportional to the number of firms.

The demand for the overall bundle of chemicals inputs - the aggregate demand curve for chemical products - is given by:

$$n.X = D(p^{-\bullet})$$

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[7] See Dixit and Stiglitz (1977) and Atkinson and Stiglitz (1980), chapter 7.3. The model is a minor extension of that presented in the latter reference.

[8] In other words, the production function is separable between chemicals and other inputs.

[9] The bundle of inputs of chemicals, denoted by • , is assumed to have the constant elasticity form:

$$\Gamma^{\rho} = \Sigma_i X_i^{\rho}.$$

where n is the overall number of chemical firms, X is the average output per chemicals firm, and p is the price of chemicals. D is the overall demand function for chemicals products, whilst • is the aggregate elasticity of demand for chemical products .

How is the market equilibrium determined? Each firm attempts to maximise its profit, and entry occurs until the marginal firm can only just break even. Each firm attempts to maximize its profits, subject to the strategies of its competitors. The profit maximisation condition results in the familiar equality of marginal revenue and marginal cost. The price equation for chemical firms can be written as:

$$p = c. [\rho.(1-\bullet /n)]^{-1}$$

where p is the price and c is the marginal cost of the average firm. The term in square brackets gives the mark-up of prices over marginal costs. This depends on an indicator of the elasticity of substitution between different chemicals produc ts, • (when • is close to 1 the products are perfect substitutes), the number of firms, n, and •, a parameter that takes into account the partition of the overall product markets into important categories of sub -products.

The third equation needed to char acterise the market is an equation determining the entry and exit of firms from the industry. Firms will continue to enter the industry as long as above -normal excess profits are being made; likewise firms will exit the industry when profitability is lower than in other industries. The third equation determines when firms neither want to enter nor leave the industry. It is therefore called the zero excess profit condition:

$$p.X = F + c.X$$

The left-hand side represents total sales revenue. The right hand sid e represent total costs: equal to overhead costs including the normal rate of return on capital employed (F), plus variable costs (marginal cost times output).

These three equations can be solved to determine the overall market equilibrium, giving the equilibrium chemicals price, (p), the equilibrium number of firms (n), and the equilibrium output per firm (X).

Finally we can assess the increase in costs for downstream users arising from the changes in the number of product varieties. The standard technique is the so-called "compensating variation". The compensating variation is the minimum additional cost to a downstream user of obtaining the same overall output as it produced prior to the change in chemicals market conditions. In our case, we have approximated this amount by the following difference:

$$CV = p^*.n^*.X^* - p^o.n^o.X^o$$

This is the difference between the cost of the required compensating inputs (X*) at the new prices (p*) and the new number of products (n*) and the cost of the original set of inputs at original prices and the original set of inputs (denoted by the superscript "o"). The required compensating set of inputs, X*, is computed by determining the how much extra of the restricted set of products would be required to obtain the same amount of output as with the original larger set of products[10].

[10] The original bundle of inputs is given by: $\Gamma^{0\bullet} = \Sigma_i X_i^{0\bullet} = n^0.X^{0\bullet}$. With a restricted number of products (excluding say k products), the input bundle becomes $\Gamma^{*\bullet} = \Sigma_{j\bullet k} X_j^{*\bullet} = n^*.X^{*\bullet}$. Equating the two functions, we obtain the required amount of consumption of each remaining product is $X^* = [(n^0/n^*)^{(1/\rho)}.Xu]$.

2.2 The properties of the model

In this section, we explore the properties of the model diagrammatically. A more formal approach to the model properties is included in annex 1.

Diagram 1 shows the relationships between price and quantity for the typical firm to illustrate the determination of the equilibrium in the model .

The first relationship is the *zero excess profit condition* (Z). This is equivalent to the average total costs curve (with the inclusion of normal profits in costs), since zero excess profits implies that price must be equal to average total costs. Average total costs are composed of average overhead costs per unit of output plus the marginal cost of an additional unit of output (a ssumed constant in our analysis). The zero excess profit curve therefore slopes downwards with an asymptote at the marginal cost. This curve is independent of the number of firms producing in the industry.

The second relationship is the *price curve* (P). This is a horizontal line, since prices determined as a mark-up over marginal cost. The extent of this mark -up however is not independent of the number of firms. For instance, should the number of firms in the industry decrease, than competition would decre ase and the price curve would rise.

The third relationship is the *aggregate demand curve* (D), which can be illustrated for the typical firm. This curve shows the relationship between the average quantity demanded per firm and the aggregate industry price. This will be a downward sloping curve with a slope determined by the aggregate elasticity of demand. The curve will depend on the number of firms in the industry: if firms leave the industry, there will be more demand for any given firm, and the curve wil l move upwards. This aggregate demand relationship is obviously not equivalent to the demand curve as perceived by the firm itself: the firm's own demand curve will be much more elastic, since it does not expect its competitors to respond to changes in its own strategy.

The equilibrium (O) will be determined as the point that all three curves cross. Any disturbance from equilibrium will be restored by changes in the number of firms in the industry, which in turn will shift both the price setting and aggreg ate demand curves.

