CHALMERS

Corporate Investment to Increase Interest in Mathematics, Science and Technology

A general analysis for the Volvo Group

Master of Science Thesis

NICHOLAS TENGELIN

Department of Technology Management and Economics
Division of Quality Sciences
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden, 2009
Report No. E 2009:093

THESIS FOR THE DEGREE OF MASTER OF SCIENCE

Corporate Investment to Increase Interest in Mathematics, Science and Technology

A general analysis for the Volvo Group

NICHOLAS TENGELIN

Department of Technology Management and Economics
Division of Quality Sciences
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden, 2009

Corporate Investment to Increase Interest in Mathematics, Science and Technology

A general analysis for the Volvo Group

NICHOLAS TENGELIN

Göteborg 2009

Department of Technology Management & Economics

Division of Quality Sciences

Chalmers University of Technology

SE-412 96 Göteborg

Sweden

Telephone +46 (0)31-722 1000

Chalmers Reproservice

Göteborg, Sweden 2009

Corporate Investment to Increase Interest in Mathematics, Science and Technology

A general analysis for the Volvo Group

Nicholas Tengelin, Chalmers University of Technology

Abstract

It goes without saying that for most companies, in most industries, the company's talent is its most valuable and critical asset. But what happens if the recruitment base is not big enough for a company or whole industry, and who are the real stakeholders? This thesis looks into the special case of talented personnel in mathematics, science and technology (MST), a base that is claimed by many to be shrinking. But is the supply base really shrinking below the size of demand? If so, what is causing this to happen, who is at fault, what can be done about it and what is industry's role? The objectives of this thesis are (1) to identify if there is reason for the Volvo Group to invest resources in increasing interest in mathematics, science and technology education and careers and, if so, (2) to identify how such investment should best be made.

The thesis shows that the Volvo Group must (A) strengthen its employee offering and employer branding effort in Sweden to ensure the Group's relative attractiveness as an employer, as a backlog in the workforce production of engineers is now unavoidable. In order to avoid a prolonged workforce deficit, the Volvo Group should (B) lobby the Swedish Government to execute researchers' recommendations on improving the image of maths, science and technology (MST), MST professionals and MST careers as well as improving MST education and curriculum. For the same reason, the Volvo Group should (C) partner with other companies in collaborating with schools by taking part in activities that put MST into meaningful life and career contexts, provide role models and provide career information. Doing nothing and relying on others to act is financially out of the question; the resulting workforce deficit would create a loss of net income amounting to SEK 1.8 billion over 2010-2025 for the Volvo Group in Sweden alone, provided the Swedish National Agency for Higher Education's labour market forecast is accurate. Statistics from Eurostat and OECD indicate similar trends, but are not comprehensive enough to allow the same detailed level of conclusion. School business partnership, in Sweden and elsewhere in Europe, should be built in cooperation with other local, national or European stakeholders in order to ensure cost effectiveness.

The Volvo Group faces similar challenges in France and Japan. In fact, although Europe and most of the analysed countries have experienced increases in the absolute number of graduates from MST tertiary education from 1998 to 2006, negative demographic trends, a stabilisation of access to tertiary education and drops in the proportion of students choosing MST is likely to have a negative or, in some cases, very negative impact on absolute numbers in the years to come. At the same time, and despite the current financial crisis, demand is likely to increase, creating a workforce deficit in many of the analysed countries. Negative attitudes to education and work in science and technology among Europe's young further support this conclusion. The question is not whether there is a problem, but rather how big the problem is. Unfortunately, due to the lack of better workforce demand forecasts, a good answer cannot be provided.

The main factors behind the proportional decline in choice of MST education are (I) the image of maths, science and technology – (a) Science and technology needs are perceived to be fulfilled, and (b) Certain specialisations may be perceived as a threat to society –, (II) the image of MST professionals and careers – (a) Jobs not perceived to be meaningful, (b) Lack of attractive role models, (c) Lack of information and understanding of careers, (d) Job market perceived as unstable, and (e) Careers perceived as unattractive – and (III) MST education and curriculum – (a) Education is not seen as meaningful and does not sufficiently address students' values and concerns, (b) Pedagogical innovation is required, and (c) Teachers are ill-equipped. Significant transversal gender aspects exist in each of these factors.

Schools are not "real" or definitive stakeholders, which is a critical conclusion as it expels the notion that the problems are for them to resolve. The reason is that they see their role as preparing and equipping their students for prosperous lives as democratic citizens rather than providing employers with personnel. Thus, it is up to European private and public corporations and employers, universities and legislators to work together to tackle the factors above, concretising researchers' recommendations on how, at national and local levels along with carefully prepared implementation plans. In doing so, they need to give the gender aspects special attention. The complex cultural differences between the worlds of schools, universities, legislators and corporations need to be handled with respect, but also need to be overcome. Europe's young depend on it.

Key words: 'Talent shortage', 'Workforce deficit' and 'School business collaboration'

Investissements des entreprises visant à accroître l'intérêt pour les mathématiques, la science et la technologie

Analyse générale à l'intention du Groupe Volvo

Nicholas Tengelin, Chalmers University of Technology

Résumé

Pour la plupart des entreprises de la majorité des branches d'activité, il va sans dire que des collaborateurs de talent constituent la ressource la plus précieuse et la plus cruciale. Mais que se passe-t-il si la base de recrutement ne suffit pas pour répondre aux besoins d'une entreprise ou de tout un secteur et qui sont les véritables parties prenantes ? Cette thèse s'intéresse au cas spécifique du personnel de haut niveau dans les domaines des mathématiques, de la science et de la technologie (MST), dont de nombreuses personnes affirment qu'il va en se raréfiant. Mais cette offre est-elle vraiment en train de devenir inférieure à la demande ? Si c'est le cas, pourquoi, à qui la faute, comment y remédier et quel rôle pour les industriels ? La présente thèse a deux objectifs : (1) découvrir si le Groupe Volvo a une bonne raison d'investir des ressources dans l'accroissement de l'intérêt pour les études et les carrières dans les mathématiques, la science et la technologie et (2) identifier les modalités de cet investissement.

La thèse montre que le Groupe Volvo doit (A) renforcer son offre employés et son image de marque d'employeur en Suède pour se rendre attractif, car les ingénieurs vont inévitablement devenir une denrée de plus en plus rare. Pour éviter un déficit de main d'œuvre prolongé, le Groupe Volvo doit (B) faire pression sur le gouvernement suédois afin qu'il applique les recommandations des chercheurs visant à redorer le blason des mathématiques, de la science et de la technologie (MST), des professions et des carrières dans les MST, mais aussi qu'il améliore les études et le cursus dans ces domaines. Pour la même raison, il aurait intérêt à (C) nouer des partenariats avec d'autres entreprises afin de collaborer avec des écoles en participant à des activités plaçant les MST dans des contextes de vies et de carrières gratifiantes, mettre en avant des personnes dont les jeunes auront envie de suivre l'exemple et fournir des informations sur les carrières. Ne rien faire et compter sur les autres pour agir est financièrement hors de question. Le déficit de main d'œuvre qui en résulterait entraînerait une perte de revenu net de 1,8 milliard de SEK entre 2010 et 2025 pour le Groupe Volvo en Suède uniquement, si les prévisions du marché du travail de l'Agence nationale suédoise pour l'enseignement supérieur sont exactes. Les statistiques d'Eurostat et de l'OCDE avancent des tendances similaires, mais ne sont pas suffisamment exhaustives pour parvenir à une conclusion aussi détaillée. Il conviendrait de mettre en place des partenariats avec des écoles en Suède et ailleurs en Europe, en collaboration avec d'autres parties prenantes locales, nationales ou européennes, afin d'assurer la rentabilité de l'initiative.

Le Groupe Volvo est confronté aux mêmes défis en France et au Japon. En fait, bien que l'Europe et la plupart des pays analysés aient constaté une augmentation du nombre absolu de diplômés du troisième cycle en MST entre 1998 et 2006, les tendances démographiques négatives, la stabilisation de l'accès aux études de troisième cycle et la chute de la proportion d'étudiants choisissant ces matières risquent d'exercer un effet négatif ou, parfois même, très négatif sur les nombres absolus dans les années à venir. Dans le même temps et en dépit de la crise financière actuelle, l'augmentation probable de la demande dans un grand nombre des pays analysés risque d'entraîner un déficit de main d'œuvre. L'attitude négative des jeunes européens face aux études et aux professions scientifiques et techniques conforte cette conclusion. La question n'est pas de savoir s'il existe un problème, mais d'en déterminer l'ampleur. Malheureusement, l'absence de meilleures prévisions de la demande de main d'œuvre interdit de donner une bonne réponse.

Les principaux facteurs sous-jacents au déclin proportionnel du choix d'études MST sont (I) l'image des mathématiques, de la science et de la technologie - (a) les besoins scientifiques et techniques sont perçus comme satisfaits et (b) certaines spécialisations peuvent être perçues comme des menaces pour la société -, (II) l'image des professions et des carrières dans les MST - (a) les emplois ne sont pas perçus comme intéressants, (b) manque de personnes dont l'exemple puisse donner envie de les imiter, (c) manque d'informations et de compréhension des carrières - et (III) études et cursus MST - (a) les études semblent manquer d'intérêt et ne répondent pas suffisamment aux valeurs et aux préoccupations des étudiants, (b) il faut faire preuve d'innovation pédagogique et (c) les enseignants sont mal équipés. Pour chacun de ces facteurs existent également d'importants aspects transversaux liés au genre.

Les écoles ne sont pas des parties prenantes « réelles » ou définitives. Cette conclusion cruciale évince la notion que la résolution des problèmes relève de leur compétence. En effet, elles considèrent que leur rôle est de préparer et d'armer leurs étudiants à mener des vies prospères en tant que citoyens de pays démocratiques plutôt qu’à fournir du personnel à des employeurs. Il revient donc aux entreprises et aux employeurs des secteurs public et privé européens, aux universités et aux législateurs de s'attaquer ensemble aux facteurs ci-dessus afin de concrétiser les recommandations des chercheurs sur les méthodes à utiliser, au niveau national et local, soutenues par des plans de mise en œuvre soigneusement préparés. Ce faisant, ils devront prêter une attention particulière aux aspects liés au genre. Les différences culturelles complexes entre l’univers des écoles, des universités, des législateurs et des entreprises sont à gérer avec respect, mais aussi à surmonter. Les jeunes d’Europe en dépendent.

Mots clés : « pénurie de talents », « déficit de main d’œuvre » et « collaboration écoles-entreprises »

企业应加大投入，提高人们对数学与科技领域的兴趣

针对沃尔沃集团的全面分析 Nicholas Tengelin，查尔姆斯理工大学

摘要

对于大多数行业中的大多数公司来说，人才是最宝贵、最重要的资产，这是一个不言而喻的事实。但是，如果求职者群体的数量不足以满足某家公司或整个行业的需求，会发生什么情况呢？哪些是真正的利益相关方？ 本文将探讨数学与科技（MST）领域的人才的特殊情况，许多人认为，这类人才已呈现日益减少的趋势。 但是，这类人才的供给量是否确实已缩减到无法满足需求的程度？如果确实如此，那么导致这种情况的原因是什么？是谁的过错？可以采取哪些措施来解决这个问题？行业应该发挥什么作用？ 本文希望找到以下两个问题的答案：(1) 沃尔沃集团是否有必要投入资源来提高人们对数学与科技领域的教育和职业机会的兴趣？(2) 如果应该，那么最好的投入方式是什么？

本文将说明：(A) 沃尔沃集团必须强化在瑞典的员工录用和雇主品牌打造工作，以确保集团作为用人单位的相对吸引力，因为工程师人才的储备现已是势在必行。 (B) 为了避免此类人才出现长期不足的情况，沃尔沃集团应说服瑞典政府采纳研究人员的建议，提升数学与科技（MST）、MST 专业人员与 MST 相关职业的形象，改进 MST 教育和课程。 (C) 出于同样的原因，沃尔沃集团还应与其他公司建立伙伴关系，通过参与能将 MST 融入到有意义的生活和职业环境中的活动来与学校进行合作，树立职业榜样和提供职业信息。 从财务角度看，无所作为和指望他人采取措施都是行不通的；如果瑞典高等教育署针对人才市场的预测结果准确的话，仅在瑞典，人才缺口这一情况在 2010 年至 2025 年期间就会为沃尔沃集团造成总计高达 18 亿瑞典克朗的净收入损失。 欧盟统计局和经济合作与发展组织（OECD）提供的统计数据也显示出类似趋势，但由于数据不够全面，因此得出的结论没有这么详细。 在瑞典和欧洲的其他国家或地区，应该通过与当地、全国乃至整个欧洲的其他利益相关方开展校企合作来确保成本效益。

沃尔沃集团在法国和日本也面临相似的问题。 实际上，在 1998 年至 2006 年之间，欧洲及大多数我们分析的国家/地区的 MST 高等教育毕业生的绝对数量有所上升。但是，人口负增长、高等教育录取机制的稳定性、选择 MST 的学生的比例降低等情况可能会在未来几年对这个绝对数量产生负面影响，在某些情况下，这种负面影响可能会非常严重。 同时，尽管当前存在金融危机，对此类人才的需求仍可能呈上升趋势，会在我们分析的多个国家/地区导致人才缺口。 欧洲年轻人对科技领域的教育和职业持消极态度，为我们的上述结论提供了进一步的依据。 因此，我们要讨论的不是问题是不是存在，而是问题究竟有多严重。 遗憾的是，由于缺乏更详细的人才需求预测数据，现在还无法提供确切的答案。

选择 MST 教育的人数比例下降的主要原因包括：(I) 对数学与科技的认识 — (a) 认为目前的科学技术已经满足了相关需求，(b) 认为某些专业化会对社会产生威胁；(II) 对 MST 专业人士和职业的认识 — (a) 认为工作没有意义，(b) 缺乏令人崇拜的榜样，(c) 对相关职业不了解、不理解，(d) 认为就业市场不稳定，以及 (e) 认为相关职业缺乏吸引力；(III) MST 教育和课程 — (a) 认为 MST 教育没有意义，且不能充分帮助学生实现他们的价值和解决他们的问题，(b) 需要进行教学创新，以及 (c) 师资水平不高。 上述各种原因之间存在明显的性别差异。

学校不是“真正的”或最终的利益相关方，这是一个重要结论，它反驳了“问题应由学校解决”这种观点。 原因在于，学校认为自己的任务是将学生培养成为具有民主精神的公民，使他们具备获得幸福生活的能力，而不是为用人单位提供人才。 因此，欧洲的私营或公营企业、用人单位、大学和立法人员应该携起手来，按照详细制定的实施计划，落实研究人员针对如何在国家或地区范围内处理上述问题提出的建议。 在这个过程中，他们需要特别注意性别方面的差异。 学校、立法机构以及企业之间的复杂文化差异必须得到尊重，同时也必须克服， 而欧洲年轻一代的希望就寄托于此。

关键词： “人才短缺”、“人才缺口”和“校企合作”

理数技術分野に対する関心を高めるための企業による投資

ボルボ・グループを対象とした一般分析

チャルマース工科大学、Nicholas Tengelin

要旨

言うまでもないことだが、ほとんどの業界における大半の企業にとって、その企業の人材が最も価値のある重要な資産である。しかし、採用しようとする人材の基盤が、企業にとって、あるいは業界全体にとって不十分である場合はどうなるだろうか。また、本当の利害関係者は誰だろうか。本論では、理数技術分野（MST）の才能ある人材という特別なケースについて詳しく調べることにする。この基盤は、「縮小している」という声が多く聞かれる。しかし、人材の供給基盤は、需要の規模を下回るほど本当に縮小しているのだろうか。それが本当なら、何が原因で、誰の過ちなのか、この問題に対処するために何ができて、業界の役割は何なのか。本論の目的は、（1）理数技術分野の教育およびキャリアへの関心を高めるために、ボルボ・グループがリソースを投資する理由があるか、またあるとすれば（2）どのような投資を行うのが最適なのか、を特定することである。

本論では、ボルボ・グループが（A）スウェーデンにおいて、社員への待遇を強化するとともに雇用者側のブランド確立に対する努力を強化し、雇用者としてのグループの相対的な魅力を確保する必要があることを示している。技術者を創出する労働力の留保は、もはや避けられない課題となっているためである。長期にわたる労働力不足を回避するために、ボルボ・グループは、（B）理数技術分野（MST）、MSTの専門家、MSTのキャリアに対するイメージの改善、およびMSTの教育とカリキュラムの改善に関する研究者の提案を実施するように、スウェーデン政府に働きかける必要がある。同じ理由で、ボルボ・グループは（C）MSTを生活とキャリアの面から有意義なものにしたり、キャリアに関する情報やロール・モデルを提供したりする活動に参加することで、他の企業との連携や学校との協力を図る必要がある。何もしないで他者の行動をあてにすることは、経済的に見て問題外である。スウェーデン高等教育庁の労働市場予測が正しい場合、このままいくと労働力不足のために2010年から2025年の間にボルボ・グループの純利益における損失は、スウェーデン国内のみで18億SEKにのぼると見られている。EC統計局およびOECDによる統計も同様の傾向を示しているが、それらの統計は、上記と同レベルの詳細な結論を導き出せるほど包括的な内容ではない。スウェーデンおよび欧州各地で、地方や国、または欧州レベルの利害関係者と協力して、学校と産業界のパートナーシップを構築し、費用対効果を確保する必要がある。

ボルボ・グループはフランスと日本でも同様の課題に直面している。事実、欧州および分析を行った国のほとんどで、MSTの高等教育を受けた人の絶対数は1998年から2006年の間に増加しているが、将来は、人口の減少傾向、高等教育への進学率の安定化、MSTを専攻する学生の割合の減少のため、絶対数が減る（場合によっては大きく減る）ことが予想されている。同時に、現在起きている経済危機にもかかわらず、分析を行った多くの国で不足する労働力の創出に対する要求は高まると思われる。欧州の若年層における理数技術分野の教育や仕事に対する否定的な見方も、この結論をさらに支える要因となっている。論点は、問題が存在するかどうかではなく、問題がどの程度大きいのか、である。残念ながら、労働力の需要に関する十分な予測がないため、現時点ではこれに適切に回答することは不可能である。

MSTの教育を選択する人口の比例的な減少の背後には、主に次のような要因がある。（I）理数技術分野に対するイメージ -
（a）科学技術のニーズはすでに満たされたと考えられている、（b）特定の専門分野が社会への脅威と見なされている。（II）MSTの専門家およびキャリアに対するイメージ -
（a）有意義な仕事だと思われていない、（b）魅力的なロール・モデルが欠如している、（c）キャリアに関する情報と理解が不足している、（d）雇用状況が不安定と見られている、（e）キャリアに魅力が感じられない。（III）MSTの教育およびカリキュラム -
（a）この分野の教育が有意義なものだと思われておらず、学生の価値観や懸念に十分な配慮がなされていない、（b）教育改革が必要である、（c）教員の能力が不足している。これらの要因のそれぞれに、ジェンダーについて重大かつ横断的な側面が存在している。

学校は「本当の」または最終的な利害関係者ではない。この結論は、これらの問題を学校が解決するものだという考えを排除する上で非常に重要である。その理由として、学校が認識している自身の役割は、学生が将来、民主的な市民として豊かな人生を送れるように準備し能力を授けることであって、雇用者に従業員を供給することではないことが挙げられる。そのため、上記の要因に対する対処は、欧州の民間企業および公共団体、雇用者、大学、議会の共同的な取り組みにかかっている。そして、研究者の提案を国および地方レベルで、慎重に策定された実施計画に沿って実行に移す必要がある。そのなかで、関係者はジェンダーの側面にも特別な注意を向ける必要が出てくる。学校、大学、議会、企業のそれぞれの世界の間にある複雑な文化的差異は尊重しなければならないが、同時に克服する必要もある。欧州の若者の将来はこの努力次第である。

キーワード：「人材不足」、「労働力不足」、「学校と産業界の連携」

Investering från näringslivet för att öka intresset för matematik, naturvetenskap och teknik

En generell analys för Volvokoncernen

Nicholas Tengelin, Chalmers Tekniska Högskola

Sammanfattning

Det behöver knappt sägas att för de flesta företag, i de flesta industrier, så är företagets kompetens dess mest värdefulla och avgörande tillgång. Men vad händer om rekryteringsbasen är för liten för ett företag eller en hel industri och vilka är egentligen de verkliga intressenterna? Detta examensarbete tittar på specialfallet kompetens inom matematik, naturvetenskap och teknik (MNT), en rekryteringsbas som många påstår krymper. Men krymper verkligen rekryteringsbasen så till den grad att den understiger eller kommer att understiga efterfrågan? Om svaret är ja, vad är orsaken, vem är skyldig, vad kan göras åt det och vad är näringslivets roll? Målen med examensarbetet är (1) att identifiera om det finns skäl för Volvokoncernen att investera resurser i att öka intresset för utbildningar och arbete inom matematik, naturvetenskap och teknik och om svaret är ja, (2) identifiera hur en investering bäst bör göras.