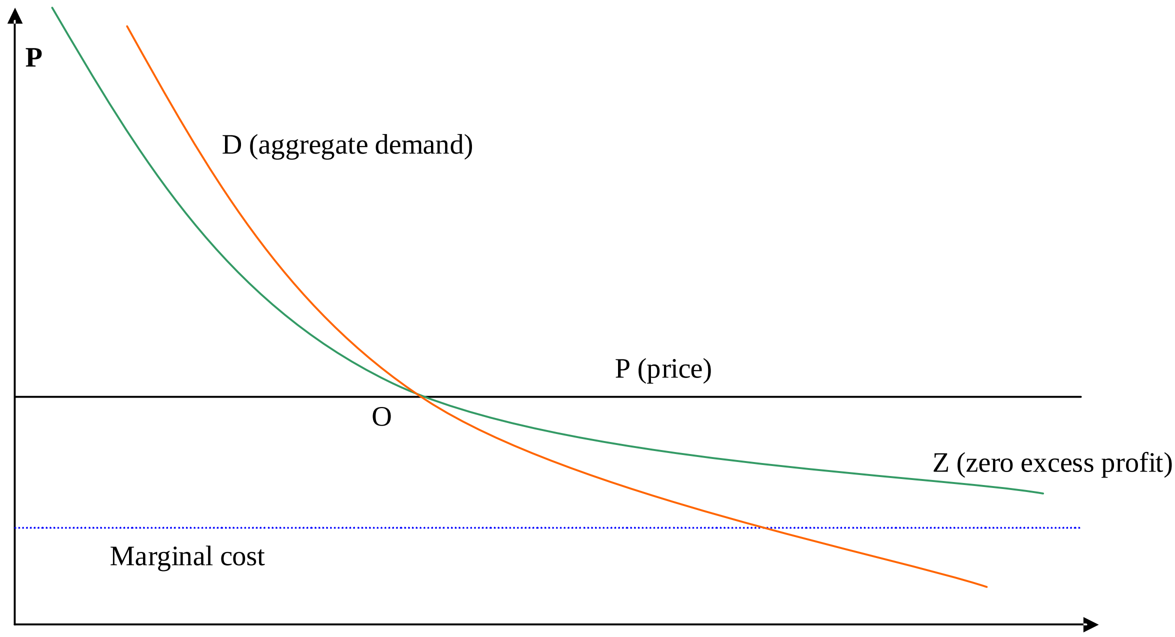
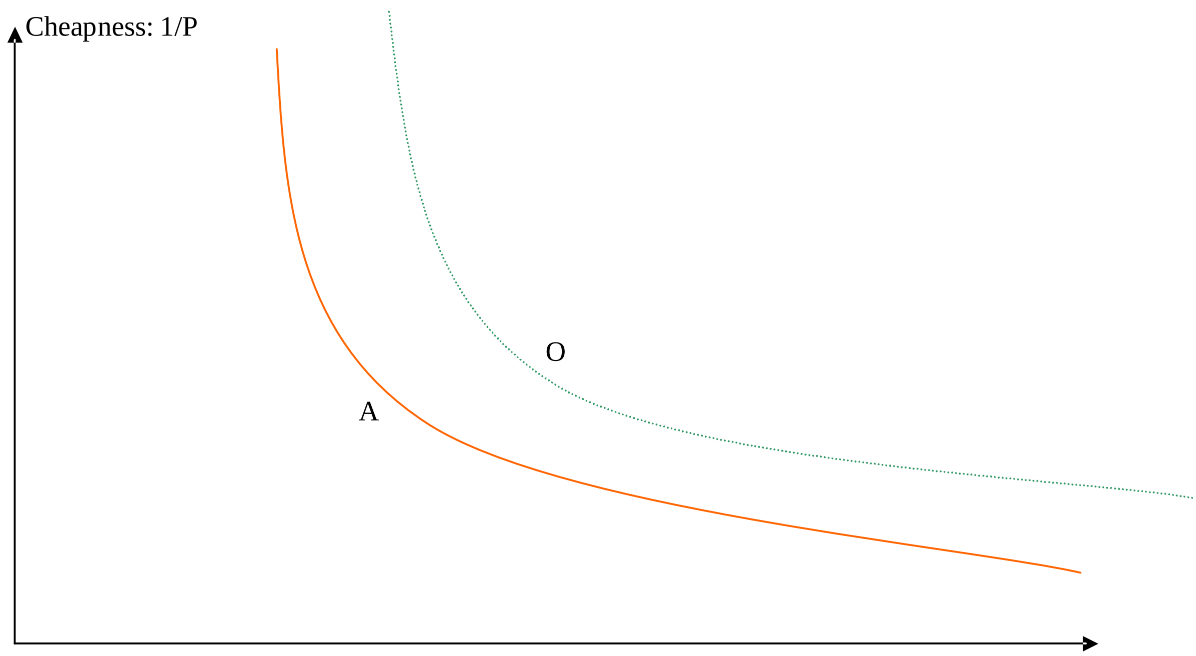


Diagram 1: equilibrium of the model



Graph 2: indifference curves for downstream users

Diagram 2 shows the influence of changes in the price and availability of chemicals on downstream users. The axes of the diagram show the cheapness and variety of chemicals measured respectively by the reciprocal of the price of chemicals (1/p) and the number of available chemicals (n). The diagram shows conventional indifference curves for different combinations of the cheapness and variety of chemicals : the indifference curve passing through O is strictly preferred to that passing through A. The cost changes between different indifference curves are quantified in monetary terms in the model through the "compensating variation", which gives the cost of obtaining an equivalent set of required inputs at new prices and with a new number of available products.

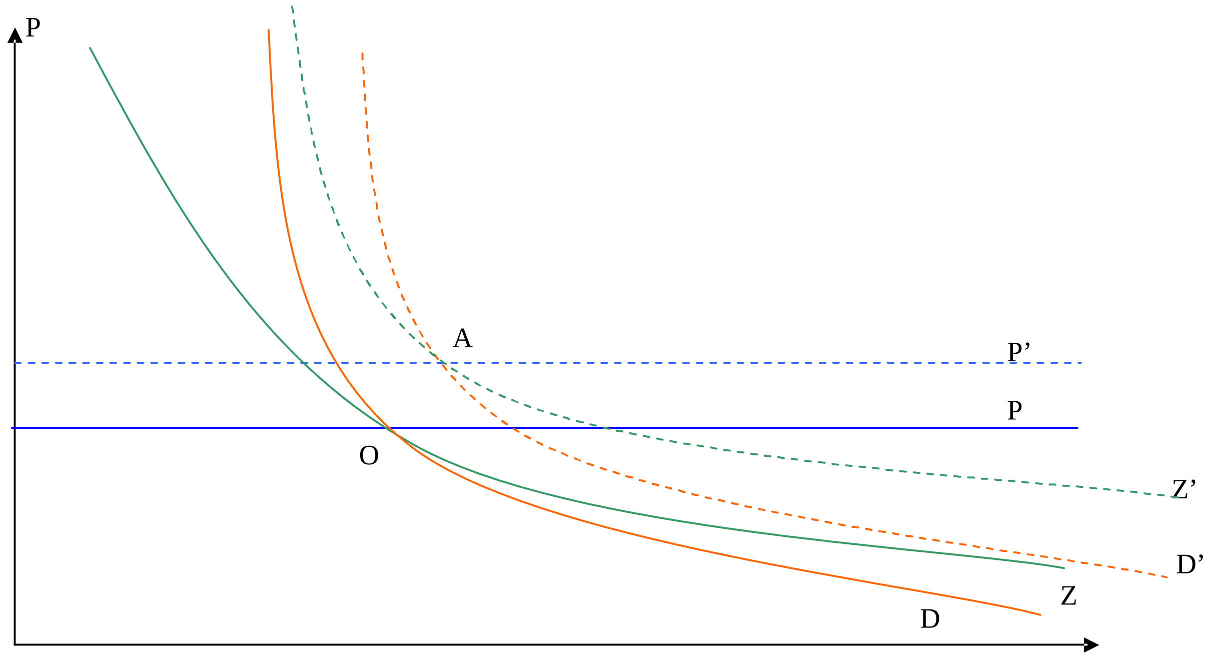
2.2.1 An increase in overhead costs

The imposition of testing costs and other requirements result in an increase in firms' overhead costs.

The effects on equilibrium in the industry in this case are shown in diagram 3. The zero excess profit curve moves upwards, but with an unchanged asymptote. At existing prices and quantities, there will be a profit shortfall. Firms will therefore leave the industry. As firms leave the industry, the aggregate demand curve will move upwards, since each remaining firm will have a larger share of overall demand. The price setting curve will also move higher, since with fewer competitors, a higher mark-up becomes possible.

The new equilibrium will be established with fewer firms in the industry. The prices and quantities sold of the remaining firms in the industry will be higher than originally. This will allow chemicals firms to make up the required revenue to cover higher costs, partly through higher prices and partly from being able to benefit more from economies of scale.

Since both chemicals prices have increased and the number of varieties of chemicals on the market has fallen, the costs to downstream users will have definitely been increased by the imposition of testing and registration costs. In terms of diagram 2, downstream users will move from the original position, O, to a position A on a lower indifference curve. The rise in costs to downstream users is measured by the compensating variation.



Graph 3: new equilibrium after an increase in overhead costs

2.2.2 A reduction in the substitut ability of chemicals

A reduction in the substitutability of chemicals (a reduction in the parameter •) may result from the increasing differentiation of products or (as in the sequel) from a partial and non -random withdrawal of pr oducts from the market. It has two effects within the model: first, the elasticity of substitutability between products is reduced; secondly, it reduces the overall efficiency of the output of the chemicals industry, shift ing the objective function of downstream users so that greater quantities of chemical inputs are required to obtain the same downstream output .

The first effect is illustrated in diagram 4. A reduction in the elasticity of substitution will lower the price elasticity of demand for chemicals firms, allowing them to set higher prices. Hence the price curve will move upwards. In the absence of entry of new firms into the industry, each firm would make excess profits (at a temporary equilibrium at B). However, the assumption of the model is that excess profits will attract new entry into the industry: this will have the effect of moving back the aggregate demand curve. The zero excess profits curve depends on the firm's own costs and will remain unchanged.

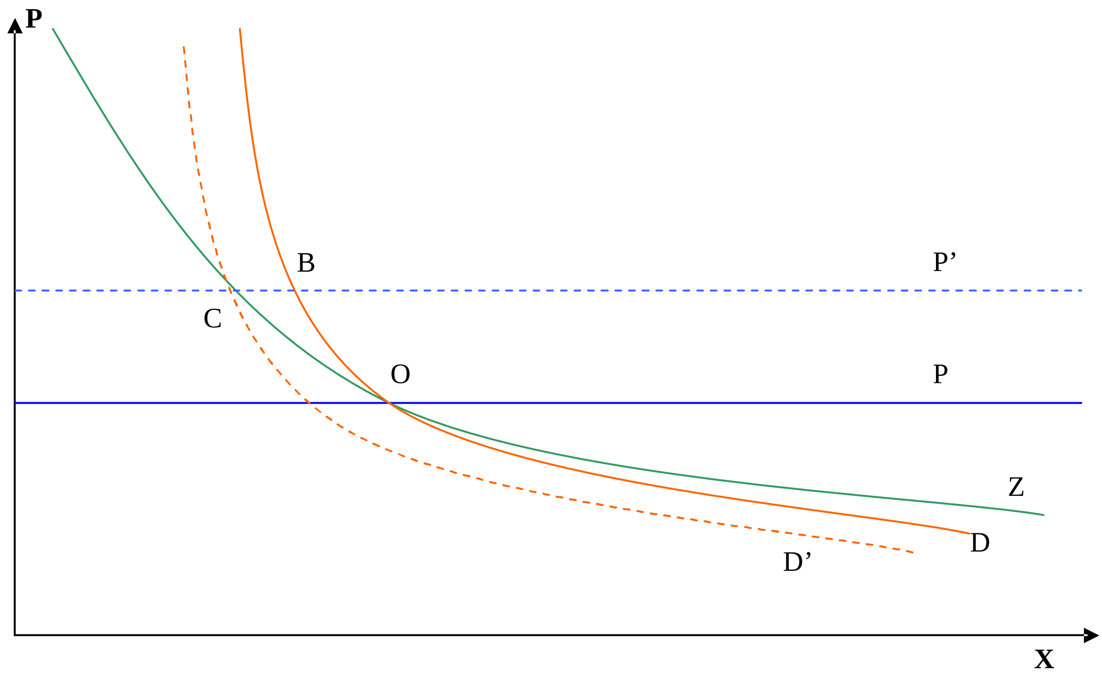
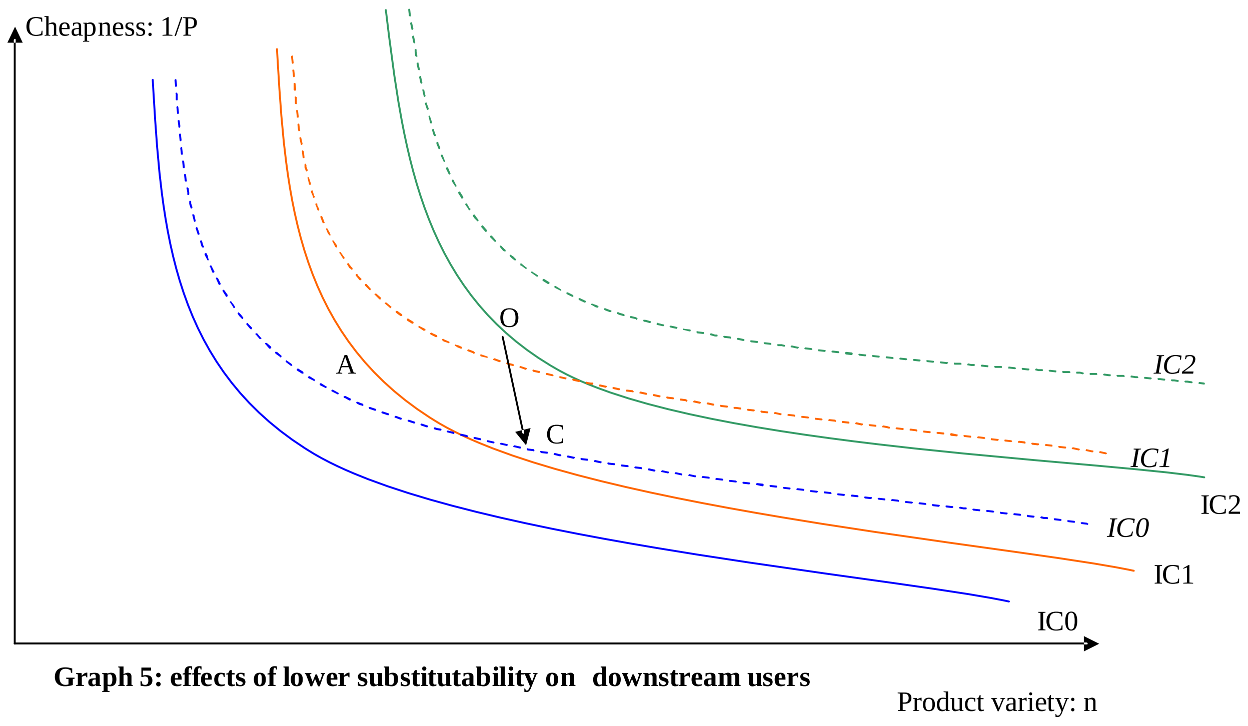