Examensarbetet visar att Volvokoncernen måste (A) stärka arbetstagarerbjudandet och arbetsgivarvarumärket i Sverige för att säkerställa koncernens relativa attraktivitet som arbetsgivare, eftersom en eftersläpning i arbetskraftsproduktionen av ingenjörer nu är oundviklig. För att undvika en utdragen arbetskraftsbrist, bör Volvokoncernen (B) arbeta för att den svenska regeringen skall följa forskarnas rekommendationer om att förbättra bilden av matematik, naturvetenskap och teknik (MNT), yrkesverksamma och karriärer inom MNT samt utbildningar och läroplaner inom MNT. Volvokoncernen bör av samma skäl, tillsammans med andra företag, (C) samarbeta med skolan för att sätta in MNT-ämnena i meningsfulla livs- och karriärsammanhang och bidra med förebilder och karriärinformation. Att göra inget och lita på att andra skall agera är ekonomiskt helt oförsvarbart; den resulterande arbetskraftsbristen skulle leda till ett inkomstbortfall på SEK 1,8 miljarder för Volvokoncernen i Sverige 2010-2025, förutsatt att Högskoleverkets arbetsmarknadsprognos är rättvisande. Statistik från Eurostat och OECD visar liknande trender, men är inte tillräckligt omfattande för att tillåta samma detaljerade grad av slutsatser. Samarbete mellan skola och näringsliv, i Sverige och i övriga Europa, bör byggas i samverkan med andra lokala, nationella och europeiska intressenter för att säkerställa kostnadseffektivitet.

Volvokoncernen står inför liknande utmaningar i Frankrike och Japan. Faktum är att, även om Europa och de flesta av de länder som analyserats har sett en uppgång i det absoluta antalet examinander från högre utbildning i MNT över 1998-2006, så kommer en negativ demografi, en stabilisering av tillträdet till högre utbildning och en minskande andel studenter som väljer MNT att ha en negativ eller väldigt negativ inverkan på de absoluta antalen under åren som kommer. Samtidigt och trots nuvarande finanskris, kommer efterfrågan att öka och leda till en arbetskraftsbrist i många av de länder som analyserats. Negativa attityder till utbildning och arbete inom MNT bland Europas unga lämnar ytterligare stöd till slutsatserna. Frågan är inte om det finns ett problem, utan snarare hur stort problemet är. På grund av avsaknaden av bättre arbetskraftsprognoser, kan inget bra svar ges.

De huvudsakliga faktorerna bakom den minskande andelen som väljer utbildning inom MNT är (I) bilden av MNT – (a) samhällets behov av MNT uppfattas som uppfyllt, och (b) vissa inriktningar uppsattas som samhällsfarliga –, (II) bilden av MNT-yrken och -karriärer – (a) yrken och karriärer uppfattas inte som meningsfulla, (b) förebilder saknas, (c) information om karriärmöjligheter saknas, (d) arbetsmarknaden uppfattas som instabil, och (e) karriärer uppfattas som oattraktiva – och (III) MNT-utbildningarna – (a) utbildningarna ses inte som meningsfulla och tar inte hänsyn till ungdomars värderingar och funderingar, (b) pedagogisk innovation behövs och (c) lärare är illa rustade. Betydande tvärgående könsaspekter existerar i samtliga faktorer.

Skolan är inte en verklig intressent; en väsentlig slutsats eftersom det dömer ut föreställningar om att problemen är skolans att lösa. Anledningen är att skolan ser det som sin roll att förbereda och utrusta sina studenter för liv som demokratiska samhällsmedborgare snarare än att leverera arbetskraft till arbetsgivare. Således återstår det för näringslivet, universiteten och lagstiftarna att själva hantera faktorerna ovan och konkretisera forskarnas rekommendationer om hur detta bäst görs, på nationell och lokal nivå tillsammans med noggrant utarbetade implementeringsplaner. I det, måste genusaspekterna ges särskild uppmärksamhet. De komplexa kulturella olikheterna mellan skolan, universiteten, lagstiftarna och näringslivet måste hanteras med respekt men de måste också övervinnas. Europas unga är beroende av det.

Nyckelord: ’Kompetensbrist’, ’Arbetskraftsbrist’ och ’Samverkan skola näringsliv’

Acknowledgements

It is a pleasure to show gratitude to and thank the many people that have made this thesis possible. I am especially indebted to my supervisors Sverker Alänge and Lena Peterson at Chalmers University of Technology and Jan-Eric Sundgren at AB Volvo for their encouragement, constructive criticism and support throughout my thesis work.

I am enormously grateful for the many comments from and discussions with educators, researchers, policy makers and content providers in science education around the world. Professor Svein Sjøberg at the University of Oslo, Bengt Johansson at the Swedish National Centre for Mathematics Education, Professor Jonathan Osborne at Kings College London, Marc Durando at European Schoolnet, Alexa Joyce at European Schoolnet, Maruja Gutierrez-Diaz at the European Commission, Ana Serrador at the European Commission, Frédéric Sgard at the Organisation for Economic Co-operation and Development (OECD) and Erik Henriks at the Swedish Ministry of Education all deserve special mention.

Since January 2007 and in parallel with my studies for the degree of Master of Science in Electrical Engineering at Chalmers University of Technology, I have been employed by AB Volvo with the responsibility of supporting Leif Johansson, President AB Volvo and CEO Volvo Group, in his respective chairmanships of a European Round Table of Industrialists (ERT)[1] working group on maths, science and technology education as well as the Swedish Governments Technology Delegation (Teknikdelegationen - see chapter 5). In addition, I have had the responsibility of initiating the Swedish school business collaboration project MATENA (see chapter 5). My parallel commitments have substantially fed into each other and thus benefited this thesis.

I owe my deepest gratitude to Wim Philippa, Laura Asbjornsen, Abigail Jones, Xanthe Visram, Barbara Rens and the rest of the team at ERT for their tremendous support, hard work and dedication. I would like to thank Tricia Tarrant at Royal Dutch Shell, Peter Wiesenekker at Royal Philips Electronics, Ingrid Petersson at AstraZeneca, Donatella Segre Weitzen at the Fiat Group, Tommi Juusela at Nokia Corporation, Dr Frank Stefan Becker at Siemens and the rest of the ERT working group for their valuable contributions.

I am grateful to Johan Ancker at the Association of Swedish Engineering Industries (Teknikföretagen), Peter Larsson at the Swedish Association of Graduate Engineers (Sveriges Ingenjörer), Helen

[1] The European Round Table of Industrialists (ERT) is an informal forum bringing together around 45 chief executive officers and chairmen of major multinational companies of European parentage

Dannetun at the Institute of Technology at Linköping University, Teresa Jonek – First Secretary to the Technology delegation – and the rest of the Technology Delegation for their wise and important input.

Thank you also to Cecilia Warrol Ersson at the Association of Swedish Engineering Industries (Teknikföretagen) as well as Ingrid Lindahl and Gunilla Hell Bellman at the West Sweden Chamber of Commerce and Industry (Västsvenska Industri- och Handelskammaren) for our many constructive discussions.

I would like to extend my special thanks to my colleagues at Public and Environmental Affairs (AB Volvo), Corporate HR (AB Volvo) and Volvo Business Services for their encouragement and support. Inge Horkeby at Public and Environmental Affairs (AB Volvo) and Paulina Persdotter at Volvo Business Services deserve a specific mention; their perspicacity often helped move my work forward.

Finally, I would like to emphasise gratitude to Hanna Kensfors, my fiancé, for all her emotional support and proof reading.

Nicholas Tengelin
Göteborg, September 2009

Contents

1. Introduction

It goes without saying that for most companies, in most industries, the company's talent is its most valuable and critical asset. Therefore, companies invest huge amounts of resources in acquiring, deploying, developing and retaining talented personnel (Deloitte Research, 2004). In most of the world, national, regional or local educational systems provide the base from which companies acquire personnel, be it the educational systems' primary mission and responsibility or not. But what happens if the base is not big enough for a company or a whole industry and who are the real stakeholders?

This thesis looks into the special case of acquiring talented personnel in mathematics, science and technology (MST), from a base that is claimed by many to be shrinking. Headlines like "Lack of engineers costs Germany billions" (Financial Times Deutschland, 2007), "Science crisis in the making" (The Japan Times, 2006), "Manufacturing skills could effectively disappear in our own lifetime" in the Daily Mail, United Kingdom, (Barrow and Cavazza, 2006), "America is in trouble in science and education" (USA Today, 2007), "The EU's labour-shortage time bomb" (EurActive.com, 2007) and "In 2020, Sweden will be lacking 50.000 engineers" in Dagens Nyheter, Sweden, (Gustavsson, 2007) have sent cold chills through the mathematics, science and technology community across the world. European industry leaders in the European Round Table of Industrialists[1] make the case that the shrinking base is a pressing issue requiring the attention of a multitude of stakeholders. In fact, the European Round Table of Industrialists (2008, p.1) state that they have "identified increasing young people's interest in mathematics, science and technology as essential for sustainable economic growth in Europe".

But does or will the shortage really exist? Is the supply base really shrinking below the size of demand? If so, what is causing this to happen, who is at fault, what can be done about it and what is industry's role?

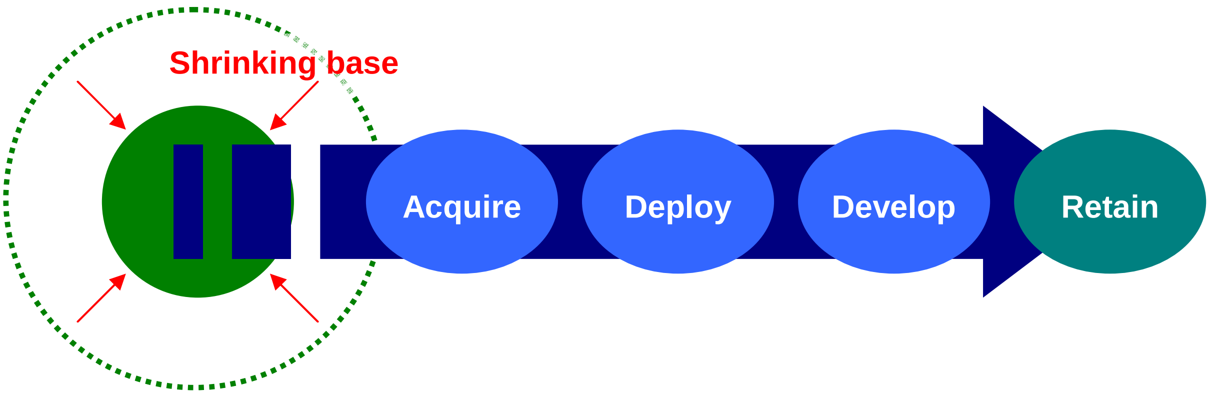

Figure 1 (Source: Adapted from Deloitte Research (2004))

[1] The European Round Table of Industrialists (ERT) is an informal forum bringing together around 45 chief executive officers and chairman of major multinational companies of European parentage

1.1. Rationale

The rationale for conducting this thesis work for the Volvo Group is concern that the base from which the Group is dependent on being able to acquire talented personnel in MST is shrinking. Note that the Group's dependency in itself is accepted as true. Note also that it is the availability of human resources in MST that is being assessed and not the Group's ability to attract human resources in MST.

1.2. Objectives

The objectives of this thesis are to

- Identify whether there is reason for the Volvo Group to invest resources in increasing interest in mathematics, science and technology education and careers; *and if so*
- Identify how such investment should best be made

1.3. Scope of thesis

1.3.1. Workforce requirements as per Geography and Market

The Volvo Group acts in an increasingly global market, with production facilities in 19 countries and sales activities in around 180 countries (AB Volvo, 2009). This thesis accepts as true that the Group is dependent on being able to acquire talented personnel in MST at most of these locations. However, for reasons of restricted resources, this thesis is delimited to Europe and the European market.

1.3.2. Research

This thesis is, for reasons of restricted resources, delimited to analysis of readily available research and statistics. No complementary data collection will be carried out.

1.4. Method of inquiry and Thesis outline

The method of inquiry and thesis outline go hand in hand. Although many informal consultations with researchers, policy makers and industry leaders have guided the inquiry, all of the theory, data, discussions and conclusions in this thesis are based solely on a review of published research papers, policy reports and statistics.

First, an inquiry is undertaken to verify claims that the base from which the Group is dependent on being able to acquire talented personnel in MST is shrinking, and that this will lead to difficulties in recruiting. Evidence including data on demographics, student access to education, student choice of MST, student attitudes to MST, adult attitudes to MST and demand of human resources in MST is presented and analysed along with conclusions in chapter 2.

Second, a stakeholder analysis based on some of the models and methods described by Fassin (2009), Freeman (1984), Mitchell et al. (1997), Varvasovszky and Brugha (2000), Earl and Clift (1999) and Bunn et al. (2002) is conducted to get a clear view of who the stakeholders are in order to set subsequent conclusions in relation to the role the stakeholders might have or take in the issue at hand. The analysis is presented along with conclusions in chapter 3.

Third, research papers are reviewed in order to identify what the problem is and who could be doing something about it. This is presented along with conclusions in chapter 4.

Fourth, an inquiry into current attempts to address the problem is undertaken to provide the means to align subsequent recommendations with ongoing activities across Europe. This is presented along with conclusions in chapter 5.

Before drawing final conclusions in chapter 7, an analysis of corporate options and incentives to respond, based on the previous chapters, is presented in chapter 6.

For the benefit of the reader, an extensive number of relevant graphs have been kept out of the main report and collected in appendix 1. Calculations can be found in appendix 2.

2. Is there really a problem?

There is concern that the base from which the Volvo Group is dependent on being able to acquire talented personnel in maths, science and technology (MST), is shrinking. But is this really true and, if so, will it really lead to difficulties recruiting? This chapter attempts to provide the answer by verifying that the *supply* actually is shrinking, and that the *demand* for talented personnel in MST is or will become larger than the supply.

2.1. Method and framework

2.1.1. The problem in detail

Behind the problem lie a number of potential issues that can be identified from the schematic in figure 2. Note that flows through the pink area, typically controlled by companies through employer branding and other recruitment activities, is outside the scope of this thesis.

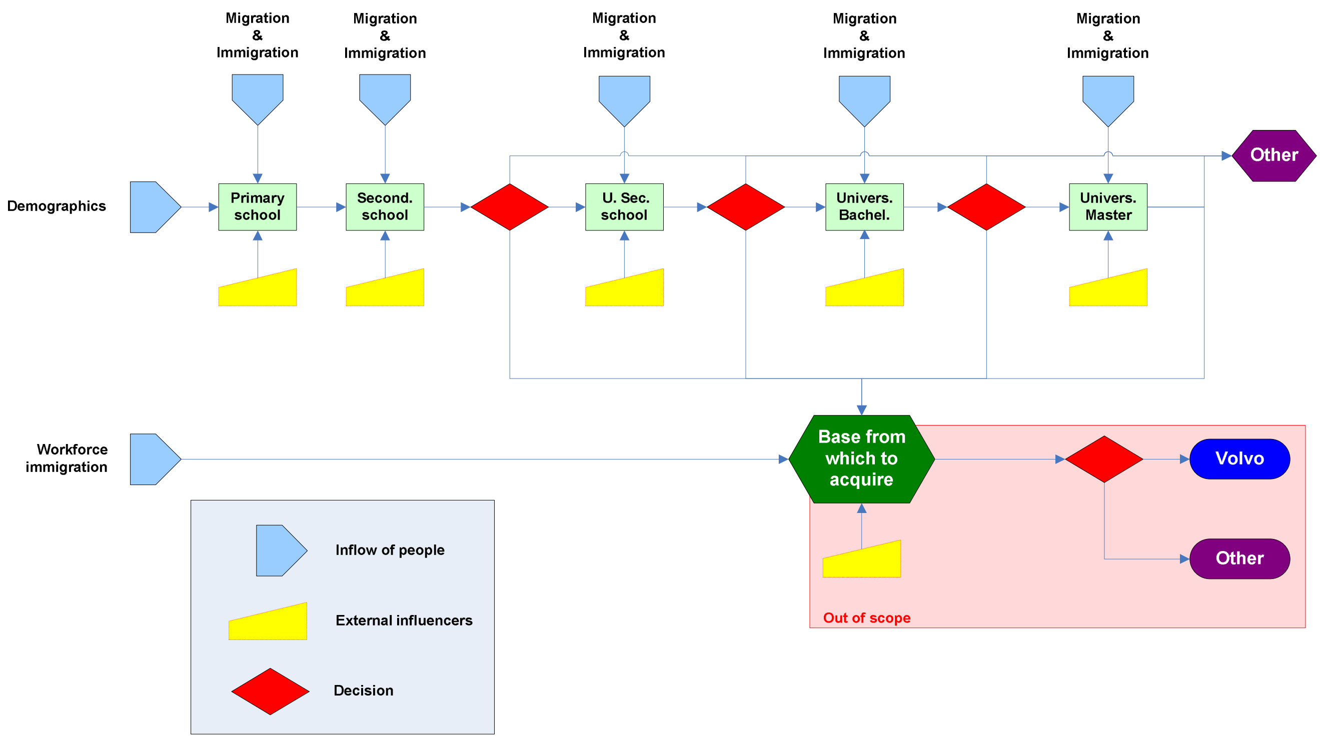

Figure 2 Schematic flows of people into a generic European education system (light green boxes), labour market sectors (hexagons) and, finally, Volvo or another employer.

Following the schematic in figure 2 from top to bottom and from left to right, the potential issues can be identified as follows. If the supply base actually is shrinking, either

– *fewer people are entering the education system from the start or at later stages* (the number is mainly determined by demography but also by school capacity, migration and immigration);

- *fewer people are completing education* (educational attainment);
- *fewer people are choosing MST education* (the number is determined by people themselves but influenced by the education system and external influencers); *or*
- *workforce immigration is declining*

2.1.2. Data sources

Statistics that quantify the flows identified in section 2.1.1 are of interest to the analysis.

Demography

Historical statistical data on demographics and demographical projections are continuously provided by numerous organisations around the world. This thesis relies on Eurostat for European data and the United Nations Population Division for data on China, Japan and the United States. For Europe the total 18-year-old population year by year from 1990/1993 to 2025 is presented in some cases along with trend lines. The age, 18 years, has been chosen for its proximity to both upper secondary school and university, and the method of presentation has been chosen for its simple detail. For the reference countries, China, Japan and the United States, the total 15- to 19-year-old population every five years from 1990 to 2030 is presented along with trend lines. This differs from the presentation chosen for Europe, as more detailed comparable data has not been found available.

The data will serve the purpose of this thesis well.

Migration and immigration

Data on migration and immigration is neglected for reasons of limited resources. This source of people is currently limited compared to European births, depicted in the section on demography, but not negligible. The exclusion increases the error margin of the conclusions in this thesis.

It should be added that current trends indicate that the net flow of workers into (+) and out of (-) Europe will be negative in the next decades, mostly due to the ongoing massive boom in several Asian economies.

School capacity

Data on school capacity is excluded for reasons of limited resources. With the exception of dropout rates, school capacity should be equal to educational attainment (see below). Excluding data on school capacity will therefore not significantly affect the conclusions of this thesis.

Educational attainment

Historical statistical data on educational attainment is continuously provided by numerous organisations around the world. This thesis relies on data from Eurostat and OECD. Few published forecasts have been found, and those found are simply demographical projections similar to those already presented in this thesis and have therefore not been included. The data will serve the purpose of this thesis well.

Choice of MST education

Data on the number and percentage of applicants, entrants, enrolled and graduates would provide valuable insight into different aspects that would most certainly be relevant to the conclusions in this thesis. For example, application rates can be seen as indicative of what people are interested in studying, entrance rates can be seen as indicative of confirmed choice to enter and graduation rates include dropout rates. However, detailed, homogenous, conclusive and cross-nationally comparable data on students' choice of MST education has not been found and is not likely to exist. Instead, in most cases, limited and somewhat outdated data from a recent OECD report (2008c) on science and technology graduates at the upper secondary school level, and historical data from Eurostat and OECD on MST graduates at the tertiary level, will have to suffice. Although all of the countries within the scope of this thesis were asked for more detailed statistics, only Sweden responded. Few published forecasts have been found, and those found are simply demographical projections similar to those already presented in this thesis and have therefore not been included.

Although the data will serve the purpose of this thesis, the lack of supplemental data increases the error margin of the conclusions in the thesis.

Student attitudes to MST

While what affects student attitudes and the degree to which student attitudes are actually linked to student choice will be touched upon in subsequent chapters, they are undoubtedly a parameter to be considered.

Numerous attitude surveys have been conducted. This thesis relies on three larger scale surveys that have received more attention than others:

- The Relevance of Science Education (ROSE); young learners aged 15 from more than 40 countries have expressed their views on several aspects related to science and technology (Sjøberg and Schreiner 2008).
- Eurobarometer survey; covering issues similar to ROSE for the adult population in 32 European countries and as presented by Sjøberg and Schreiner (2008).