Diagram 4: new equilibrium with lower substitutability



Graph 5: effects of lower substitutability on downstream users

The new equilibrium will therefore be established at B. At the new equilibrium, prices will be higher and more firms will be producing in the industry. Despite higher prices at the new equilibrium, excess profits will be competed away: because of the new entran ts, each firm will produce less and hence will be able to benefit less from economies of scale.

Diagram 5 illustrates the second effect of the reduction of the substitutability , the reduction in the efficiency of chemical products for downstream users. For a given price, more product variety is therefore required than previously to obtain the same downstream user output. This effect is seen in the shifting outwards of the level sets of the indifference curves of downstream users. In terms of the diagram, the original indifference curves IC0, IC1, IC2 (solid lines) are thus moved out to *IC0*, *IC1*, *IC2* (dotted lines). The shift in the equilibrium from O to C (with higher prices and lower product variety) thus results in a higher increase in downstream u ser costs (a move from IC2 to *IC0*) than a shift from O to A (from IC2 to IC1). Again, the monetary value of this shift is measured by the compensating variation.

2.2.3 The combined effect of an increase in overhead costs and a reduction in the substitutability of chemicals

The impact of the combination of an increase in overhead costs and a reduction in the substitutability of chemicals is a little complicated to conveniently show within a diagram. However the impacts can easily be assessed from the analytical results given in the annex.

The combination will definitely result in an increase in prices and is likely to result in a reduction in the number of firms, assuming that the effects of the increase in overhead costs outweigh the effect from the reduction in substitutability. The effects on downstream user welfare of combination are unambiguously to reduce it.

3. Data Sources and Model Calibration

3.1 Data sources

The EU chemical industry is one of the EU's most international, competitive and successful industries, embracing a wide field of processing and manufacturing activities. It supplies virtually all sectors of the economy. Germany represents around one quarter of the production in the European Union, followed by France, Italy and the UK.

Chemicals output covers a wide range of chemicals products. To attempt to use as relatively homogenous group of products as possible, we have separately modelled the five main sub-sectors of the EU chemicals industry. The pharmaceuticals sector was excluded since its final products are not included in the scope of the new chemicals policy [11].

The model has been applied to the following five sub-sectors of three-digit NACE industries.

- 24.1 Basic chemicals: Industrial gases, dyes and pigments, other inorganic basic chemicals, other organic basic chemicals, fertilizer and nitrogen components, plastics in primary forms and synthetic and rubbers in primary forms
- 24.2 Pesticides and other agro-chemicals products
- 24.3 Paints, varnishes and similar coatings, printing ink and mastics.
- 24.5 Soap, detergents, cleaning and polishing preparations, perfumes and toilets preparations
- 24.6 Other chemical products: Explosives, glues and gelatines, essential oils, photochemical material, prepared unrecorded media, other chemical products etc.

The model uses data for 1998 from the Eurostat Structural Business Statistics database (see Eurostat, 2000)[12]. The main sectoral data on the number of firms, turnover, and value-added is shown in the table. Some variables have been directly used via the data of the Panorama of European Industry. For instance, it is the case for the value added of sub-sectors and the number of employees. The overall output is the demand in 1998 in the chemicals industry. The number of firms by sub-sector comes from the SBS database (Eurostat).

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[11] Although intermediate products used in the pharmaceuticals industry do fall within the scope of REACH.

[12] Unfortunately, some data are missing, especially for the smaller countries. In this case, we have had to estimate data on the basis of numbers from previous years.