– OECD's Programme for International Student Assessment, PISA, report 2006 (OECD, 2007) which includes a section on student engagement in science.

These data will serve the purpose of this thesis well.

Demand for human resources in MST.

Although demand forecasts exist, they are often severely criticised for being very unreliable and have therefore been excluded. A qualitative analysis will suffice for the purpose of this thesis, but the lack of data regarding demand for human resources in MST is a weakness that will increase the error margin of the conclusions.

2.1.3. Data model and scope

As a result of the above, evidence on supply and demand, illustrated in figure 3, is taken into account, incorporating data on demographics, educational attainment, choice of MST education, student attitudes to MST and demand for human resources in MST.

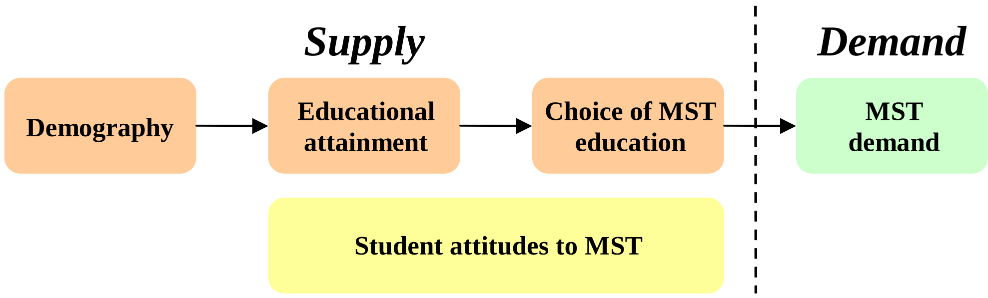

Figure 3 Data taken into account to verify that the supply base is shrinking that the demand for talented personnel in MST is or will become larger than the supply

The scope of this thesis is, as previously stated, delimited to Europe and the European market. Thus this chapter examines Europe as a whole with case studies of Belgium, France, Poland, Sweden and the United Kingdom, as these are countries of special relevance to the Volvo Group, case studies of Finland, Ireland, Italy and the Netherlands, for reference within Europe, and finally, case studies of China, Japan and the United States for reference outside Europe and due to their special relevance to the Volvo Group. The case studies are presented in Chapter 7: Appendix 1.

2.1.4. Creation of a supply indicator

The objective of creating an indicator is to enable simple and graphical communication about the subject being assessed. Ideally, a supply indicator would reflect the historic and forecast future supply of human resources in MST, in absolute numbers or in change compared to today. The creation of such an indicator would require high-quality historical and forecast future statistics on the major flows in the schematic in figure 2. However, such statistics do not fully exist, and the uncertainty in the assumptions required to fill present data gaps would render the indicator worthless. In addition, the available data is not fully comparable between countries.

As a substitute, I have constructed a qualitative supply development indicator based on an analysis of available supply data by country and by category of the data model presented in figure 3. I have assigned an indicator value on a 7-step scale of -3 to 3 to every country and category pair corresponding to its level of positive or negative development of supply.

Since the available data differs from country to country, and since several aspects of the data are simultaneously relevant to conclusions, I determined the assigned indicator values in two steps based on the multiple trends listed below. First, I established preliminary indicator values based on the primary trends (D-I, E-I and M-I) according to the intervals in table 1. Second, I established final indicator values by permitting my qualitative analysis of the secondary trends (D-II, E-II and M-II) in relation to corresponding primary trends to add or subtract a maximum of 2 to or from the preliminary values.

This qualitative indicator will enable the reader to compare development in the supply of human resources in MST between regions as well as to identify the critical factors affecting supply within a specific region.

Indicator trends and intervals

Demography

(D-I) The primary trend for the development indicator on demography is the linear trend over the period 1990/1993-2025/2030.

(D-II) The secondary trend is the projected change from 2005/2008 to 2020.

Educational attainment

(E-I) N/A

I have not used a primary trend for the development indicator on educational attainment since I have not found it possible to determine a relevant trend in the statistics currently available.

(E-II) The secondary trends are the percentage of upper secondary school graduates to the population at the typical age of graduation, the percentage of the population aged 25 to 64 having completed at least upper secondary school education, the percentage of tertiary graduates to the population at the typical age of graduation and the percentage of the population aged 25 to 64 having completed tertiary education.

Choice of MST education

(M-I) The primary trend for the development indicator on choice of MST education is the combined average of the changes in the percentage of graduates from mathematics, science and technology tertiary education and the percentage of students enrolled in mathematics, science, computing, engineering manufacturing and construction tertiary education. It is important to note that change in percentage has been chosen over change in absolute number as this excludes demography and educational attainment, which have been previously accounted for.

(M-II) The secondary trend is reserved for region specific data, and is presented and described where applicable.

		D-I	E-I	M-I
3	Extremely positive	>20%	n/a	>15%
2	Very positive	10% - 20%	n/a	7% - 15%
1	Positive	3% - 10%	n/a	3% - 7%
0	Insignificant	(-)3% - 3%	n/a	(-)3% - 3%
-1	Negative	(-)10% - (-)3%	n/a	(-)7% - (-)3%
-2	Very negative	(-)20% - (-)10%	n/a	(-)15% - (-)7%
-3	Extremely negative	<(-)20%	n/a	<(-)15%

Table 1 Development indicator with primary trend intervals

Combined indicator

In addition to the development indicators assigned to each country and category pair, I have constructed a combined indicator allowing comparability between countries. Such an indicator cannot be created in a mathematically stringent way based on available data. Instead, I have constructed a qualitative indicator by averaging the category indicators country by country to establish their relative order and scaling the country averages by a factor 1.5 to achieve a scale comparable to the original development indicators.

2.2. Supply

2.2.1. Demography

Europe is clearly facing a huge demographical challenge with the total population of 18-year-olds within the European Union (EU27) expected to decrease by 22% from 1993 to 2020, as illustrated by figure 4. The actual change from 1993 to 2008 was a 9% decrease, and the projected change from 2008 to 2020 is a 14% decrease. The linear trend over the period 1993-2025 is extremely negative (~ (-)25%).

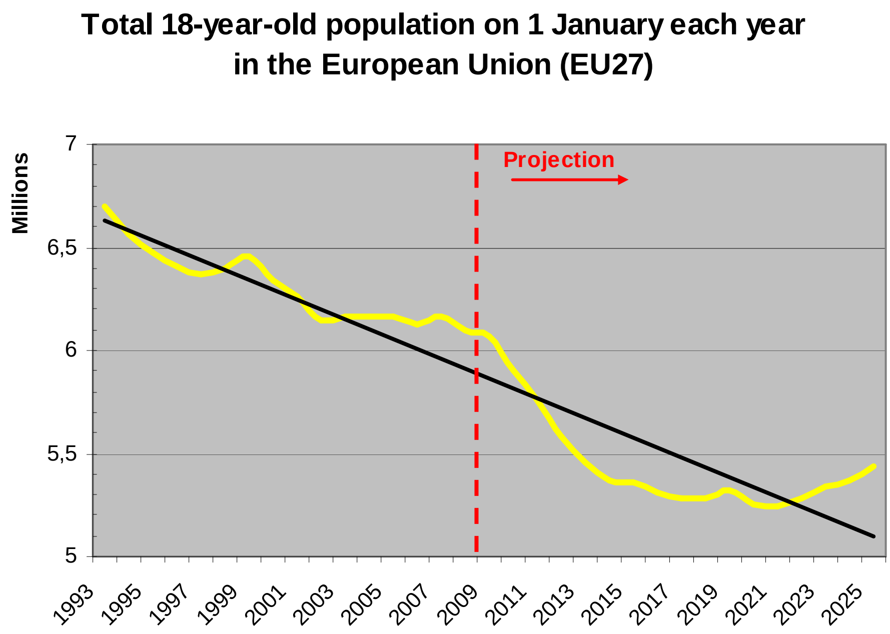

Figure 4 (Data source: Eurostat, 2009a; Eurostat, 2009b)

Figure 5 exposes large variations among the analysed countries including dramatic declines in the total population of 18-year-olds from 1993-2008 in Italy (-31%) and Japan** (-35%). As illustrated by figure 6, despite large national variations, most countries can expect a significant decrease (>3%) in the total population of 18-year-olds from 2008 to 2020. The only countries that can expect a significant increase (>3%) are Ireland and the United States of America. France and the Netherlands can expect insignificant changes (<3%).

More data on demography is presented in the national case studies in appendix 1.

Development indicator on demography

The primary trend for the development indicator on demography (D-I) is the linear trend over the period 1990/1993-2025/2030, which generates the preliminary indicator value -3 for Europe. The secondary trend (D-II) is the projected change from 2005/2008 to 2020, which does not affect the analysis, consequently generating a final development indicator on demography for Europe set to -3.

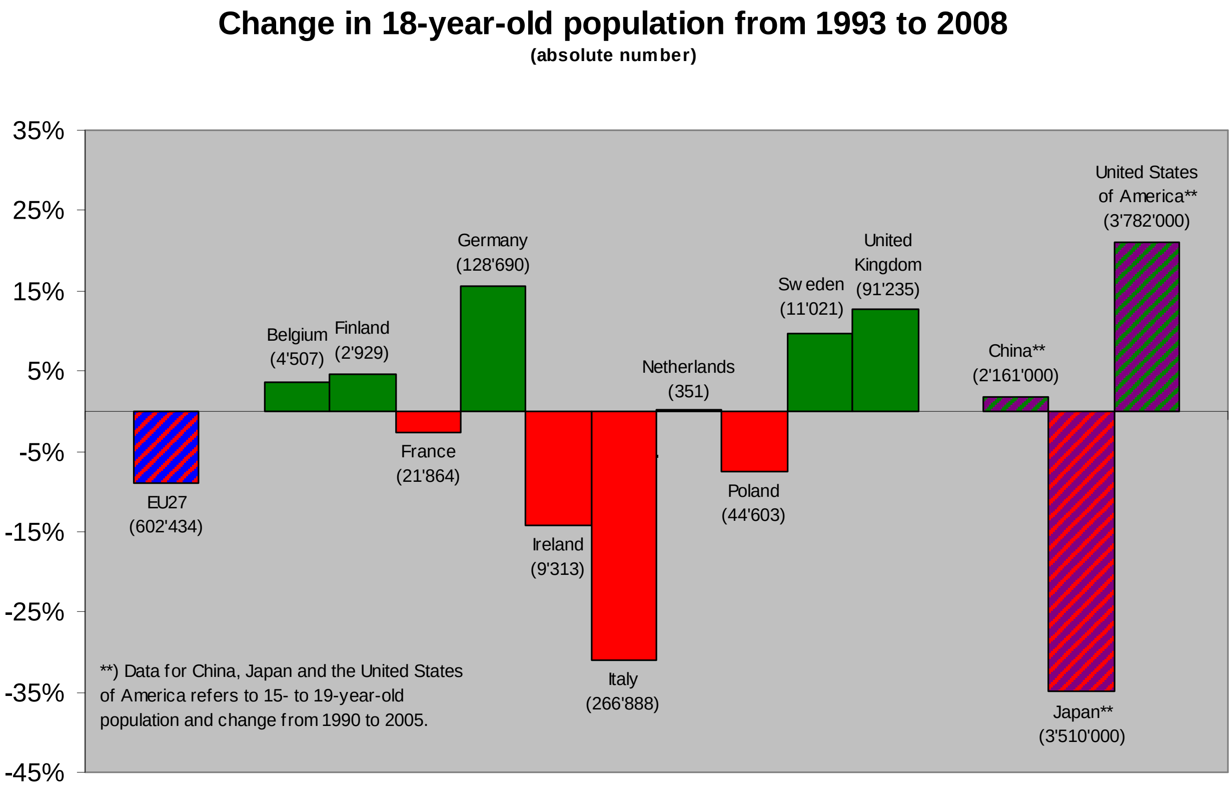

Figure 5 (Data source: Eurostat, 2009b; United Nations Population Division, 2009)

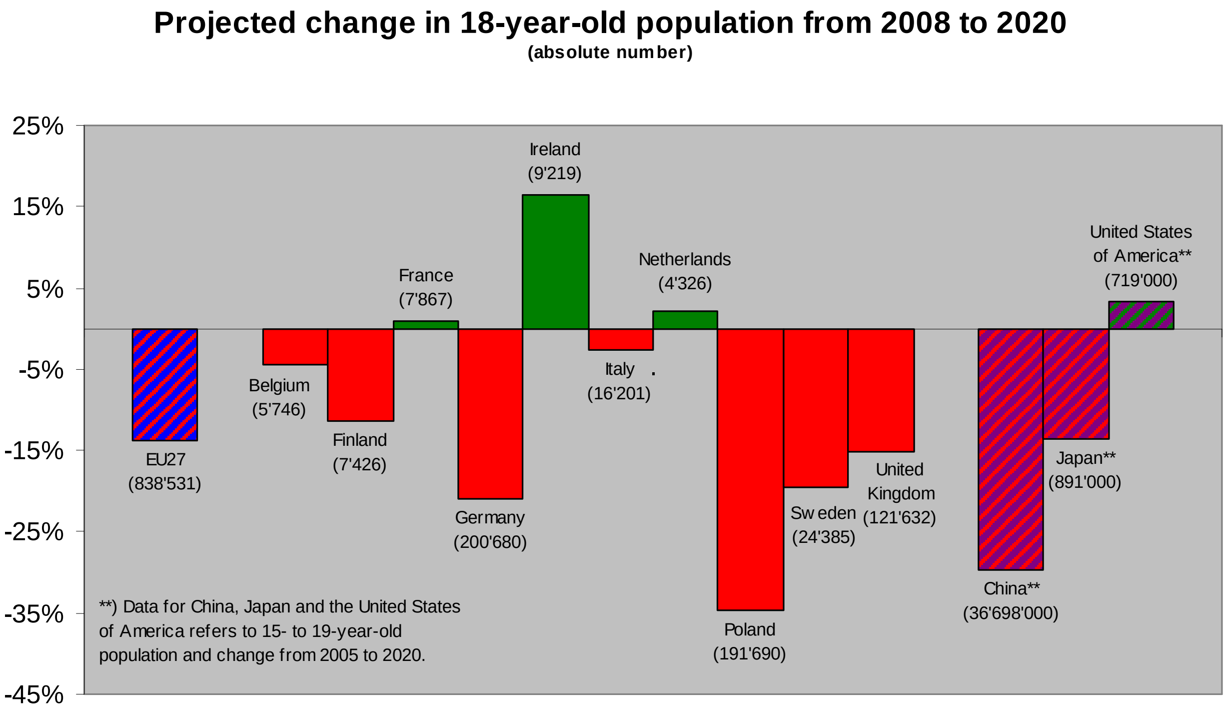

Figure 6 (Data source: Eurostat, 2009b; United Nations Population Division, 2009)

2.2.2. Educational attainment

Upper secondary school

Demography and student access to education both impact the largely varying change in the number of upper secondary school graduates illustrated by figure 7. As demography has already been accounted for in the previous section, it is more interesting to look at student attainment in relation to the current population.

Figure 8 displays the percentage of upper secondary school graduates to the population at the typical age of graduation from 1995 to 2006. All of the included countries exhibit positive trends except Poland. Sweden and the United States remain below the EU19 and OECD average for the whole period.

Figure 9, which shows the percentage of the population aged 25 to 64 having completed at least upper secondary education, paints a slightly different picture, placing Poland and Sweden at the top along with Germany. A likely cause is that more young people in Poland and Sweden graduate from upper secondary school after what has been defined as the typical age[1] of graduation than in the other countries included. In figure 9, all of the included countries exhibit positive trends including Poland.

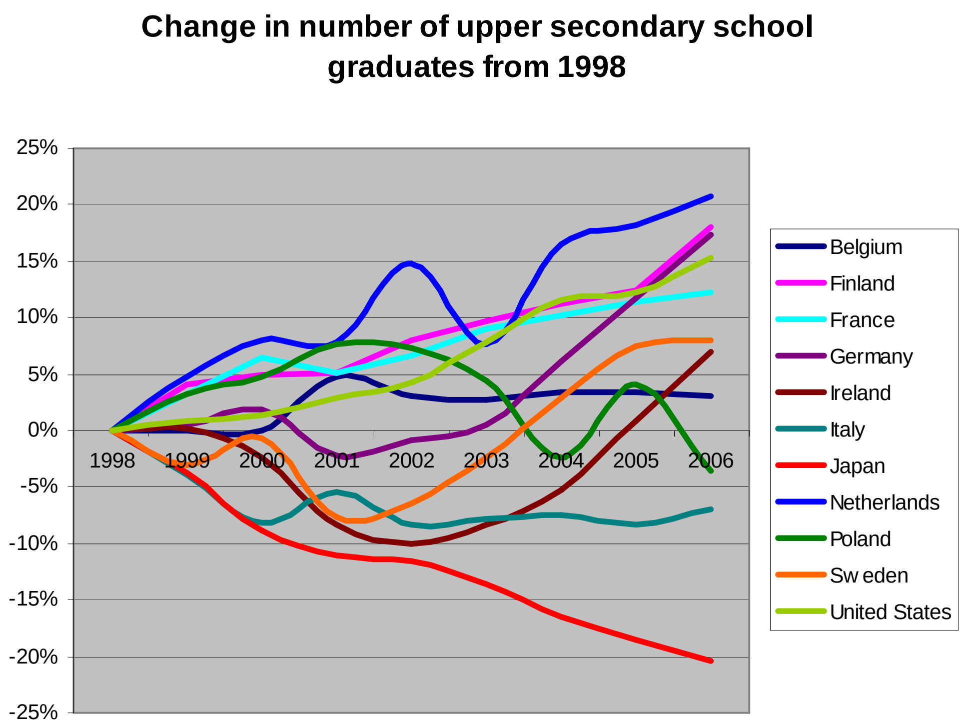

Figure 7 (Data source: Eurostat, 2009d)

[1] "The typical age corresponds to the most common age at the end of the last school/academic year of the corresponding level and the programme in which the degree is obtained." (OECD, 2008a)

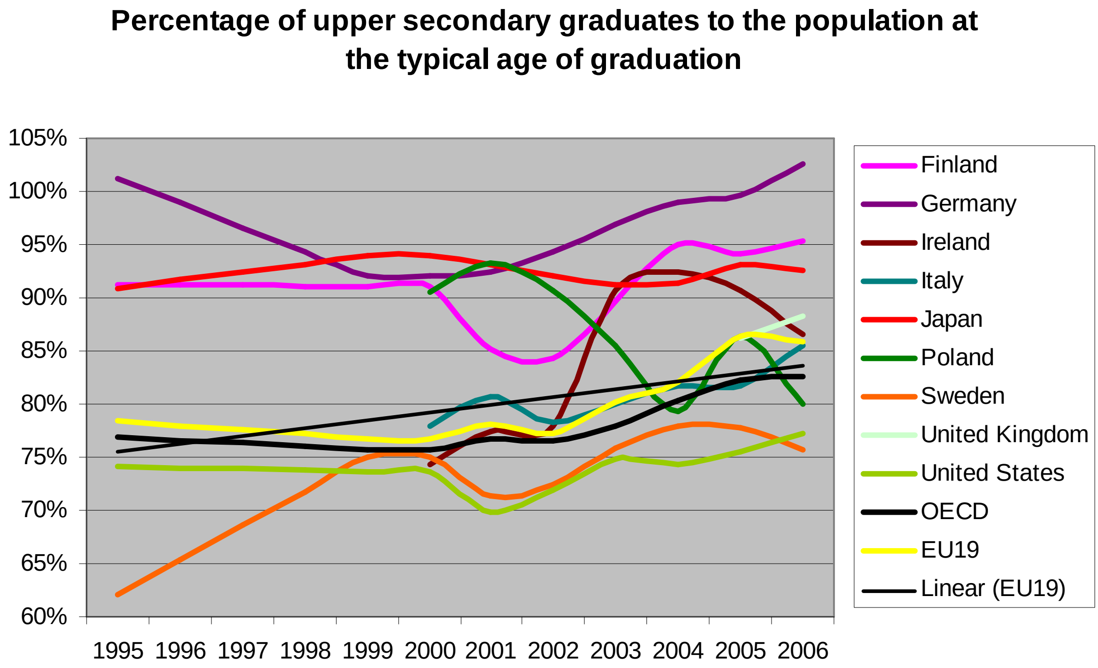

Figure 8 (Data source: OECD, 2008a)

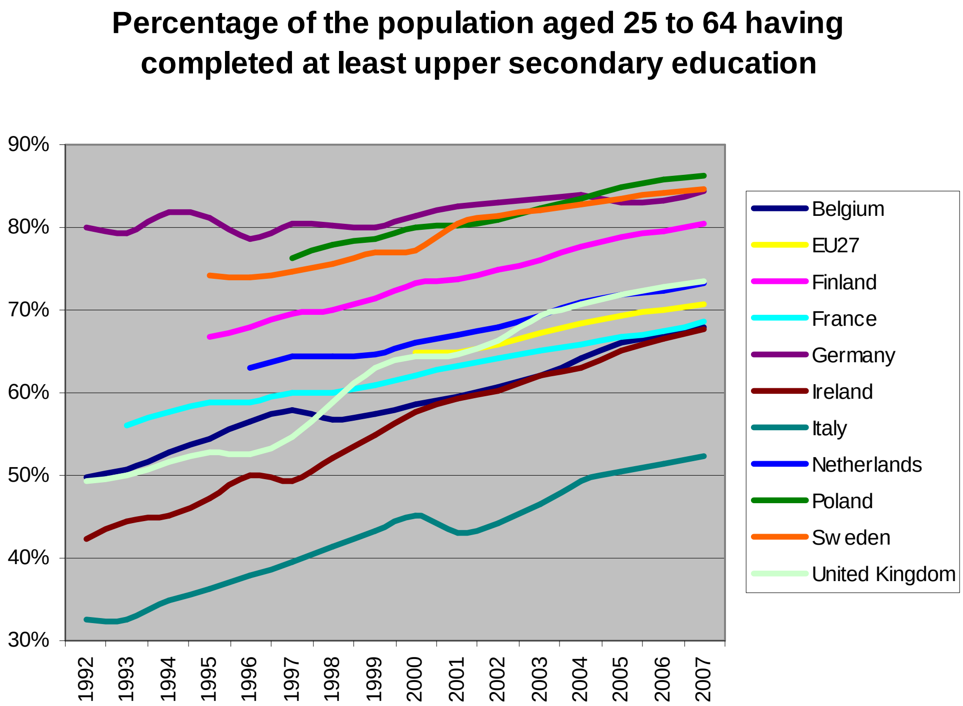

Figure 9 (Data source: Eurostat, 2009c)

Tertiary education

Similarly to the upper secondary school case, demography and access to education both impact developments in the number of tertiary graduates displayed in figure 10. Many countries have experienced very positive trends, notably Poland exhibiting a 120% increase from 1998 to 2002.

However, access to tertiary education is now expected to stabilise (OECD, 2008c). Only Japan experienced a decline, largely due to extremely negative demographic trends. As demography has already been accounted for in the previous section, it is more interesting to look at student attainment in relation to the current population.

Figure 11 shows the percentage of tertiary graduates (ISCED 5A) to the population at the typical age of graduation from 1995 to 2006. All of the included countries exhibit positive trends and most countries have experienced steep increases. Finland experienced the steepest increase during the period, but has now stabilised around 45-50%. Germany stays well below the EU19 and OECD average for the whole period.

Figure 12, which shows the percentage of the population aged 25 to 64 having completed tertiary education, paints a slightly different picture, placing Germany close to the OECD average. A likely cause is that more young people in Germany graduate from tertiary education after what has been defined as the typical age[1] of graduation than in all the other countries included. Italy and Poland remain well below the OECD average for the whole period, which is almost certainly explained by a later expansion of tertiary education than in the other analysed countries.

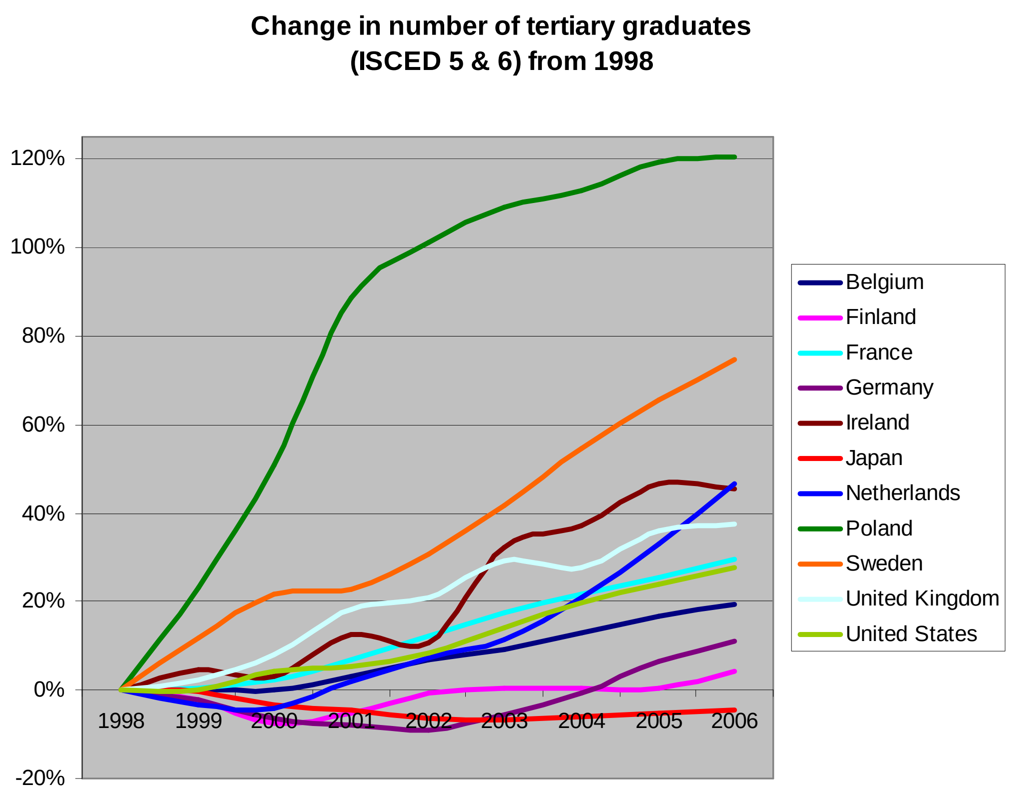

Figure 10 (Data source: Eurostat, 2009e)

[1] "The typical age corresponds to the most common age at the end of the last school/academic year of the corresponding level and the programme in which the degree is obtained." (OECD, 2008a)

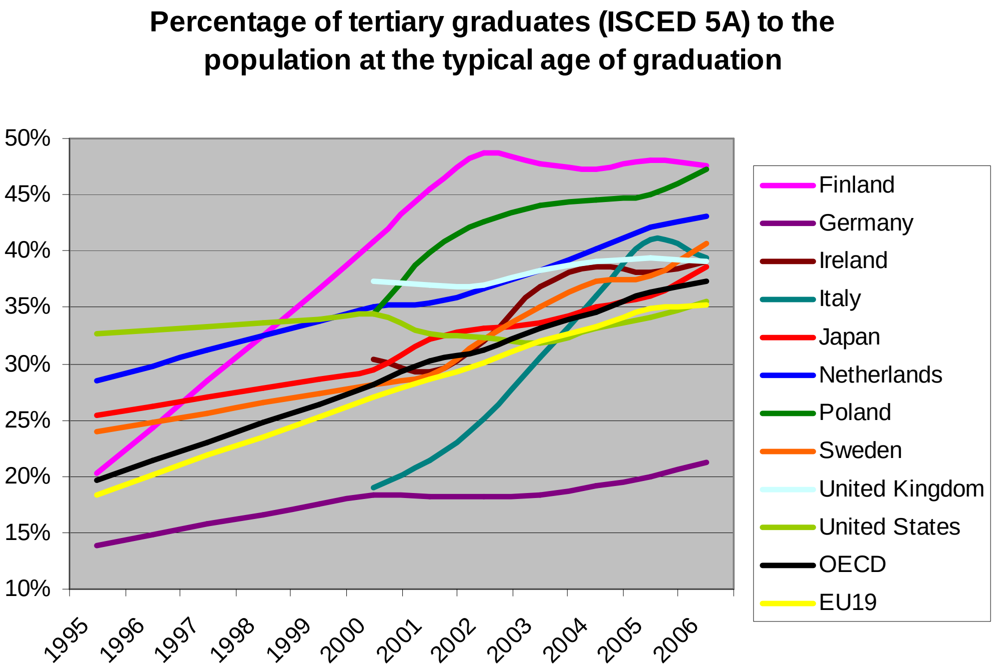

Figure 11 (Data source: OECD, 2008a)

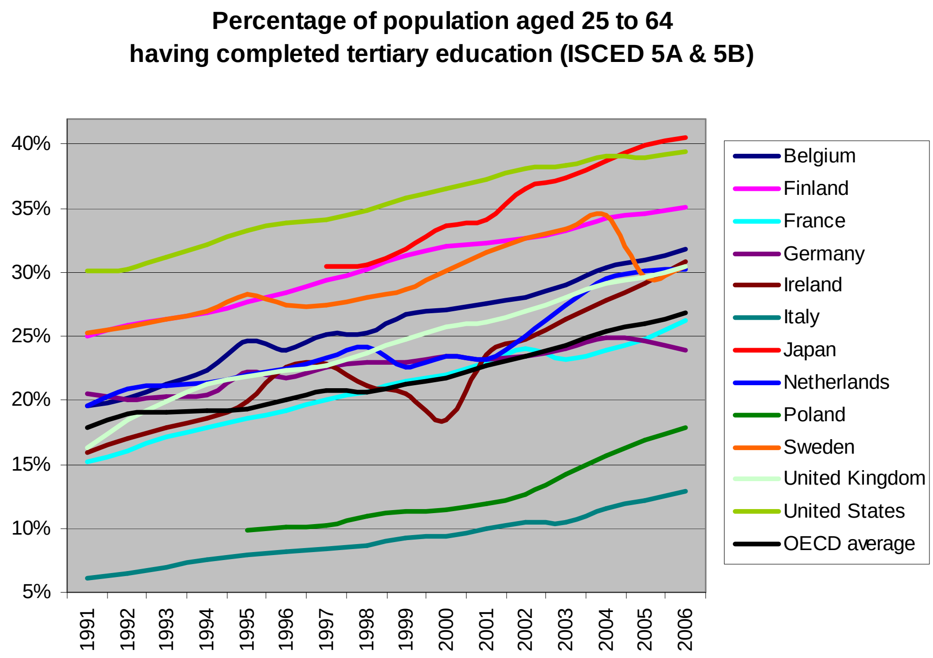

Figure 12 (Data source: OECD, 2008b; OECD, 2009a)

Development indicator on educational attainment

A primary trend for the development indicator on educational attainment (E-I) has not been chosen, as the available data needs to be analysed qualitatively. The secondary trends (E-II) are the percentage of upper secondary school graduates to the population at the typical age of graduation, the percentage of the population aged 25 to 64 having completed at least upper secondary school education, the percentage of tertiary graduates to the population at the typical age of graduation and the percentage of the population aged 25 to 64 having completed tertiary education. Europe and all of the analysed countries exhibit positive trends. However, it is not possible to conclude that the trends are *very positive* except perhaps for Italy and Poland, which are rising from very low levels. The final development indicator on educational attainment for Europe is therefore set to 1.

2.2.3. Choice of MST education

Upper secondary school

No data for Europe as a whole has been found. OECD (2008c) recently published a report called Encouraging Student Interest in Science and Technology Studies, including somewhat outdated statistics from 2003 presented in figures 13 and 14. These reveal an uneven picture, although the report (OECD, 2008c) states that many countries experienced a decline in the relative share of S&T upper secondary school students among the overall student population in upper secondary school from 1993-2003.

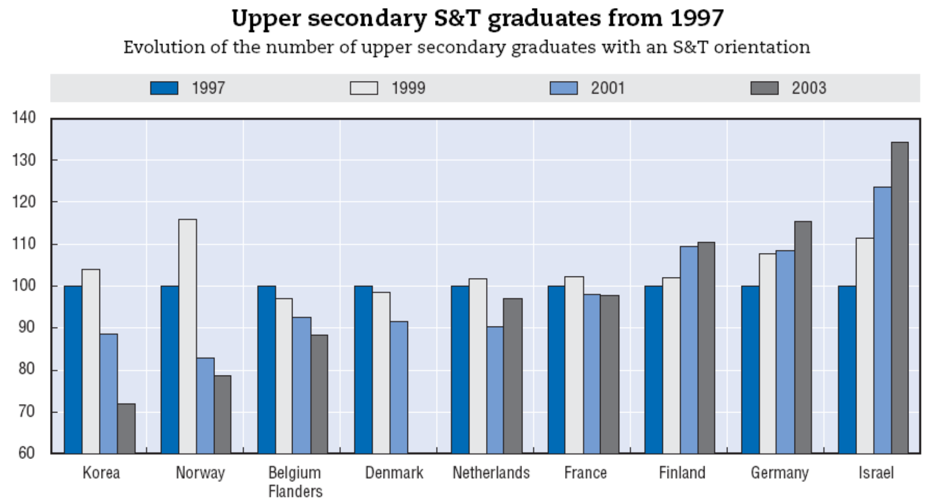

Figure 13 (Source: OECD, 2008c)

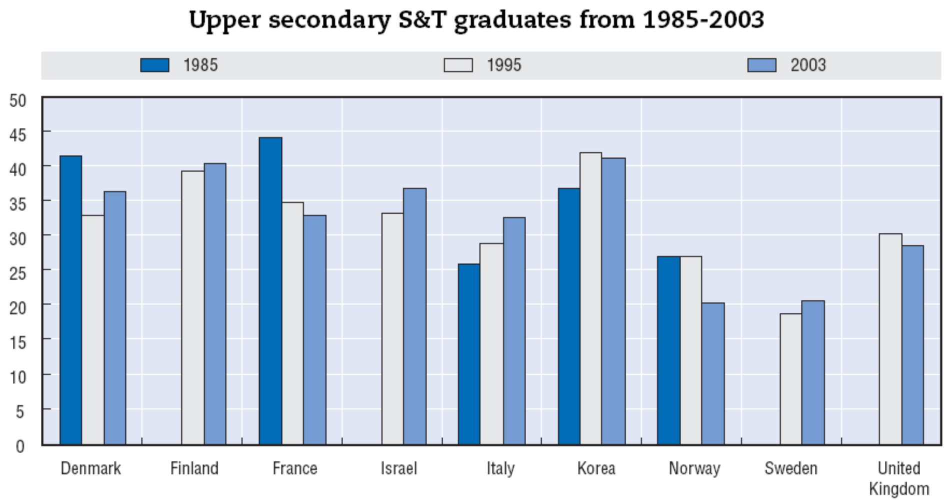

Figure 14 (Source: OECD, 2008c)

More data on choice of MST education at upper secondary school is presented in the national case studies in Chapter 7: Appendix 1.

Tertiary education

Europe and all of the analysed countries, except Japan, have experienced a large increase in the number of graduates from mathematics, science and technology tertiary education. In most cases this is mainly due to considerable increases in access to education. In some cases, notably Japan, demography has also had a large impact. This is illustrated in figures 15 and 16.

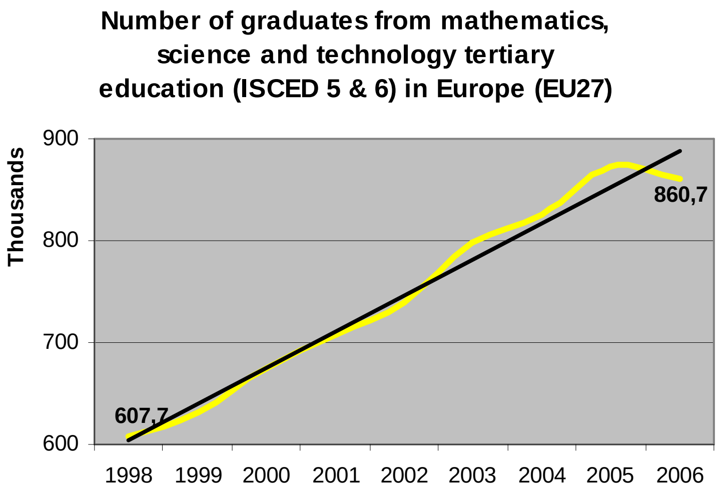

Figure 15 (Data source: Eurostat, 2009f)

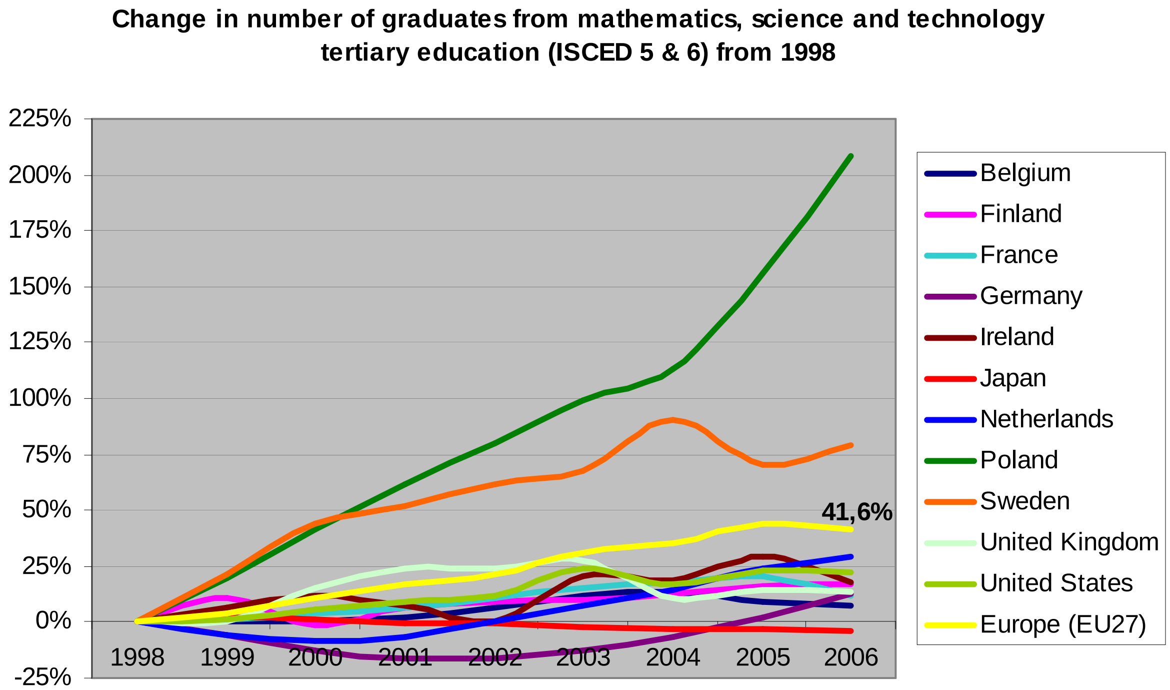

Figure 16 (Data source: Eurostat, 2009f)

As demography and educational attainment have already been accounted for in previous sections, it is more interesting to look at choice of MST education in relation to the total student population. Europe has experienced a 2.7 percentage unit or 10.8% decrease in the relative share of graduates from mathematics, science and technology tertiary education and a 1.5 percentage unit or 5.6% decrease in the relative share of students enrolled in mathematics, science, computing, engineering, manufacturing and construction tertiary education from 1998 to 2006. This is displayed in figures 17 and 18.

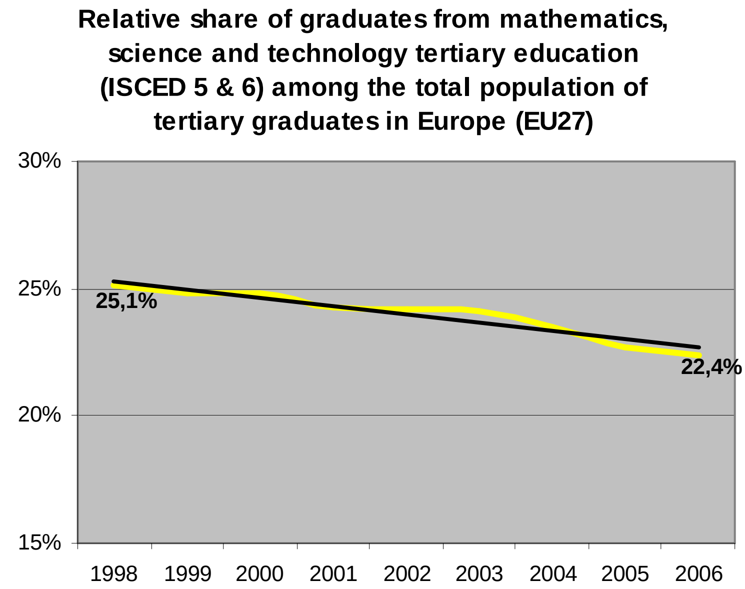

Figure 17 (Data source: Eurostat, 2009f)

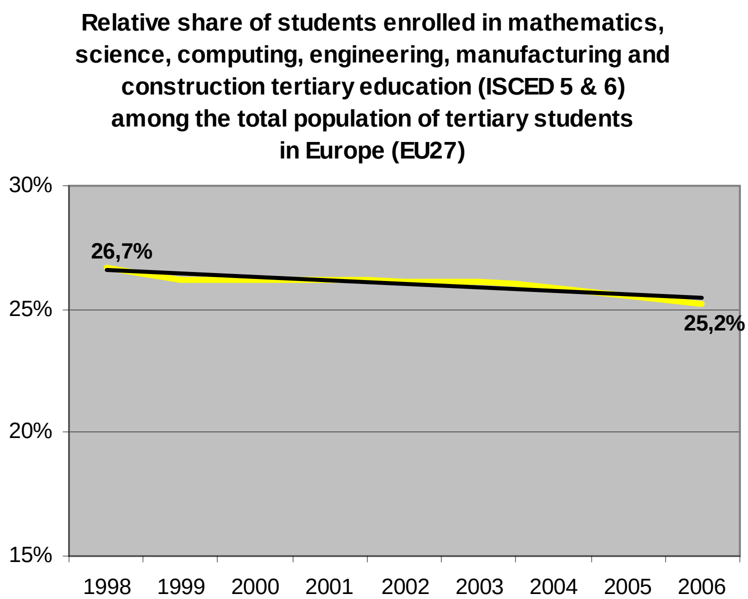

Figure 18 (Data source: Eurostat, 2009f)

Figure 19 shows the change in the relative share of graduates from mathematics, science and technology tertiary education for Europe and a number of the countries being analysed. In most countries the change from 1998 to 2006 was negative, for Sweden the change was insignificant (<3%) and for Finland and Poland the change was positive.