	Basic Chemicals	Pesticides etc.	Paints	Soap & Detergents	Other Chemicals	Total Industry
Number of firms	7000	700	4000	7000	6000	24700
Turnover (€ bn)	172,3	8,3	24,1	44,3	37,2	286,2
Value added (€bn)	52,3	2,3	7,6	13,2	12,8	88,2
VA as % of turnover	30,4%	27,7%	31,5%	29,8%	34,4%	30,8%
Turnover per firm (€ m)	24,6	11,9	6,0	6,3	6,2	11,6
VA per firm (€ m)	7,5	3,3	1,9	1,9	2,1	3,6

Table 1: Key sectoral data

The overall turnover of the chemicals industry in 1998 was € 286 bn. The basic chemicals sub-sector represented 60% of total turnover, with the soap and detergents and the other chemicals sub-sectors making up some 15% each. The paints and pesticides sub-sectors were very much smaller, making up 8% and 3% respectively.

The value-added of the chemicals sector was some € 90 bn., around 30 % of turnover. Amongst sub-sectors, the other chemicals products had the highest value-added share of 34 % of turnover, presumably as a result of the sector containing most of the specialised chemicals (explosives, photochemical material etc.). Pesticides etc. and agrochemicals have the lowest value-added share at 28%.

There were big differences between sub-sectors in terms of average size of firm. In the basic chemicals sub-sector, the turnover per firm of € 25 million is substantially higher than in any other sub-sectors. The average turnover of pesticides firms is around half this size, with the average firm size in the three other sectors being half this size again at around only € 6 million.

3.2 Calibrating the parameters

In the absence of the availability of long times series of data on chemicals prices and costs, we have calibrated the sub-sectoral models based upon the parameters required to support an equilibrium in the base year, 1998. Note that since we are using 1998 constant prices, the price of output is normalised at unity in the base year.

The table summarises the sets of parameters used in each sub -sector and the resultant average parameters for the industry as a whole.

	Basic Chemicals	Pesticides etc.	Paints	Soap & Detergents	Other Chemicals	Average Industry
Overheads per firm (€ thousand)	6332	2604	1427	1503	1407	4423
Marginal cost (per € selling price)	0,74	0,78	0,76	0,76	0,78	0,75
Substitution parameter (•)	0,79	0,86	0,77	0,78	0,83	0,79
Elasticity of substitution	4,8	6,9	4,4	4,5	5,8	4,9
Firm-level elasticity of demand	3,9	4,6	4,2	4,2	4,5	4,1
Aggregate industry elasticity of demand (•)	2	2	2	2	2	2
Number of sub-markets (•)	420	60	60	120	360	330

Table 2: Sectoral para meter values

The first parameters to be calibrated are those of the cost function. Chemicals firms are highly capital intensive and employ a relatively small and highly productive workforce. Using industry conventional wisdom, we calculate average overhea d costs as including profits and 70% of the wage bill[13]. Overhead costs are therefore defined as:

Overhead costs = value-added – 0.3 x wage bill

We derive average overhead costs per firm, we divide overhead costs by the number of firms in the sub-sector.

As might be expected the variation of overhead costs between sub -sectors is very closely related to the average size of firms. Overhead costs in the basic chemicals industry are over € 6 million a firm, compared to € 2.6 million in pesticides, and around € 1.5 million for each of the other sub - sectors.

[13] The high number of managerial and scientific personnel in the workforc e explains the accounting 70% of the wage bill as overhead costs. The proportion of direct production workers is relatively small in the chemicals industry compared to other industries.

Marginal costs are defined as average variable costs:

Marginal costs = (Turnover – Overhead costs)/ Output

Marginal costs are the lowest for the basic chemicals industry, but are generally in a very narrow range between 0.74 and 0.78 between different sub-sectors.

The key parameter in the model is the substitution parameter (•), which determines the degree of substitutability between different chemicals products. The parameter is derived from inverting the price mark-up equation. The higher is this parameter, the lower the costs of substituting competing products. It can be simply transformed into the conventional elasticity of substitution measure[14]. The average of the sectoral elasticities of substitution is 4.9, which gives us a good indication of the degree of competition in the chemicals industry: products are generally extremely substitutable. The elasticity of substitution is the highest for pesticides, which means that the opportunities to find substitutes products are easiest for this sub-sector. This remark is linked with the fact that that industry is a well-established one, with big enterprises on the market. Elasticities of substitution are slightly lower in the other sub-sectors.

A good way to understand the importance of the elasticity of substitution is to compute the firm-level price elasticity of demand. This is shown in the table in the row below the elasticity of substitution. An increase of one per cent in the price of a firm's product in the chemical industry will result in a decrease of some 4 % of its output sold. This elasticity is slightly lower for basic chemicals, and somewhat higher in the other sub-sectors.

The model also includes an estimate of the overall price elasticity of demand for the sub-sector as a whole (•), which plays a role in the aggregate demand function. This has been set at 2.0 in each sector, based on typical results from export demand functions[15].

Finally the model makes an adjustment for the number of sub-markets included under the umbrella of a sub-sector. This is important because the relative market power of firms depends on the number of its effective competitors. The number of sub-markets has been approximated by

[14] The conventional elasticity of substitution is equal to 1/(1 -•).

[15] See e.g. Landesmann and Snell (1989).

multiplying by ten the number of 4-digit sub-categories contained in each sub-sector[16]. This is defined as the parameter gamma (•) (see the price mark-up equation).

[16] This measure is broadly consistent with the number of product categories contained in each sub-sector according to the Eurostat Combined Nomenclature, with the exception of the very detailed breakdown of products in the basic chemicals sector contained in the Combined Nomenclature.

4. Assessing the Economic Effects of the New Chemicals Policy

4.1 Theoretical considerations

This section provides an empirical analysis of the impacts of the new chemicals policy proposal on the chemicals industry and its costs to downstream users

Concerning the chemicals industry itself, three key issues are crucial for the assessment of the economic effects of the new chemicals policy. The first is the relative effects of the testing and registration costs of the REACH system on the pricing and availability of chemicals. The second is the potential structural impacts of product withdrawal on the overall supply chain of the chemicals industry, increasing the substitution costs between chemical products and lowering the overall efficiency of the chemicals industry. The third issue is the extent to which the introduction of REACH may result in some temporary increase in market power of incumbent chemicals firms and the length of the time period over which this might occur.

The first issue is the relative effects of the testing and registration costs of REACH on the price and availability of chemical substances. The proposed legislation requires chemicals firms to incur these costs in order to be able to continue producing and marketing their products within the EU. The testing and registration costs can be considered largely independent of potential operational changes in the output of businesses [17] and hence it seems appropriate to consider them as equivalent to an increase in the overhead costs of firms. These higher overhead costs will produce a shortfall in profitability in the chemicals industry, which needs to be offset either through higher prices or by a reduction in the number of firms allowing more scope for economies of scale. Part of the increase in testing and registration costs will be passed through to downstream users in the form of higher prices. However, some of the adjustment will also be reflected in a reduction in the number of firms and products in the market.

The second issue is the extent to which product withdrawal may have structural effects through the supply-chain of the EU chemicals market. In particular, the withdrawal of some chemical substances may result in an overall poorer performance of those chemical preparations that remain on the market. This is because the products of the chemicals industry are largely chemical

[17] They increase only at the order of magnitude testing thresholds in the proposed legislation: 1, 10, 100, and 1000 tonnes respectively.

preparations rather than individual chemical substances. Such preparations are ready-prepared mixtures of basic chemical substances: a typical chemical preparation sold by the industry may contain between 5 – 500 mixtures of basic substances, sourced from numerous suppliers. It is therefore likely that the withdrawal of any particular substance will lead to the need to reformulate or replace a wide variety of preparations. As well as entailing the costs of reformulation, the actual performance of the reformulated preparations may in some cases be poorer than that of the original preparation.

The third issue is the extent to which REACH may have some temporary effects on the degree of competition in the chemicals industry, in particular, in raising the market power of existing chemicals firms. For example, a firm or consortium once having secured the registration (and – if required – successful authorisation) of a substance might through this process acquire some temporary market power relative to potential new entrants. Whilst it is very uncertain exactly how long such a situation would persist, for the policy simulations the assumption has been made that such effects might extend for up to some four years beyond the last registration deadline.

Turning to the impacts of the policy on downstream users, two sources of influence can be distinguished: first, an increase in the overall price of chemicals, because testing costs will be passed through in whole or part to downstream users depending on the degree of competition; secondly, the need to find substitutes for those chemicals substances and preparations that have been withdrawn from the market. The extent of these effects will depend on the degree to which chemicals firms temporarily increase their market power.

Part of additional testing and registration costs will be passed through in the form of higher prices to downstream users, however, some chemical substances will also be withdrawn from the market. Whilst surviving firms will increase their production of remaining substances to compensate for those substances taken off the market, this will still result in higher substitution costs for downstream users. These substitution costs will occur because downstream users will need to find potentially higher cost or less-effective replacements for those substances removed from the market. In some cases, downstream users may be able to find available substitutes relatively easily or be able to reformulate the required preparations themselves. In other cases, production techniques or products may need to be modified, resulting in additional investment, longer production times, and/or a deterioration in product quality and competitiveness.

In some cases, chemical producers will withdraw substances even though their value to downstream users is higher than the testing and registration costs thus avoided. In general, the chemicals industry is characterised by large numbers of downstream users, long and complex value-chains, and limited information flows between producers and clients owing to reasons of confidentiality. In these cases, communication between suppliers and users occurs largely through the price mechanism. Hence the removal of a chemical substance from the market may result in aggregate costs to downstream users well in excess of the avoided testing and registration costs.

4.2 Estimating the indirect costs of the new chemicals policy for downstream users

To estimate empirically the indirect costs of the new chemicals policy for downstream users, we have examined two policy impact scenarios. In each case, the direct testing and registration costs of the introduction of the new chemicals strategy are estimated at € 2.3 billion over 11 years, based upon Commission staff estimates published in the Extended Impact Assessment of the new chemicals policy (CEC 2003b). The overall costs to downstream users have been evaluated by taking the net present value over 11 or 15 years of the annual estimated increase in downstream user costs based upon the compensating variation methodology.

The first "normal expectation" scenario examines the impact of the introduction of REACH, where it is assumed that the policy does not have any effect on the efficiency of the chemicals supply chain or the average elasticity of substitution between chemical products. In this scenario, the implications for downstream users come solely from the pass-through of testing and registration costs and the effects of the withdrawal of chemical substances on individual downstream users

The second "higher substitution cost" scenario illustrates the effects where the withdrawal of substances further increases the costs of substitution, through the cumulative effects of the withdrawal of substances in terms of adaptation to the whole of the chemicals supply chain. In this case, it has been assumed that the efficiency of the chemicals industry is reduced marginally in proportion with the withdrawal of chemical substances. The effects of some temporary increase in the market power of the suppliers of chemical substances are also examined in this case.

4.2.1 Normal expectation scenario

The first "normal expectation" scenario examines the costs of the introduction of the new chemicals strategy based upon Commission staff estimates of the cost of testing and registration costs of € 2.3 billion (CEC 2003b), and assuming that no substantive structural substitutability problems arise as a result of the withdrawal of products from the market.

The following assumptions are made in this scenario:

- Ex ante average testing and other direct costs of € 9,800 per firm per for 11 years[18], with a continuation of temporary market power by chemicals firms for another 4 years[19].
- The overall average elasticity of substitution is unchanged by the introduction of the new chemicals policy.

The detailed results of the scenario are shown in table 3.

	Annual cost to downstream users	Change in no. of firms	Change in price of chemicals	Change in output per firm	Change in industry output
	€ billion	%	%	%	% volume
Normal expectation scenario	€ 0.3 bn.	-0.5%	+0.02%	+0.3%	-0.0%

Table 3: Normal expectation scenario: detailed results

[18] Our calculation of ex ante direct costs per firm for testing, registration, authorisation etc. is based on the Commission staff estimates published in the Extended Impact Assessment of the Chemicals Policy (CEC 2003b). The average direct costs per firm are approximately € 108,000 over 11 years. The new chemicals policy is to be introduced in stages over a time horizon of 11 years. It is assumed that firms spread the cost of testing equally over this ten-year period, resulting in a per annum required testing cost of some € 9,800 per firm per year. Given the evidence of the limited available testing capacity in the EU, it would be rational for firms to attempt to spread their testing and other expenditures smoothly over the time horizon. This would minimise the risk of spikes in the price of testing in the run up to the successive deadlines.

[19] We have assumed that the value of this to be equal to higher additional profits per firm of € 9,800 a year, equivalent to the potential additional testing costs required of a new entrant.