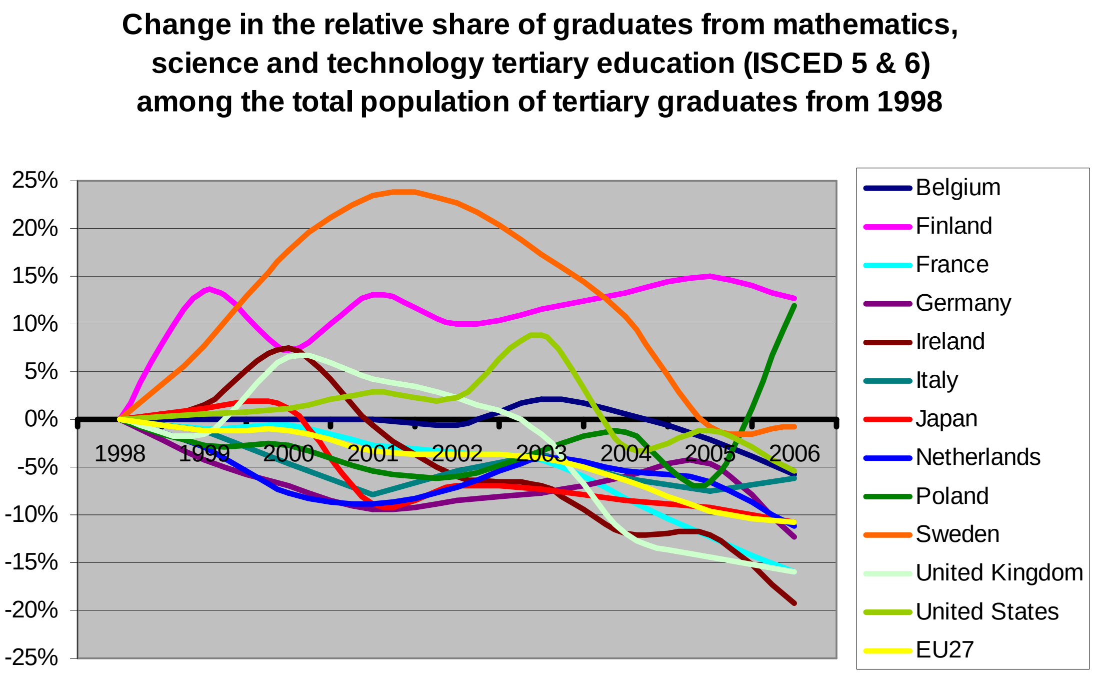

Figure 19 (Data source: Eurostat, 2009f)

More data on choice of MST education at the tertiary level is presented in the national case studies in the appendix.

Development indicator on choice of MST education

The primary trend for the development indicator on choice of MST education (M-I) is the combined average of the changes in the percentage of graduates from mathematics, science and technology tertiary education and the percentage of students enrolled in mathematics, science, computing, engineering manufacturing and construction tertiary education which generates the preliminary indicator value -2 for Europe. The secondary trend (M-II) is not applicable, which sets the final development indicator on choice of MST education for Europe to -2.

2.2.4. Supply development indicator

The assigned development indicators for Europe are illustrated in figure 20 together with the combined indicator for Europe constructed according to section 2.2.4. It is clear that Europe is facing very negative trends in the supply of human resources in MST. The most important contributing factor is an extremely negative trend in demography, although a very negative trend in choice of MST education is not far behind. The national case studies, presented in Chapter 7: Appendix 1, allow the comparison of regional combined indicators presented in figure 21. France, Germany, the Netherlands, Sweden and the United Kingdom are the worst off of the analysed countries in Europe whereas Finland and Poland show positive trends.

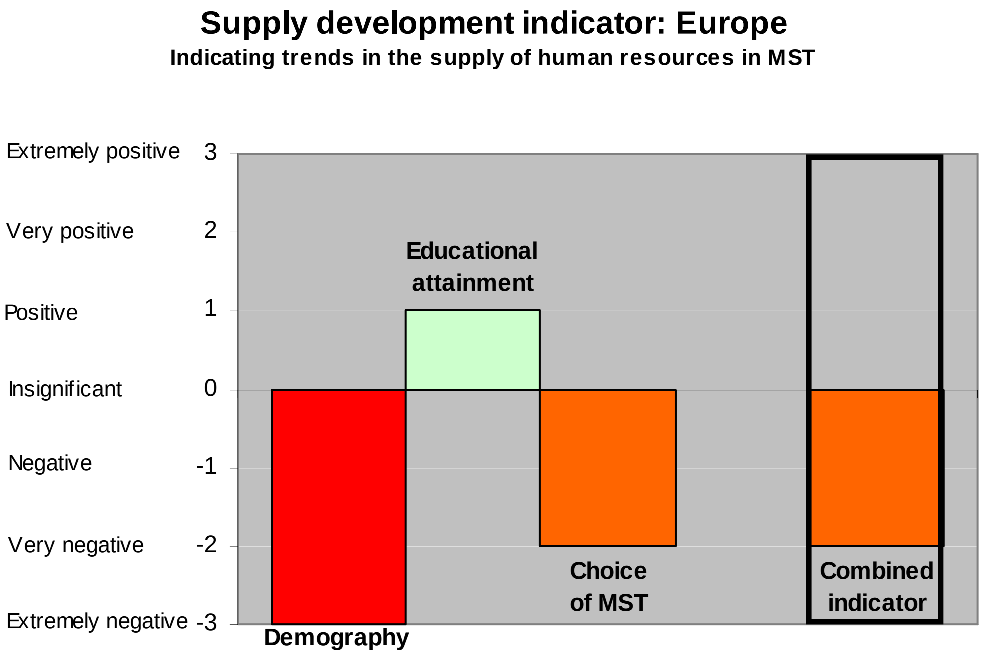

Figure 20

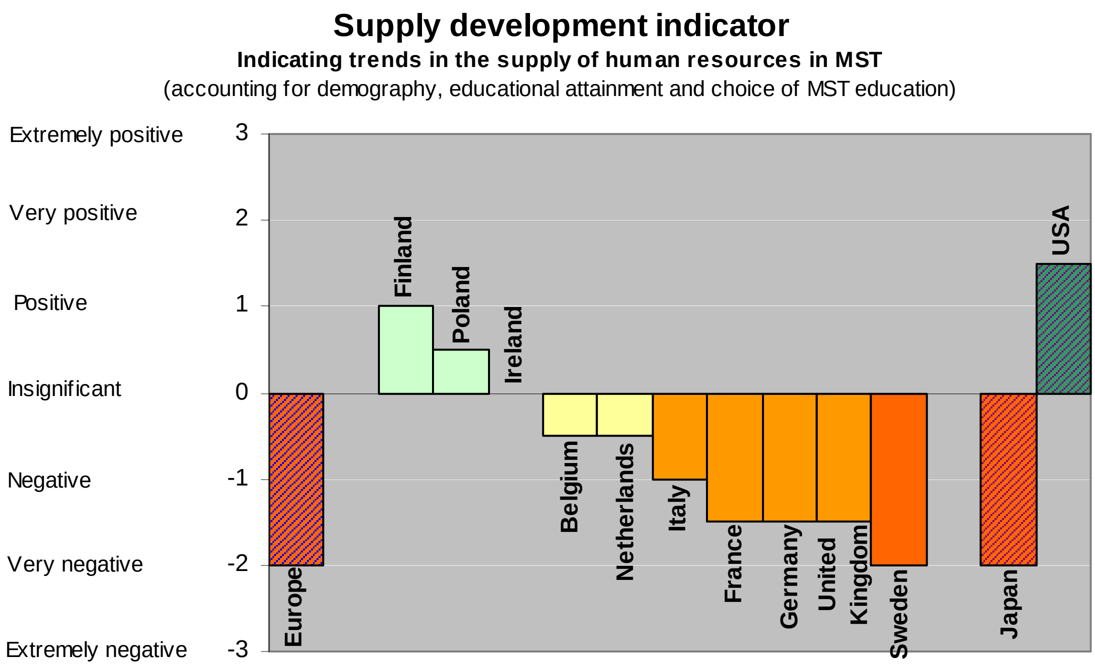

Figure 21

2.3. Demand

Although macro-level demand forecasts exist, they are often severely criticised for being unreliable. Inadequate data, questionable assumptions, complex contextual dependencies and countless variables all contribute to making the analysis troublesome. At the micro level, many employers have severe difficulties in predicting their own future demand for human resources even just two or three years ahead.

The scientific representation of demand for human resources in MST is the foreseen recruitment requirement of current employers given a set of variables in a scenario. Some of the variables are easy to foresee, such as upcoming retirements and competence exchange (change in workforce competence composition). The age pyramid in figure 22 shows that large age groups heading for retirement will have to be replaced by much smaller age groups, which is likely to lead to a substantial increase in the annual demand rate for human resources in MST. Figure 23 is an example of competence exchange where the competence composition at the member companies of the Association of Swedish Engineering Industries is being upgraded, increasing the demand rate for human resources with higher education and thereby also the demand rate for human resources in MST. Other variables are more difficult to foresee, such as fluctuations in the financial market or changes in consumer behaviour. The current financial crisis is an example that few foresaw. The demise of the dot.com boom is another.

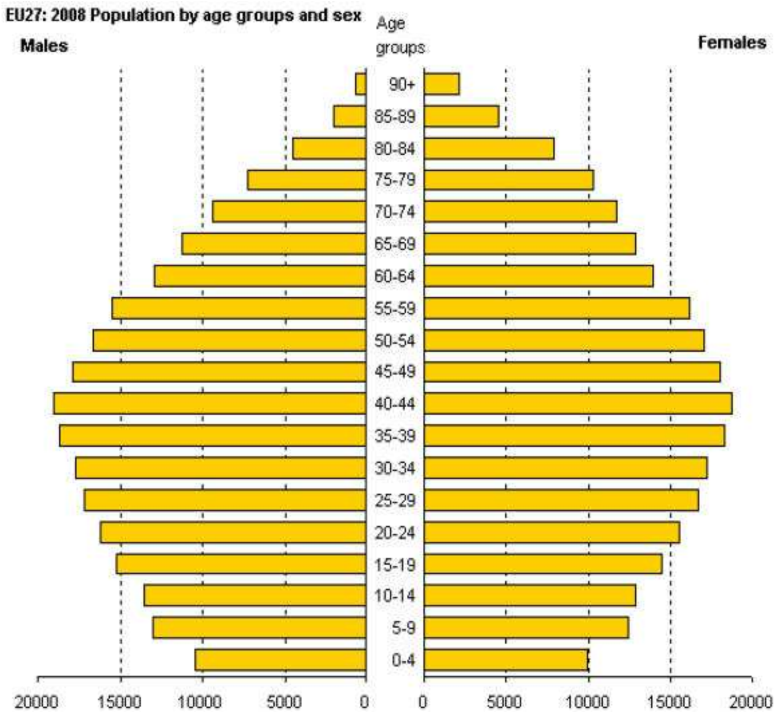

Figure 22 EU27: 2008 population by age group and sex
(Source: Economic Policy Committee, 2009)

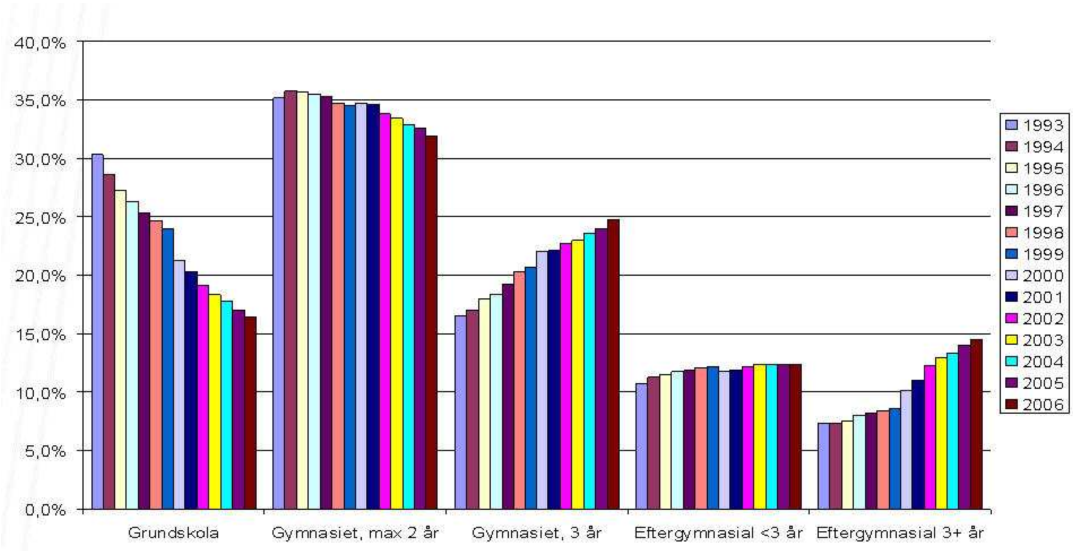

Figure 23 Level of education among the employees of the Association of Swedish Engineering Industries' member companies.
Y-axis: Percentage of the total workforce
(Source: Teknikföretagen, 2009)
Swedish translation
Grundskola = Primary and Secondary School
Gymnasiet, max 2år = Upper Secondary School, 2 years or less
Gymnasiet, 3år = Upper Secondary School, 3 years
Eftergymnasial <3år = Tertiary education, less than 3 years
Eftergymnasial 3+ år = Tertiary education, 3 years or more

Another predominant representation of demand for human resources in MST is the political one. The European Commission and EU member state governments continuously reiterate the fundamental importance of MST in a knowledge-based economy, dependent on research, development (R&D) and innovation to drive competitiveness ensuring social and economic growth. Industry supports this; the European Round Table of Industrialists (2008, p.1) states that they have "identified increasing young people's interest in mathematics, science and technology as essential for sustainable economic growth in Europe".

Indeed, MST education and R&D investment are both highlighted in the Lisbon agenda. Although the Lisbon MST benchmark – an increase in the total number of graduates in MST by 15% from 2000 to 2010 – has been surpassed (see section 2.3), the Lisbon target to increase the proportion of European GDP invested in research from 1.9% to 3% is still far off, and will arguably require many more people working in MST. See figure 24.

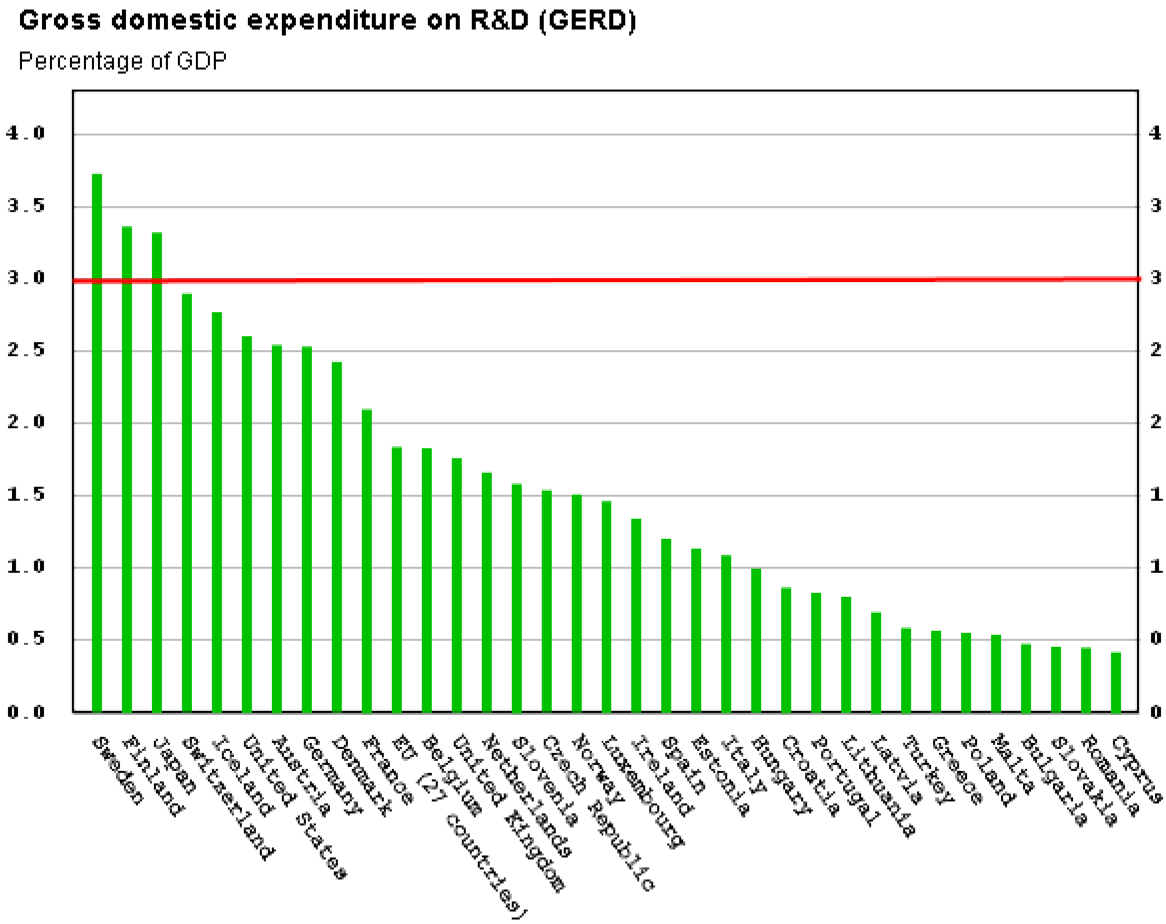

Figure 24 Gross domestic expenditure on R&D in 2006.
The Lisbon target is 3%, as indicated by the red line.
(Source: Eurostat, 2009g)

The scientific and political representations of demand for human resources in MST relate in the way that *pull* and *push* – classic business terms in marketing and supply chain management – relate to each other. Pull and push mechanisms often operate together, which is likely to be the case also in the development of demand for human resources in MST. Either way, most pull and push aspects indicate an increase in demand, while few indicate a decrease. It appears that worry expressed by Osborne and Dillon (2008) – "… encouraging or persuading young people to pursue careers in science without the evidence of demand would be morally questionable" – is perhaps unjustified. It seems evident that the future will require more people with basic and advanced skills in MST, not less.

2.4. Student attitudes to MST

While what affects student attitudes and the degree to which student attitudes are actually linked to student choice will be touched upon in subsequent chapters, they are undoubtedly a parameter to be considered.

The following figures 25-34, as presented by Sjøberg and Schreiner (2008), show some very interesting trends. Note that the questions that the results are in response to can be found at the bottom of each figure. The countries on the Y-axis are presented in order according to their United Nations Human Development Index (HDI), meaning that the least developed countries are at the top and the most developed countries are at the bottom. The X-axis is a scale from disagree to agree. Sjøberg and Schreiner (2008) have included comments and conclusions on the results in each figure. Figures 25 and 27 are based on data from a recent Eurobarometer survey (displayed to the upper left where applicable – see logotype) and cover adult attitudes, while figures 26 and 28-34 are based on ROSE data (see section 2.2.2) and cover attitudes of young learners at the age of 15.

In addition to the comments made by Sjøberg and Schreiner (2008), it is interesting to note the apparent negative correlation between the analysed countries' level of development and young people's attitudes to education and careers in science and technology, displayed in figures 32, 33 and 34.