In this scenario, there is a small rise in the overall price of chemicals of 0.02%. There is also a small reduction in the number of firms and products. The number of products in the market is reduced in value-terms by 0.5%, equivalent to the withdrawal of some € 1.4 billion a year of existing chemical turnover from the market [20]. The equilibrium nature of the model ensures that the great majority of this turnover is replaced by increased production of other chemical products. The rise in annual costs to downstream users is therefore only € 0.3 billion a year, just 20% of the value of the products withdrawn from the market.

In the normal expectation scenario, the present value of the downstream user costs of the introduction of the new chemicals strategy to the downstream industries would be € 2.8 to € 3.6 billion over 11 to 15 years respectively.

4.2.2 Higher substitution costs scenario

The higher substitution costs scenario examines the potential impact on downstream user costs of negative effects on the chemicals supply chain stemming from the withdrawal of chemical substances from the EU market.

This supply-chain effect was identified in the study by Mercer consultants (Mercer 2003, see also A.D. Little, 2002) of the potential effects of REACH on the French economy. Mercer investigated the supply-chain of chemicals industry from producers of basic chemicals and intermediate products, through specialist chemicals industry and formulators of substances to the retailers and end-users of chemicals. The Mercer analysis attempted to identify the impact of a reduction in the number of substances at each stage in the supply-chain and thus identified the existence of a possible cascading effect through the supply-chain. The withdrawal of small-volume fine chemical substances in particular was identified as a problem for their users, specialist producers of chemicals such as the pharmaceuticals, cosmetics, detergents, and paints sectors etc. The consequent loss of specialist chemicals was seen as then impacting on downstream user sectors as varied as electronics, motor cars, and textiles.

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[20] The biggest impacts on product firm and product withdrawal of around 0.6 -0.7% of turnover are seen in the paint, soap and detergents, and other chemicals sectors of the industry, where most SMEs are concentrated. The effects in the basic chemicals and pesticides segments of the industry are much less pronounced with losses of 0.1% and 0.3% of turnover respectively.

To examine the potential consequences of this effect, we have examined a scenario in which there is a reduction in the elasticity of substitution between the chemical substances remaining on the market. This has two consequences: first, the costs of substitution between products is increased; and secondly, it reduces the overall efficiency of chemical products as inputs to downstream industries.

To calibrate the required size of this reduction in the elasticity of substitution, we have assumed that change ensures that the ordinary price elasticity of demand for the products of remaining firms declines in proportion to the reduction in the number of products produced [21]. For instance, a one percent reduction in products produced would reduce the average remaining firm's price elasticity of demand by approximately one percent (i.e. from, say, 4.00 to 3.96).

The withdrawal of certain chemical substances may result in serious adaptation costs and/or substantially poorer substitute substance qualities or performance for some downstream users than would be suggested by current observation, and would overall reduce market competition amongst the remaining suppliers. In the limit, where suitable substitute substances are not available, downstream users may be obliged to cease activities previously based on this substance altogether. Such effects would result in an overall lowering of the average elasticity of substitution for chemicals products.

The following assumptions are therefore made in this scenario:

- Ex ante average testing and other direct costs of € 9,800 per firm per for 11 years, with a continuation of temporary market power by chemicals firms for another 4 years.
- The overall average elasticity of firm demand is lowered by the same proportion as the reduction of products in the market.

The detailed results of the scenario are shown in table 4.

[21] The intuition for the assumption comes from Salop's (1979) model of spatial location on a circle. The results were obtained through iteration.

	Annual cost to downstream users	Change in no of firms	Change in price of chemicals	Change in output per firm	Change in industry output
	€ billion	%	%	%	% volume
Higher substitutability costs scenario	€ 0.4 bn.	-0.4%	+0.11%	+ 0.0%	-0.2%

Table 4: Higher substitutability costs scenarios: detailed results

In this scenario, as a result of the lower elasticity of substitution, the price of chemical products rises by some 0.1 %. Since the price has risen further, there is in this case less need for a reduction in the number of firms and products: the number of products withdrawn from the market in value-terms is just 0.4% of overall production, worth € 1.1 billion per year. Whilst the equilibrium nature of the model ensures that most of this turnover is replaced by increased production of other chemical products, the lowering of the elasticity of substitution and the overall efficiency of the output of the chemicals industry raises the annual costs to downstream users relative to the normal expectation scenario. The annual impact on the costs of downstream users is therefore higher in this scenario at some € 0.4 billion a year, some 35% of the withdrawal of production.

In the higher substitution costs scenario, the present value of the indirect costs of the introduction of the new chemicals strategy to the downstream industries would be € 4.0 to € 5.2 billion over 11 to 15 years respectively.

5. An Assessment of the Economic Impacts of the New Chemicals Policy

In this paper we have made an assessment of the economic impacts of the new chemicals policy on the chemicals industry and its cost to downstream users .

The exact size of the additional costs t o downstream industries depends crucially on two factors. First, the extent to which the withdrawal of chemical substances has an effect on the chemicals supply-chain, resulting in an increase in substitution costs and a reduction in the efficiency of chemical products. Secondly, it depends on the time frame of any such disruption or temporary increase in market power.

Two scenarios for the costs of REACH to downstream users have been investigated: a "normal expectations" scenario and a "higher substituti on costs" scenario. Both scenarios are based upon estimated testing and registration costs of € 2.3 billion. In each case a lower and upper estimate of the costs are derived for two time periods: 11 years (the time to register all substances currently on the EU market) and 15 years (to allow for a longer adjustment period).

The "normal expect ation" case examines the impact of the introduction of REACH, where the implications for downstream users come solely from the pass -through of testing and registration costs and the effects of the withdrawal of chemical substances on individual downstream users.

A "higher substitution costs" scenario illustrates the effects where the withdrawal of substances further increases the costs of substitution, through the cumulative effects of the withdrawal of substances in terms of adaptation to the whole of the chemicals supply chain. In this case, it has been assumed that the efficiency of the chemicals industry is reduced marginally in proportion with the withdrawal of chemical substances. It also results in some increase in the market power of the suppliers of substitution substances. In this case, higher downstream user costs would be expected.