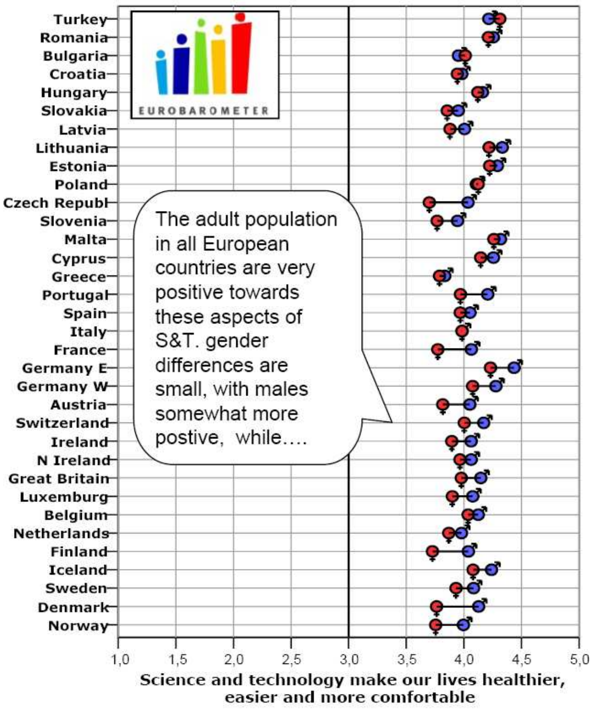

Figure 25 (Source: Sjøberg and Schreiner, 2008)

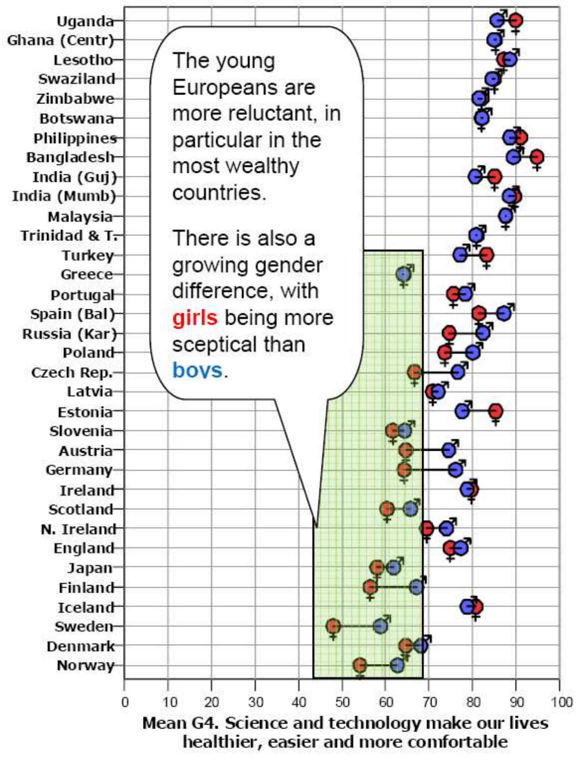

Figure 26 (Source: Sjøberg and Schreiner, 2008)

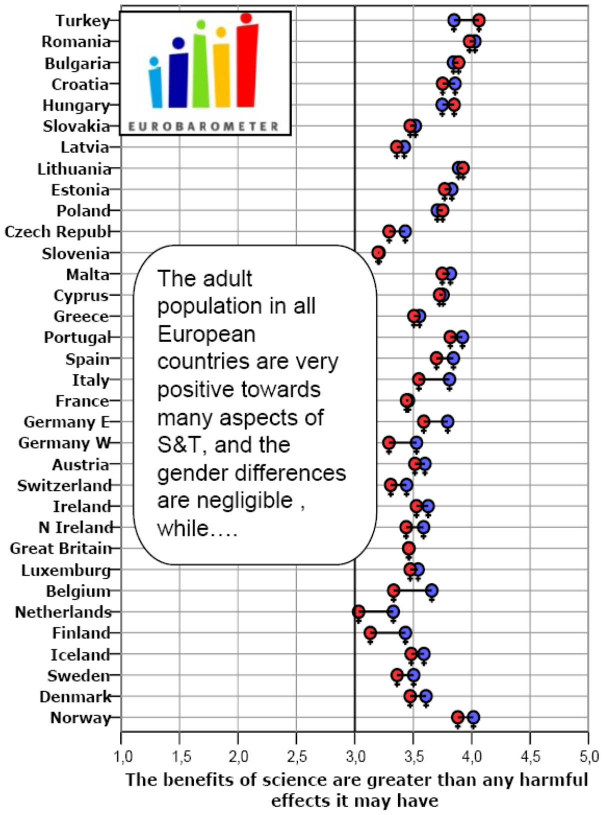

Figure 27 (Source: Sjøberg and Schreiner, 2008)

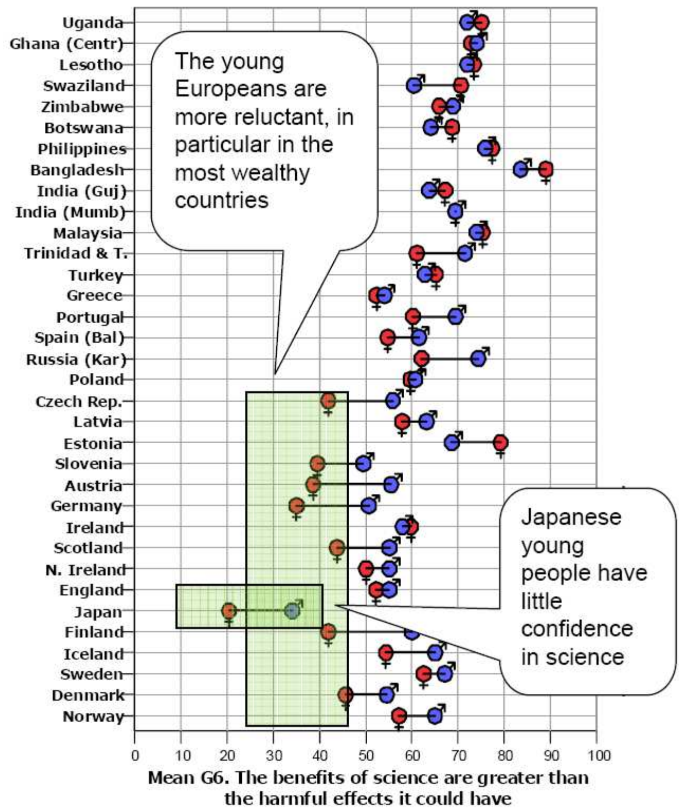

Figure 28 (Source: Sjøberg and Schreiner, 2008)

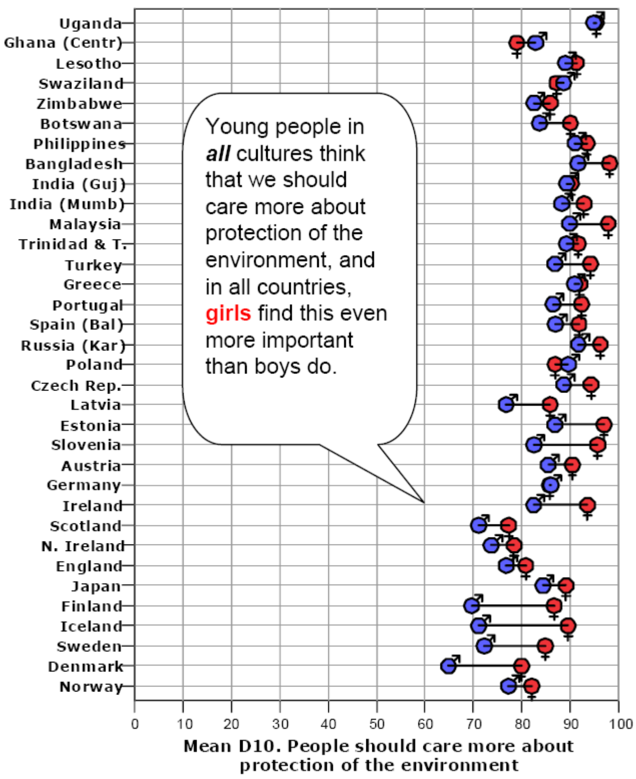

Figure 29 (Source: Sjøberg and Schreiner, 2008)

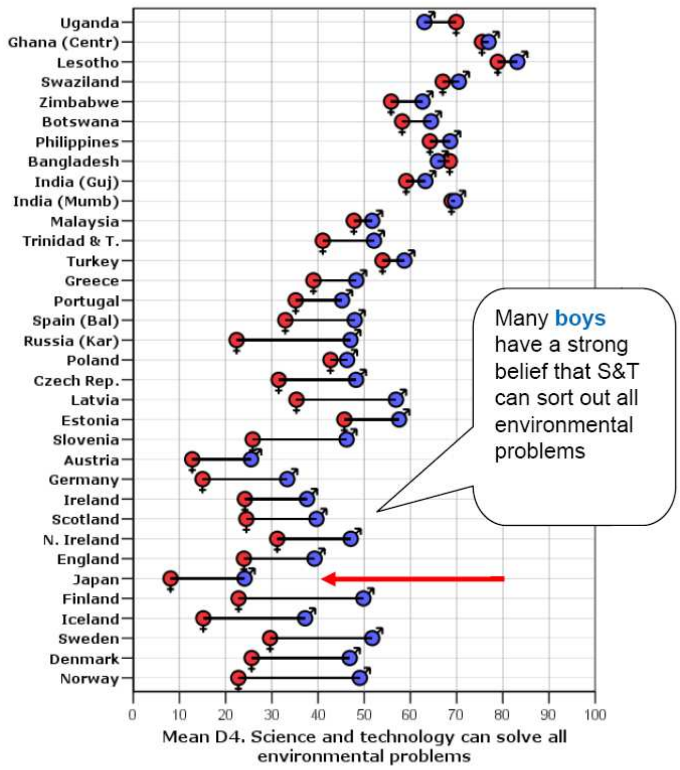

Figure 30 (Source: Sjøberg and Schreiner, 2008)

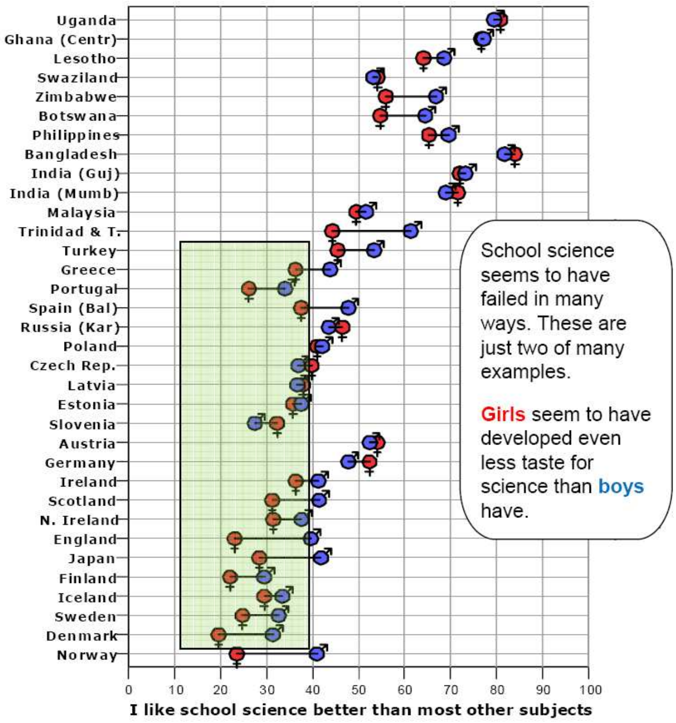

Figure 31 (Source: Sjøberg and Schreiner, 2008)

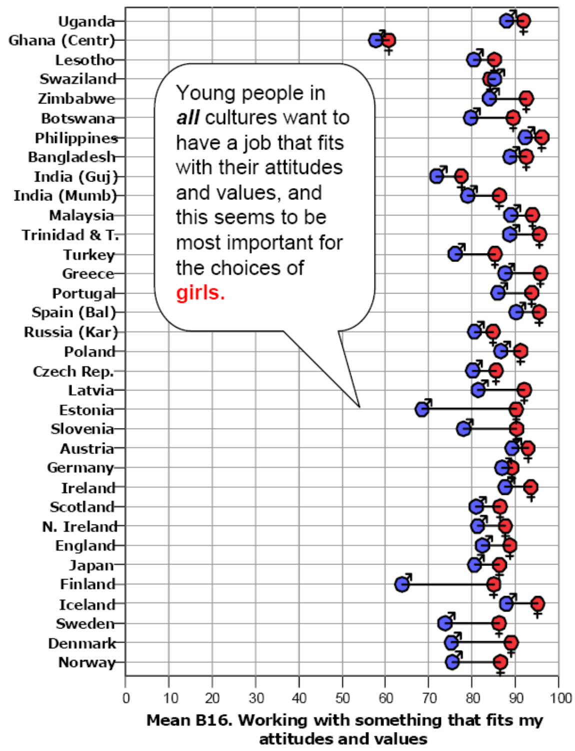

Figure 32 (Source: Sjøberg and Schreiner, 2008)

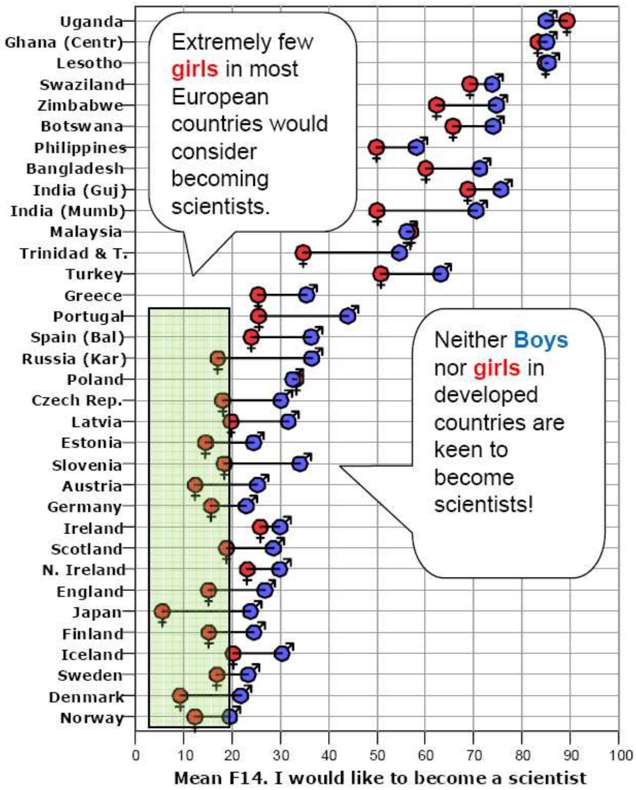

Figure 33 (Source: Sjøberg and Schreiner, 2008)

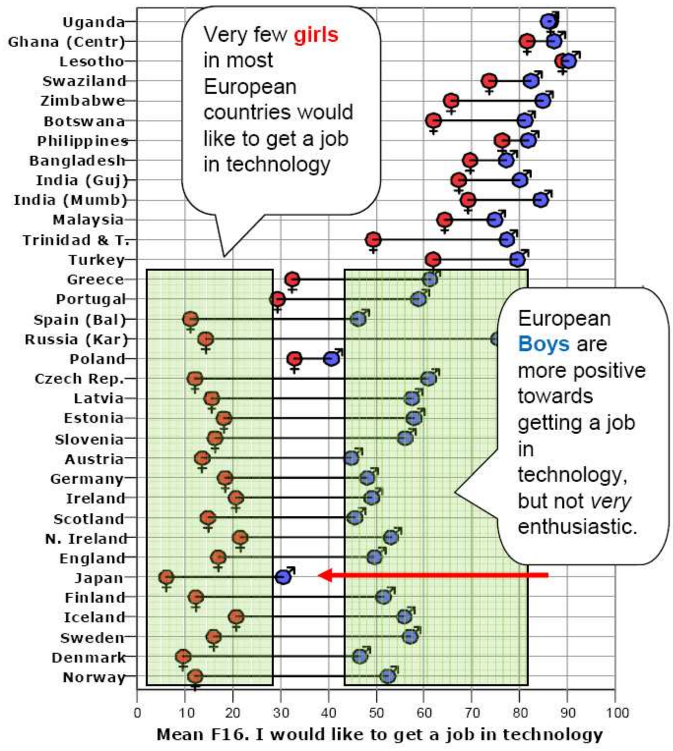

Figure 34 (Source: Sjøberg and Schreiner, 2008)

2.5. Conclusions

This chapter started by raising the question of whether there is a problem. Is the base from which the Volvo Group is dependent on being able to acquire talented personnel in maths, science and technology (MST) actually shrinking and, if so, will this lead to difficulties recruiting? An attempt to verify that the *supply* actually is shrinking that the *demand* for talented personnel in MST is or will become larger than the supply has been undertaken and provides the following answer.

Europe and most of the analysed countries experienced increases in the absolute number of graduates from maths, science and technology tertiary education from 1998-2006. However, negative demographic trends, a stabilisation of access to tertiary education and drops in the proportion of students choosing MST is likely to have a negative or, in some cases, very negative impact on absolute numbers in the years to come. At the same time, and despite the current financial crisis, demand is likely to increase, creating a workforce deficit. Negative attitudes to education and work in science and technology among Europe's young further support this conclusion. So yes, there is a problem. However, due to the lack of better workforce demand forecasts, it is not possible to say how big the problem is.

3. Stakeholder analysis

At this stage, it is important to have a clear view of who the stakeholders are in order to set subsequent conclusions in relation to the role the stakeholders might have or take in the issue at hand.

Fassin (2009), adapted, states that “A *stakeholder* refers to any individual or group that maintains a *stake*” in the issue “in the way that shareholders possess shares” in a company. Two types of stakeholders emerge from the literature: the *claimant* and the *influencer* (Kaler, 2002; in Fassin, 2009). A *claimant* has “some sort of claim” (Kaler, 2002) on the issue being resolved, while an *influencer* requires only a “capacity to influence” (Kaler, 2002) the issue (adapted from Kaler, 2002). A single stakeholder may also be of both types (Kaler 2002). However, the theory of stakeholder analysis is disputed, largely due to varying definitions of what a stakeholder actually is. In the case of a stakeholder in business, Fassin (2009) states that “Due to globalisation and technological evolution, with improved communications and information systems, virtually everyone and everything, everywhere, can “affect or be affected” by the decisions and actions of a business enterprise.” In a similar manner, one could undoubtedly argue the same for stakeholders in the issue at hand. However, in order to achieve useful results, the mapped and categorised stakeholders must be the most relevant in response of the objectives of this thesis and kept to a limited number.

3.1. Stakeholder mapping

A literature review, taking the initial definition of a stakeholder and the <u>potential</u> sub-issues into account, yields the following <u>potential</u> stakeholders.

Small/large private/public corporations/employers
Shareholders
Board
CEO
Top management
Middle management
HR organisation
Employees
Customers
Suppliers
Unions
Employers associations
Trade associations

Schools (primary, secondary and upper secondary)
Management
Teachers
Career counsellors
Students
National agencies for lower education, curriculum development and school improvement
Teachers associations
Student unions
Parents (of students)
Siblings (of students)
Friends (of students)

Universities
Management
Faculty
Career counsellors
Students
National agencies for higher education
Student unions
Parents (of students)
Siblings (of students)
Friends (of students)

Legislators
Local/regional governments
National governments
European Parliament
European Commission

Media
Daily newspapers
Television
Radio
Internet

Other
Employment agencies
Statistical agencies
Science centres
Science museums
Science exhibition

3.2. *Stakeholder categorisation according to Fassin's Stake Model*

3.2.1. Definitions

Although many stakeholder models exist, Fassin (2009) presents one that has a particularly useful graphical interpretation. Fassin (2009) categorises stakeholders into three main categories: "real" *stakeholders*, *stakewatchers* and *stakekeepers.* For the issue at hand, the following definitions hold (adapted from Fassin, 2009):

- *Stakeholders* are *claimants* "who hold a concrete stake" in the issue.
- *Stakewatchers* "do not have a real stake themselves" but "protect the interests of real stakeholders". "They are often proxies or intermediaries" such as pressure groups.
- *Stakekeepers* "are independent regulators, who have no stake" in the issue "but have influence and control".

3.2.2. Graphical interpretation of definitions

Based on the previous definitions, Fassin (2009) provides a graphical interpretation, shown in figure 35, for the case of stakeholders in business. The category 'non stakeholders' has been removed from the original figure.

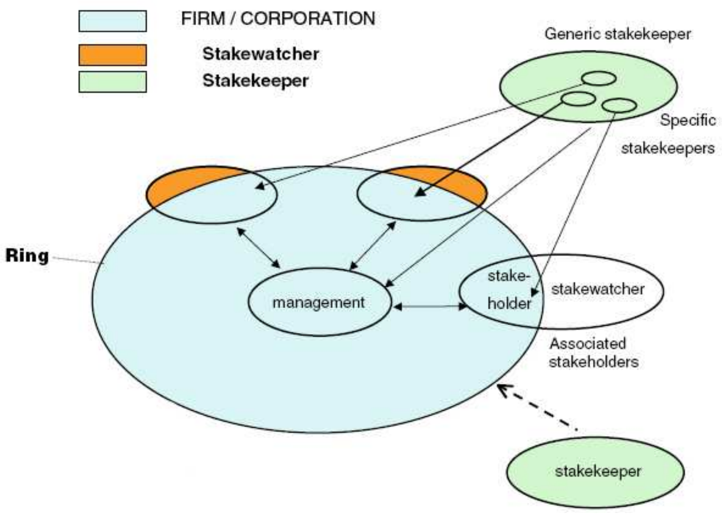

Figure 35 Graphical interpretation of the stakeholder model presented by Fassin (2009) for the case of stakeholders in business. (Source: Adapted from Fassin (2009))

3.2.3. Analysis of potential stakeholders and results

This section presents the result of the analysis according to Fassin's (2009) Stake Model followed by a short discussion, particularly on potentially controversial categorisations. A full presentation of the analysis of every potential stakeholder is outside the scope of this thesis, as it would not contribute to the conclusions.