	Lower estimate (11 years)	Upper estimate (15 years)
Normal expectation	€ 2.8 billion	€ 3.6 billion
Higher substitution cost	€ 4.0 billion	€ 5.2 billion

Table 5: Alternative present value estimates of costs to downstream users

Table 5 presents the results of the two scenarios. In either case, the use of the microeconomic model suggests that only some 0.5% of the overall value of chemical substances, approximately 1-2% of all substances[22], will be withdrawn from the market as a result of REACH.

In the "normal expectation" case, the costs to downstream users of the introduc tion of REACH is assessed to be in the range € 2.8 – 3.6 billion. These costs will occur in the form of higher chemical prices resulting from the passing through of testing and registration costs and as a result of the additional substitution costs for downstream users of chemicals in finding p otentially higher cost or less-effective replacements for those substances removed from the market. In the "higher substitution cost" scenario, the costs to downstream users of the introduction of REACH is assessed to be in the range € 4.0 – 5.2 billion.

It is important to clarify the status of the estimate of the costs to downstream industry costs given in this paper. In particular, the estimate includes the majority of the testing and registration costs that have been passed through to downstream users. Hence the testing and registration costs should not be added to the downstream industry costs to give the overall costs of the REACH proposal. Moreover, while the principal economic mechanisms have been captured by the model it should be understood that th e model - nor indeed any other available model - does not and cannot encapsulate all of the economic mechanisms resulting from REACH proposal.

[22] Assuming that the withdrawal rate for substances below 100 tonnes is some 2 to 4 times higher than that for substances above 100 tonnes.

- Firstly, it should be emphasised that the estimated effects on downstream industries represent the immediate cost effects. The estimates therefore do not include any consequences on the international competitiveness of the downstream users of chemicals. .
- Secondly, the model does not quantify the impacts of REACH on innovation. For the moment, there is no readily-available technique for quantifying these effects. In general terms however, the introduction of REACH may in the short-run affect the resources available for R&D; whilst, in the longer-term however the modifications made to the R&D regime by REACH should give incentives for innovation [23].

[23] See Delgado and Wolf (2003).

ANNEX 1: The Analytics of the Model

To fully understand the functioning of the model, we need to examine the links between shifts in the key parameters and the variation of differe nt endogenous variables. These will be derived using the equations which giving the equilibrium of the model.

- **Rearranging the zero -excess profit condition, we have that:**

$$(p\text{-}c).X = F$$

Hence, we can totally differentiate that equation to obtain:

$$\mathbf{dF/F = (p/(p\text{-}c))dp/p + dX/X} \qquad \mathbf{(A1)}$$

An increase in fixed costs will to passed through onto prices or onto output (benefit from economies of scale). The impact on prices will depend on the behaviour of the mark -up of the firm.

- **We also know that X, n, and p are rela ted through the aggregate demand curve**

$$n.X = D\ (p^{-\bullet})$$

Transforming this equation into logarithms and totally differentiating, we directly obtain:

$$\mathbf{dn/n = -e.dp/p - dX/X} \qquad \mathbf{(A2)}$$

- **The equation of the price mark -up gives us an indication of the relation be tween p, n and r.**

Since:

$$p = c.\ [\rho(1\text{-}\bullet/n)]^{-1}$$

Differentiating this equation, we have:

$$\mathbf{dp/p = - h.dn/n - d r/r} \qquad \mathbf{(A3)}$$

$$\textbf{where } h = -(\bullet/n) / [1\text{-}\bullet/n] < 0$$

- **The analysis of variations in welfare costs:**

To calculate the compensating variation, we have deter mined X such as:

$$X^* = (n/n^*)^{(1/\rho)}.X$$

Then, the compensating variation is equal to:

$$CV = n^*.p^*.X^* - n.p.X$$

Where the proportional variation in terms of welfare could be approximated by:

$$\Delta CV \approx n^*.p^*.X^* / n.p.X$$

Substituting the value of X*, we obtain:

$$\Delta CV \approx (n^*/n)^{[(\rho-1)/\rho]}.p^*/p$$

In other words, if we transform that via logarithms, we have:

$$\mathbf{- d\ welfare/welfare = [(r -1)/ r]\ dn/n + dp/p \quad - [(ln\ n)/ r]\ d r / r} \qquad \textbf{(A4)}$$

This equation puts the emphasis on the role of rho in terms of loss of welfare. In fact, rho has two influences. First, a *change* in rho directly increases welfare by shifting the objective function. Secondly, the *level* of rho influences the impact of the withdrawal of firms from the market. The higher rho is, the lower the loss of welfare from product withdrawal, because downstream users will be able to find more easily substitutes substances.

- **Solving for the reduced -form equation for welfare costs in terms of the parameters for fixed costs (F) and the elasticity of substitution (r)**

First we solve fo r the reduced-form equations for the number of firms and prices.

- **The reduced-form equation for the number of firms**

Using (A1), (A2) and (A3), we can solve for the proportional change in the number of firms:

$$\mathbf{dn/n = (1 - D h)^{-1}[-D\ d r / r - dF/F]} \qquad \textbf{(A5)}$$

$$\textbf{where } D = \mathbf{p/(p-c)} - e$$

Hence an increase in overhead costs will lead to a proportional reduction in the number of firms, whilst a reduction in the elasticity of substitution will proportionally raise the number of firms.

- **The reduced-form price equation**

From (A1), (A2) and (A3), we have a similar equation for proportional change in prices:

$$\mathbf{dp/p = (1\text{-}Dh)^{-1}(\text{-}h\ dF/F - d r/r)} \qquad \mathbf{(A6)}$$

Hence both an increase in overhead costs or a reduction in the elasticity of substitution will lead to a proportional increase in pric es.

Substituting (A5) and (A6), we can conclude that:

Welfare costs:

$$\mathbf{dw/w = (1\text{-}Dh)^{-1}[(r\text{-}1)/r + h].dF/F + \{ (1\text{-}Dh)^{-1}[(r\text{-}1)/r + 1] + [(\ln n)/r]\}.d r/r} \quad \mathbf{(A7)}$$

Hence both an increase in overhead costs or a reduction in the elasticity of substitution will lead to a proportional reduction in welfare.

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