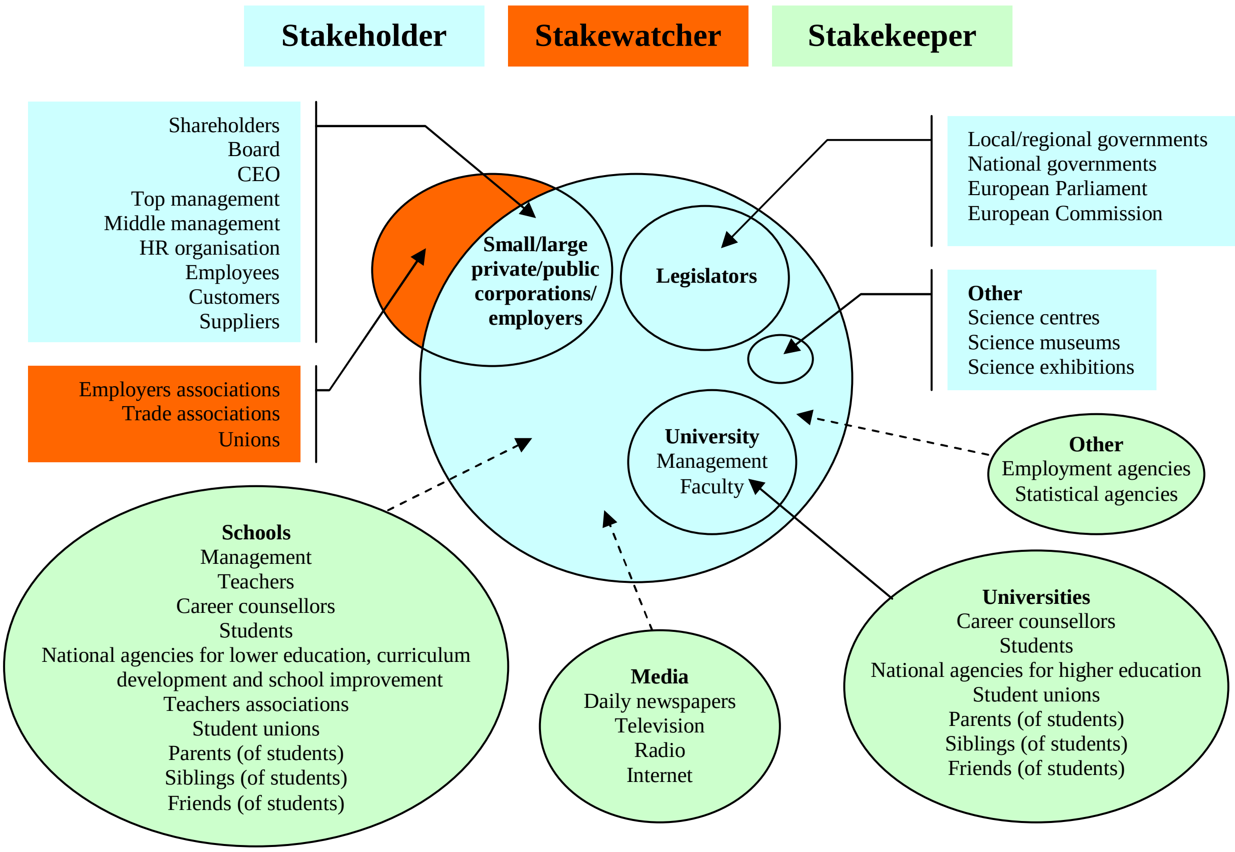

Figure 36 Graphical result of stakeholder categorisation. (Source: Adapted from Fassin (2009))

Potential stakeholders linked to Private and public corporations and employers in MST have either been categorised as stakeholders by definition of the issue itself or as stakewatchers who want to protect their associated stakeholders' interests.

Potential stakeholders linked to Schools have been categorised as stakekeepers, thus defining them as independent regulators with no stake in the issue being resolved. The rationale is that a generic European lower education system sees its role as preparing and equipping its students for prosperous lives as democratic citizens. It does not see its role as providing employers with personnel.

An illustration of the above is the Swedish Education Act 1985:1100, which states that "education shall provide the pupils with knowledge and skills and, in co-operation with the homes, promote their harmonious development into responsible human beings and members of the community". Employment in relation to curriculum is only mentioned once: Upper Secondary School programmes "shall form the basis for further education at higher education level and for employment". Working life in relation to curriculum is only mentioned once: adult education shall give adults an "opportunity to strengthen their position in working life". This is not a lot of mention, considering that the Swedish Education Act 1985:1100 is 50 A4 pages long.

Potential stakeholders linked to Media have been categorised as stakekeepers as they have no stake, but do have influence and control (Fassin, 2009).

The categorisation of potential stakeholders linked to Universities is similar to that of Schools, with the difference that University management and faculty have been defined as stakeholders as opposed to stakekeepers. The reason is that a generic European higher education system to a large extent sees its role as preparing and equipping students for employment and working life. In addition, Universities in MST are themselves dependent on being able to acquire personnel in MST.

Employment agencies and statistical agencies have been defined as stakekeepers as they have no stake but have influence and control.

Science centres, museums and exhibitions have been defined as stakeholders as their roles include disseminating science into society.

Potential stakeholders linked to Legislators have been defined as stakeholders as the public holds them responsible for ensuring economic growth within their mandated territories.

3.3. Stakeholder categorisation according to Mitchell et al.

Mitchell *et al.* (1997) provides another way of classifying stakeholders, which I believe relevant in analysing individuals and groups, from different social and cultural contexts, that potentially have a stake in this issue.

3.3.1. Definitions of stakeholder attributes

Mitchell *et al.* (1997) define the following stakeholder attributes.

- *Power*. “A relationship among social actors in which one social actor, A, can get another social actor, B, to do something that B would not have otherwise done” (Mitchell *et al.*, 1997).
- *Legitimacy*. “A generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs or definitions” (Mitchell *et al.*, 1997).
- *Urgency*. “The degree to which stakeholder claims call for immediate attention.”

3.3.2. Graphical illustration of defined attributes and stakeholder categories

Based on the previous three defined attributes, Mitchell *et al.* (1997) provide a graphical illustration, shown in figure 37, which includes seven main stakeholder categories. The categories are defined by which of the three attributes they possess.

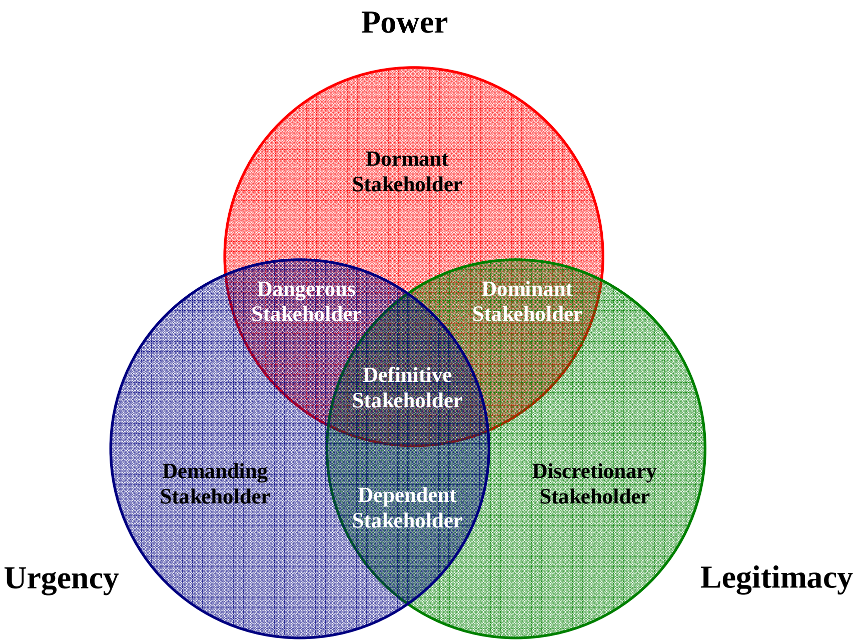

Figure 37 Graphical illustration of stakeholder attributes and categories as described by Mitchell *et al.* (1997). (Source: Adapted from Mitchell *et al.*, 1997)

For the issue at hand, the following definitions hold (adapted from Mitchell *et al.*, 1997):

- *Dormant Stakeholders* have the power to affect the issue but no urgency or legitimacy, and therefore no reason to engage in its resolution.
- *Demanding Stakeholders,* who urgently want to affect the issue but have no power or legitimacy, "are the mosquitoes buzzing in the ears" (Mitchell *et al.*, 1997) and warrant no attention from other stakeholders.
- *Discretionary Stakeholders* have the legitimacy to affect the issue but no power or urgency, and are simply recipients of any outcome.
- *Dangerous Stakeholders,* who have the power and urgently want to affect the issue but have no legitimacy, can be coercive and harmful to its resolution.
- *Dependent Stakeholders* have the legitimacy and urgently want to affect the issue but no power and depend on others to resolve it.
- *Dominant Stakeholders* have the power and legitimacy to affect the issue but no urgency. "They may or may not ever choose to act on their claims" (Mitchell *et al.*, 1997).
- *Definitive Stakeholders* possess all the attributes and are central to the issues resolution.

3.3.3. Analysis of potential stakeholders and results

This section presents the result of the analysis according to Mitchell *et al.* (1997) followed by a short discussion, particularly on potentially controversial categorisations. A full presentation of the analysis of every potential stakeholder is outside the scope of this thesis.

All of the potential stakeholders linked to Private and public corporations and employers, except Customers, have been categorised as definitive stakeholders. They have legitimacy and urgently want to affect the issue by definition of the issue itself. Subsequent chapters will show that they also have power. Customers have not been categorised as a stakeholder as they do not possess any of the stakeholder attributes.

University management and faculty have been categorised as definitive stakeholders as they have legitimacy and urgently want to affect the issue, for reasons previously described in 3.3.3, and subsequent chapters will show that they also have power. The remainder of the potential stakeholders linked to Universities have been categorised as dominant stakeholders as they lack urgency.

All of the potential stakeholders linked to Legislators have been categorised as definitive stakeholders as they have power and legitimacy by definition, and as they have urgency for reasons previously described in 3.3.3.

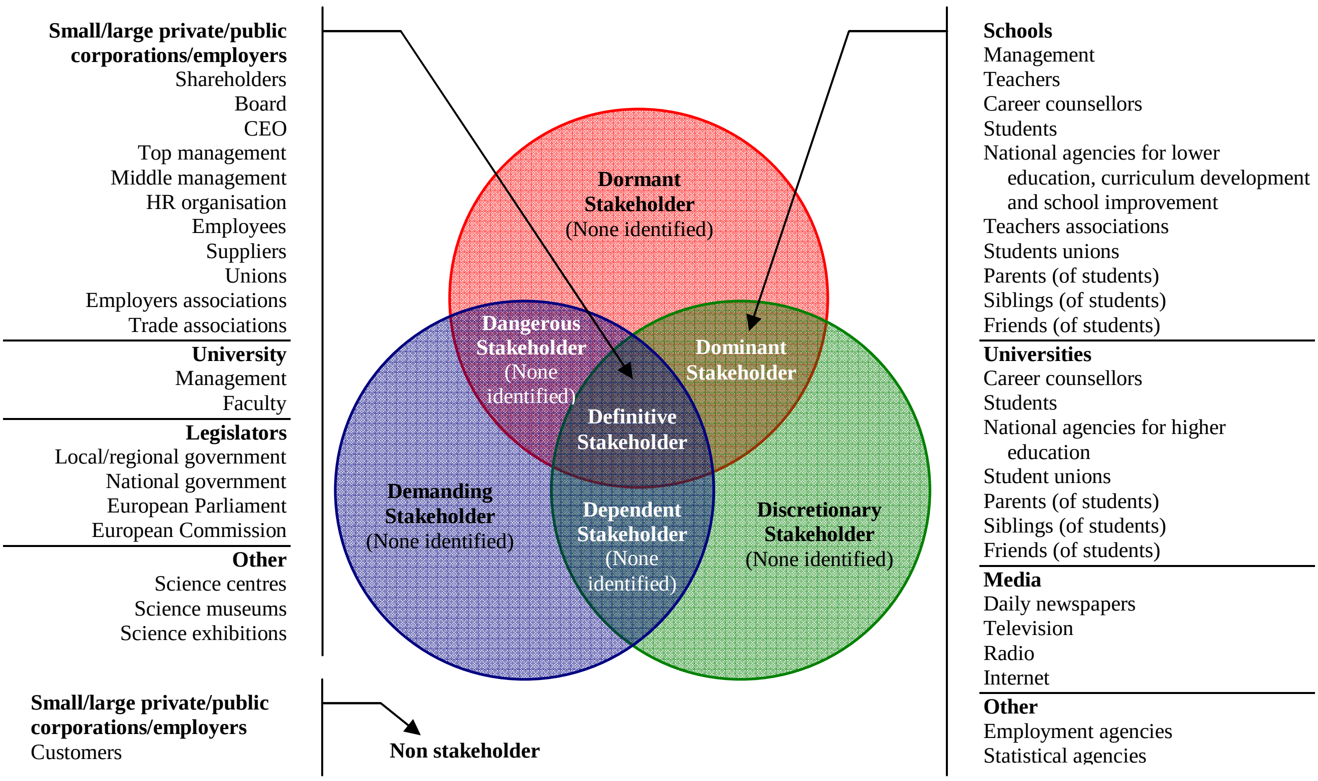

Figure 38 Graphical result of stakeholder categorisation. (Source: Adapted from Mitchell *et al.*, 1997)

Science centres, museums and exhibitions have been defined as definitive stakeholders for reasons previously described in 3.3.3.

All of the potential stakeholders linked to Schools and Media as well as Employment agencies and Statistical agencies have been categorised as dominant stakeholders as they lack urgency for reasons previously described in 3.3.3.

3.4. Conclusions

The issue is complex and engages many stakeholders of various categories. However, it is interesting to note that the methods of Fassin (2009) and Mitchell *et al.* (1997) both identify the following four stakeholder groups:

- Private and public corporations and employers
- University management and faculty
- Legislators
- Science centres, museums and exhibitions

The fact that Schools are stakewatchers and not stakeholders, according to the methods of Fassin (2009), and dominant stakeholders and not definitive stakeholders, according to the methods of Mitchell *et al.* (1997), is critical as will be shown in subsequent chapters.

4. What is causing the problem and who could be doing something about it?

While negative demographic trends clearly have had and will have negative impact on the absolute supply of human resources for maths, science and technology, an analysis of causes of the same lies outside the scope of this thesis. This chapter focuses on the other major issue with negative impact: the proportional decline in choice of maths, science and technology education.

Backtracking from right to left through figure 39 below, it is the decision to choose and the choice of maths, science and technology education as such that is of interest. While chapter 2 measured structural choice, determined by application to the various stages of Europe's education systems, emotional choice, i.e. intended structural choice, is made earlier and must also be taken into account. But what is it that determines structural and emotional choice? What is causing the proportional decline in choice of MST education, and who could be doing something about it? Measured attitudes are an indicator of emotional choice, and therefore research into student attitudes to MST as such, MST education and MST careers will be drawn upon in the analysis. However, measured attitudes, conscious or unconscious, are externally triggered responses to predetermined questions and do not necessarily exhibit a one-to-one relationship to choice itself. Finally, attitudes are, in turn, seen to a large degree as being the result of influence from influencers. So who are the influencers and how are they influencing choice?

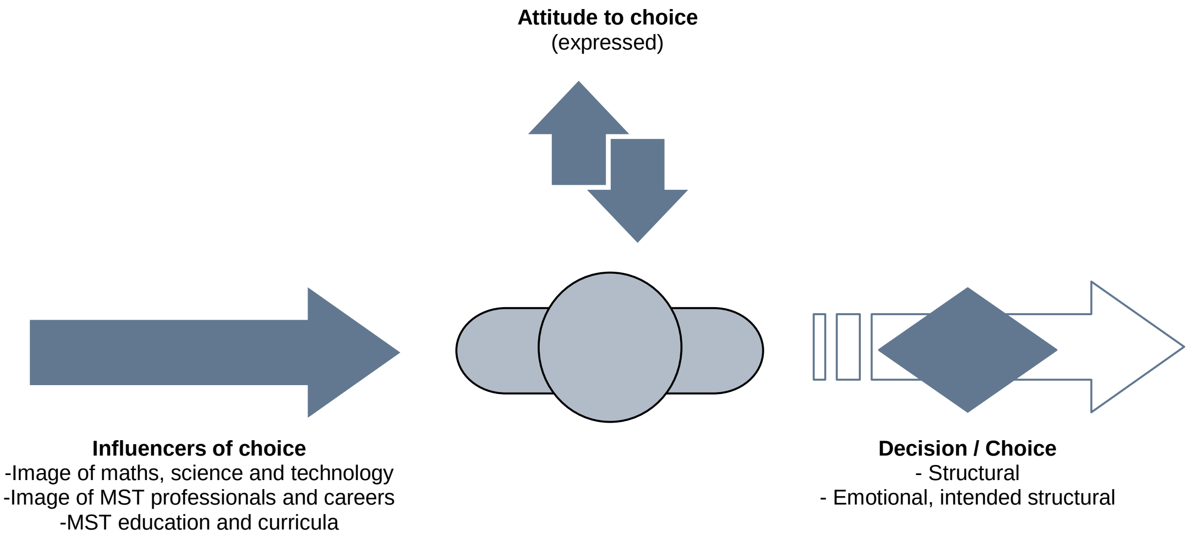

Figure 39

4.1. Method

The link between influencers of choice and choice itself is explored based on a review of well-cited literature. This is done under three headings corresponding to three of the five groups of factors influencing student choice identified by OECD (2008c): (1) image of maths, science and technology, (2) image of MST professionals and careers and (3) MST education and curricula. The fourth group, (4) teacher training, qualification and development, is addressed within the framework of the first three. The fifth group, (5) gender and minorities, is split. Gender will be handled separately as an important transversal issue running through the first three as well as within the framework of the first three. Minorities will be addressed within the framework of the first three. Although three of OECD's (2008c) headings are used, it is important to note that the review under each heading is based on multiple sources and not necessarily in line with the views expressed by OECD (2008c).

Following the review under each heading, recommendations targeted at stakeholders as identified in chapter 3, neglecting their *incentive* to react, are put forward as conclusions based on the analysis. Finally, the recommendations will be summed up and discussed at the end of the chapter.

4.2. Observations of modern youth

First of all, a few observations of modern youth are presented as critical to the subsequent analysis.

4.2.1. Young people's identity construction

The researchers behind ROSE (see section 2.5), Schreiner and Sjøberg (2007), argue that young peoples' educational choices are an important part of their identity construction. Whereas identities in pre-modern societies were perceived to be handed out or ascribed on the basis of factors such as social status, modern societies emphasise the individual's independence and responsibility to develop her identity herself, through her own personal choices (Giddens, 1991, and Côté, 1996, in Schreiner and Sjøberg, 2007). Every choice made and action taken in public can be interpreted as a sign of one's identity including school attainment, subject preferences and classroom behaviour (Goffman, 1959; *and* Lyng, 2004; *in* Schreiner and Sjøberg, 2007). In addition, Schreiner and Sjøberg (2007) refer to Frøsnes (1998) stating that "…signs of what one is not, are just as important as signs of what one is". The question 'What do you want to be when you grow up?' is no longer relevant. Instead young people are concerned about *who* they want to be when they grow up.

4.2.2. Age

Another observation that is important to bear in mind when reading the following sections is that research shows that young people aged 13-15 have already formed attitudes towards science education. This suggests that any attempt to influence these attitudes should start much earlier (Osborne and Dillon, 2008 and OECD, 2008c).

4.3. Factor 1: Image of maths, science and technology

4.3.1. Science and technology needs are perceived to be fulfilled

Problem

What is the problem?

Although ROSE findings show that young people all over the world find science and technology interesting and recognise science and technology as important to society and societal development, they also indicate that young people in the western world perceive the need for *new* science and technology as fulfilled.

Schreiner and Sjøberg (2007) suggest:

> "Is it possible that young people associate the task of these professions [science and technology professions, *my interpretation*] with the development of even broader bridges, even faster aircraft, newer techniques for pumping up oil, even smaller mobile phones and even faster computers with even larger storage capacities? Is it possible that young people, in particular girls, believe that today's health and environment problems overshadow the worries we may have about to 'slow' aircraft, computers' 'poor' storage capacity and 'limited' access to fossil fuels?"

The analogy with Maslow's hierarchy of needs is clear. Science and technology is seen as interesting and important to society and societal development, but because society is seen as already sufficiently served with science and technology – i.e. Apple already manufactures iPhones, the Volvo Group already manufactures trucks etc. – and scientifically and technologically fully developed – i.e. only the fine-tuning of aircraft etc. remain – science and technology is not meaningful to the young individual in the developed world. Schreiner and Sjøberg (2007) conclude that "it might be that we have now passed the era in which the work of physicists, technicians and engineers is seen as crucial to people's lives and well-being". Instead, young people are turning to education and careers higher up the hierarchy. Which these are and why they are higher up the hierarchy is outside the scope of this thesis. Nevertheless, young people need to know that their choice of education will make it possible for them to build a career that they find important and meaningful. This observation of modern youth is fundamental and supported by a growing body of research. It will be addressed again in the following sections on the image of MST professionals and careers and MST education and curricula.

Who is causing the problem?

The following stakeholders, stakewatchers and stakekeepers, described in chapter 3, are the main contributors to the problem, as they all play a key role in communicating what today's science and technology is about:

– Small/large private/public corporations/employers (stakeholder)
– University management and faculty (stakeholder)
– Legislators (stakeholder)
– Schools (stakekeeper)
– Media (stakekeeper)

Recommendations

Suggestions in the literature

Schreiner and Sjøberg (2007) suggest changing the image of science and technology by communicating an interpretation of science and technology more attuned to young people's values:

> "In addition to computers and oil pumps, the physicist and the engineer develop methods for utilising alternative energy sources, they develop technologies for eliminating landmines, create methods for more animal friendly fuel production, devise solutions for protection against deadly weapons, invent new instruments for treating diseases and so on."

My recommendations

Corporations & Employers **Universities**	- Communicate the relevance of *your* MST to *further* societal development as well as how MST fits in with young people's values and concerns through the internet, television, newspapers, radio, in the class room etc. (As an example, the Volvo Group could communicate the relevance of its products in ensuring vital societal functions such at the distribution of provisions and the linked importance of developing sustainable technologies.)

Legislators	- Encourage and fund communication of the relevance of MST to *further* societal development as well as how MST fits in with young people's values and concerns through the internet, television, newspapers, radio, in the class room etc.

4.3.2. Certain specialisations may be perceived as a potential threat to society

Problem

What is causing the problem?

Somewhat at odds to the above, some argue that young people might be turning away from science and technology as they blame science and technology for negative impact on society such as climate change. However, this is largely contradicted by the literature. OECD (2008c) brings up additional perceived potential threats to society such as genetic modification of plants and animals, cloning, stem cell research, animal testing and surveillance systems, but also concludes that “Science and technology are considered important for society and its evolution, despite concerns in specific areas, often linked to negative environmental and social consequences of science and technology”. Schreiner and Sjøberg (2007) conclude that “modern youth are relatively positive to the influence of science and technology on society”. Thus, although science and technology in specific specialisations might be perceived as a potential threat to society, science and technology in general is not.

Who is causing the problem?

The following stakeholders, stakewatchers and stakekeepers, described in chapter 3, limited to those linked to the specialisations such as those singled out above, are the main contributors causing the potential problem, as they all play a key role in communicating what the specialisations are about:

- Small/large private/public corporations/employers (stakeholder)
- University management and faculty (stakeholder)
- Legislators (stakeholder)
- Media (stakekeeper)

Recommendations

None.

4.4. Factor 2: Image of MST professionals and careers

In assessing the image of MST professionals and careers, it is important to note that a majority (60%) of the population in Europe primarily acquires their perceptions of MST professionals from television, and a large part of the remaining population acquires them from newspapers, magazines and the internet. Moreover, OECD (2008c) argues that most of the stories are inaccurate and communicate negative values. The report goes so far as to say that “Scientific ignorance among the media and public impoverishes debate about serious choices facing society”. The same might be said about the entertainment industry.

4.4.1. Jobs not perceived to be meaningful

Problem

OECD (2008c) states that "there is a sharp difference between the positive opinion of young people towards science and technology and their actual wish to pursue science and technology careers". Young people in the western world do not perceive jobs in science and technology as meaningful to them, for reasons previously described in section 4.2.1.

Recommendations

Suggestions in the literature

Among the solutions offered by the literature, Osborne and Dillon (2008) state that school science "needs to offer a better idea of … why these careers [science and technology careers, *author's interpretation*] are valuable, worthwhile and rewarding."

My recommendations

Corporations & Employers **Universities**	- Communicate why *your* science and technology careers are valuable, worthwhile and rewarding (e.g. through the internet, television, newspapers, radio, in the class room etc.)

Legislators	- Task schools with communicating why science and technology careers are valuable, worthwhile and rewarding in and around the class room - Task education agencies with following up

4.4.2. Lack of attractive role models

Problem

What is causing the problem?

Many studies indicate that young people, especially girls, in *developed countries* lack *attractive* role models in MST professions and that this is turning them away from MST careers. As opposed to their counterparts in the developing world, they have a negative stereotyped perception of a scientist "…that swings between two visions of a man in a white lab coat staring intelligently at some exotic glassware full of scientific-looking liquid, or of a wild-haired eccentric solving mile-long equations but incapable of posting a letter" (*citation* OECD, 2008c). Schreiner and Sjøberg (2007) suggest that they "…do not want to have an identity that is seen to be connected with being a physicist or an engineer".

OECD (2008c) refers to a study among students who chose to leave science and technology studies conducted by Seymour and Hewitt (1997) stating that

> "They [the students, *my interpretation*] portrayed engineers, especially, as dull, unsociable (often materialistic) people who lacked a personal or social life and were unable to relate comfortably to non-engineers. They were also portrayed as uncreative people, who avoided or decried the idea of a broader education".

In developing countries, young people have a positive perception of scientists, often seeing them as heroes in society (OECD, 2008c, and Schreiner and Sjøberg, 2007).

Who is causing the problem?

The following stakeholders, stakewatchers and stakekeepers, described in chapter 3, are the main contributors to the problem, as they all act as or play a key role in communicating attractive role models:

– Small/large private/public corporations/employers (stakeholder)
– University management and faculty (stakeholder)
– Media (stakekeeper)

Recommendations

Suggestions in the literature

Role models such as professional contacts and family members working in science and technology have a positive impact on student choice of science and technology (OECD, 2008c). OECD (2008c) states that "… as much as parents, teachers or friends, what influences them in their career choice is meeting real people working in the considered fields or professions". Many studies argue that more should be done to provide students with role models in MST professions.

My recommendations

Corporations & Employers **Universities**	- Provide role models inside and outside school attuned to young people's values and concerns - Work for the provision of role models in media

Legislators	- Task schools with integrating provision of role models into science and technology education - Task education agencies with following up

4.4.3. Lack of information and understanding of careers

What is the problem?

OECD (2008c) makes the points that “few people have an accurate understanding of science-related professions, and many are largely unaware of the range of career opportunities opened up by science and technology studies” and that “positive decisions to pursue science and technology studies and careers are often linked to better knowledge.”

Although this is a wider problem, the literature often addresses the specific role of careers advisors and teachers in school. Careers advisors are failing to inform students of the range and interest of professions science and technology studies can lead to, hindering them from making informed choices (OECD, 2008c). OECD (2008c) refer to Munro and Elsom (2000) stating that “… science and technology teachers sometimes are reluctant to advise their students about science and technology, afraid they do not have enough information and might give wrong advice”.

Who is causing the problem?

The following stakeholders, stakewatchers and stakekeepers, described in chapter 3, are the main contributors to the problem, as they all play a key role in communicating career information:

– Small/large private/public corporations/employers (stakeholder)
– University management and faculty (stakeholder)
– Schools (stakekeeper)
– Media (stakekeeper)

Recommendation

Suggestions in the literature

OECD (2008c) is comparatively expressive in its suggestions, stating that

> “The education system can do nothing about working conditions and career prospects in most science and technology professions, but it can make sure that students have access to information about science and technology careers that is accurate, credible, and avoids unrealistic or exaggerated portrayals, either negative or positive. This information should

be compiled by independent observers, and made available to the education community, parents and students. Better information on science and technology jobs should also be provided through direct contacts with professionals, and governments should earmark resources for such outreach actions, and for assessing their effectiveness."

and that

"One way to encourage greater participation could thus be to provide the various persons who advise students on choices of study and career with specific training in what science and technology has to offer. Apart from careers and orientation professionals (and of course the students), this effort should be extended to student's parents or carers."

My recommendations

Corporations & Employers **Universities**	- Work with schools to provide students, teachers, careers advisors and parents with accurate career information

Legislators	- Task schools to work with corporations and employers to provide students, teachers, careers advisors and parents with accurate career information - Task education agencies with following up

4.4.4. Job market perceived as unstable

Problem

What is causing the problem?

Gago *et al.* (2004), a report from the European Commission High Level Group on Human Resources for Science and Technology in Europe, and OECD (2008c) argue that young people may perceive the science and technology job market as unstable, with regular and significant lay-offs scaring them away from MST careers.

Although "unstable" may be a true description for individual business sectors in MST with cyclical or fading markets, somewhat to the contrary, chapter 2 makes the case that the total demand for human resources in MST is likely to increase in the future while supply is likely to lag behind. Thus, the description "unstable" does not appear to be true for the MST job market as a whole. In addition, MST job market stability in relation to other job markets has not been sufficiently investigated. It may very well be that the job market in MST is more stable than other job markets. Nevertheless, all parties would benefit from accurate job market information being made available and actively communicated.

Who is causing the problem?

The following stakeholders, stakewatchers and stakekeepers, described in chapter 3, are the main contributors to the problem, as they all act as or play a key role in communicating status of the job market:

– Small/large private/public corporations/employers (stakeholder)
– University management and faculty (stakeholder)
– Employment agencies (stakekeeper)
– Statistical agencies (stakekeeper)
– Media (stakekeeper)

Recommendations

My recommendations

Corporations & Employers / **Universities**	- Work with employment agencies and statistical agencies to improve information about the job market

Legislators	- Task employment agencies and statistical agencies to work with corporations and employers to improve information about the job market

4.4.5. Careers perceived as unattractive

Problem

What is causing the problem?

According to some reports referring to average salaries and job satisfaction rates, science and technology careers are perceived as unattractive. OECD (2008c) states that incomes are perceived as "…low relative to the amount of work involved and the difficulty of the required studies".

However, perception and reality do not appear to converge. According to Gago *et al.* (2004), “on the whole, the science, engineering and technology workforce is adequately, but not handsomely paid”. The report refers, inter alia, to a study by the Engineering Council (2004) in the United Kingdom stating that “first-time graduates with engineering qualifications are among the best paid of all professions, bettered only by those in law and clinical dentistry.” In addition, Gago *et al.* (2004) concludes that “… there is a high level of satisfaction within the science, engineering and technology career structure”. Gago *et al.* (2004) go on to argue that “much should be made of these facts to counter the general public’s perception that science, engineering and technology workers are poorly paid”.

However, the issue of salaries is perhaps not as simple as portrayed above. At the 2009 annual conference of Société Européenne pour la Formation des Ingénieurs (European Society for Engineering Education) with the theme ‘Attracting young people to engineering’, Dr Frank Stefan Becker of Siemens’ department Corporate Communications and Government Affairs presented an alternative perspective. Becker (2009) argues that it is not the average salaries of engineers that are the problem. Instead, the problem is an engineer’s *absent* prospect of earning a huge amount of money and becoming famous and a hero in society. Becker (2009) states that “we live in a media-dominated ‘jackpot society’ in which the apparent success of a few – albeit highly unlikely – ‘winners’ motivates considerably more young people to invest in such ‘lottery ticket careers’ than in less thrilling, but more secure alternatives”.

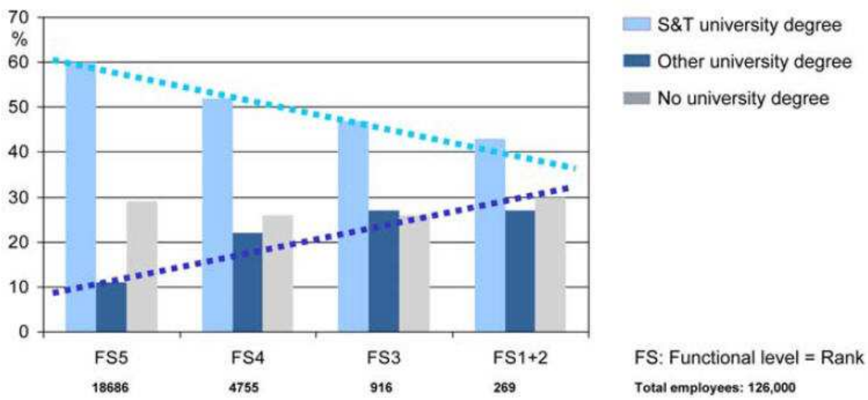

Figure 40 The educational background of managers at Siemens
(Source: Becker, 2009)

Becker (2009) also presents a case study of the educational background of managers at Siemens relative to their position in the company hierarchy. The result, displayed in figure 40, shows that the higher up the company hierarchy you look, the smaller the proportion of managers with a science and technology university degree. Meanwhile, the opposite is true for managers with other university degrees. Becker (2009) argues that career opportunities for those with science and technology degrees are thus inferior to career opportunities for those with other degrees.

I have not been able to find any similar studies, but the relationship between the educational background of managers and career opportunities at other maths-, science- and technology-intensive corporations appears important to look into.

Who is causing the problem?

The following stakeholders, stakewatchers and stakekeepers, described in chapter 3, are the main contributors to the problem, as they all act as or play a key role in communicating job satisfaction:

– Small/large private/public corporations/employers (stakeholder)
– Employers associations (stakewatcher)
– Unions (stakewatcher)
– University management and faculty (stakeholder)
– Employment agencies (stakekeeper)
– Statistical agencies (stakekeeper)
– Media (stakekeeper)

Recommendations

My recommendations

Corporations & Employers **Universities**	- Communicate salaries and job satisfaction rates - Investigate the relationship between the educational background of *your* managers and *their* career opportunities

4.5. Factor 3: MST education and curriculum

4.5.1. Education is not seen as meaningful and does not sufficiently address students' values and concerns

Problem

What is the problem?

Young people in the western world do not perceive education in science and technology as meaningful to them, for reasons previously described in section 4.3.1. OECD (2008c) states that "motivation seems to depend on the perception they have [students have, *author's interpretation*] of the subject's relevance to their own life and society". In addition, many argue that science and technology education does not sufficiently address student's values and concerns.

Who is causing the problem?

The following stakeholders, stakewatchers and stakekeepers, described in chapter 3, are the main contributors to the problem, as they all act as or play a key role in the above:

- Small/large private/public corporations/employers (stakeholder)
- Universities (stakeholder)
- School (stakekeeper)

Recommendations

Suggestions in the literature

OECD (2008c) states that "… the relevance of science and technology to students' concerns should be a central part of how science is taught and represented, not an optional extra brought in occasionally to try to boost flagging interest" and refers to a study of Finnish ninth-grade students conducted by Lavonen *et al.* (2005) suggesting:

> "Students wish most of all to increase the number of visits to places of interest and the use of experts in teaching. Guest speakers and educational visits provide a starting point that is more natural than traditional learning materials for becoming acquainted with the applications of scientific information, and show the applications of science beyond school."

Johansson and Mouwitz (2007) emphasises the need to "support and develop activities to increase interest in and provide greater insight into the value, role and significance of mathematics in everyday and working life, science and society."

Schreiner and Sjøberg (2007) suggests:

> "If young people are not concerned about further national economic growth, but desire an identity that is coherent with the late-modern post-material values, then school science could demonstrate to students that science and technology subjects play a crucial role in accomplishing exactly these values."

Osborne and Dillon (2008) suggests:

> "School science has done little to consider how it might appeal to the values and ideals of contemporary youth and their culture. Hence, our view is that what school science requires is a new vision of why an education in science matters that is widely shared by teachers, schools and society."

My recommendations

Corporations & Employers **Universities**	- Work with schools to provide meaningful life and career contexts attuned to young people's values and concerns, and to provide professional contacts

Legislators	- Task schools with working with corporations, employers and universities to incorporate meaningful life and career contexts attuned to young people's values and concerns, and professional contacts into maths, science and technology education - Task schools and education agencies with developing a new vision of why education in maths, science and technology matters, and with ensuring that this vision is widely shared by teachers, schools and society and is relevant to young people's values and concerns

4.5.2. Pedagogical innovation required

Problem

What is the problem?

Rocard *et al.* (2007), a report from the European Commission's High Level Expert Group on Science Education Renewal, argues that pedagogical innovation is required, stating that "in most European countries, science teaching methods are essentially deductive" and that "a reversal of school's science from mainly deductive to inquiry-based methods provides the means to increase the interest in science". Osborne and Dillon (2008) supports this conclusion, stating:

> "An accumulating body of research shows that the pedagogy in school science is one that is dominated by a conduit metaphor, where knowledge is seen as a commodity to be transmitted. For instance, teachers will speak of trying to 'get across' ideas or that students 'didn't get it.' In this mode, writing in school science rarely transcends the copying of information from the board to the students' notebook. … Research would suggest that this limited range of pedagogy is one reason why students disengage with science – particularly girls."

Who is causing the problem?

The following stakeholders, stakewatchers and stakekeepers, described in chapter 3, are the main contributors to the problem, as they play a key role in the above:

- School (stakekeeper)
- Education agencies

Recommendations

My recommendations

Legislators	- Task schools with implementing inquiry-based science education - Task education agencies with supporting the implementation of inquiry-based education and following it up

4.5.3. Teachers ill-equipped

Problem

What is the problem?

The literature indicates that many teachers are ill-equipped to educate young people in maths, science and technology. OECD (2008c) states that "… many science teachers do not come from a science and technology background and may have received little or no training in science and technology subjects" and that "teachers' initial and further training, as well as their intrinsic motivation to teach, have an impact on teaching quality, but also on the motivational factors that influence student attitudes to science and technology studies".

OECD (2008c) goes on to say that:

> "… a majority of those studying physical sciences in secondary education and over a quarter of those studying mathematics are educated by teachers who do not have any formal qualification in these subjects. Even qualified, experienced teachers may have insufficient knowledge of developments in such a fast-moving domain. Continuous training is often lacking or does not focus on theoretical subject content. As a result, many science and technology teachers may need knowledge updating and may not be at ease with the latest science and technology developments. And yet, the latest science and technology developments are precisely what interest most young people."

Osborne and Dillon (2008) state that "good quality teachers, with up-to-date knowledge and skills, are the foundation of any system of formal science education" and that "there is considerable evidence that recruiting teachers of science of the highest quality in many countries is either problematic, or is likely to become problematic in the coming decade."

Also Johansson and Mouwitz (2007) state that "the situation of and conditions for teachers are the most important issue", and emphasise the need to "train qualified teachers in mathematics on all levels for children, young people and adults".

Who is causing the problem?

The following stakeholders, stakewatchers and stakekeepers, described in chapter 3, are the main contributors to the problem, as they all act as or play a key role in the above:

- Small/large private/public corporations/employers (stakeholder)
- Universities (stakeholder)
- Universities *educating teachers* (stakekeeper)
- School (stakekeeper)

Recommendations

My recommendations

Corporations & Employers **Universities**	- Work with schools conducting in-service training of MST teachers and universities educating MST teachers to ensure inclusion of tuition in new scientific and technological developments, and in how MST is relevant to *your* organisation and *future* societal development

Legislators	- Task schools with conducting in-service training of non-MST-educated MST teachers to substantially raise their proficiency in MST subjects, or with replacing non-MST-educated MST teachers with teachers who are MST-educated - Task schools with working with corporations and universities to implement frequent in-service training of MST teachers on new scientific and technological developments and how MST is relevant to working life and *future* societal development - Task universities educating MST teachers to work with corporations and other universities to ensure inclusion of tuition on new scientific and technological developments and how MST is relevant to working life and *future* societal development - Take action to increase interest in MST teacher education

4.6. Gender

The statistics presented in chapter 2 on choice of MST education and attitudes to education and careers in MST, as well as the literature previously reviewed in this chapter, have revealed large gender differences. The gender aspects of current challenges in MST education are critical for societal development in a broad sense, and many argue that it is among girls and women that the largest potential to increase interest in MST education and careers exists. The gender aspects are in themselves a subject for a separate thesis. However, the following brief and general discussion based on the reviewed literature aims to shed at least some light on the issue.

4.6.1. A historic perspective

What is feminine and what is masculine, or what is socially accepted as being ‘for women’ or ‘for men’ is defined by society and has been shaped by countless previous generations. Science in its youth, in the Renaissance period, was the domain of both women and men. As Science grew and was accepted into the world of Universities, women were gradually excluded by men who created norms and official rules for scientific communication that made it impossible for women to participate. Political, moral, ethical and emotional representations of science, those traditionally perceived as feminine, were gradually deemed irrelevant and invalid. There is also a strong connection to the Catholic tradition of a male-only priesthood excluding women, particularly from mathematics and its associated sciences. Scientific terminology evolved with examples of gender discrimination; nature is often spoken of as female, while science is spoken of as male with controlling and manipulative attributes. Prestigious European Academies of Science excluded women up until recently (Sjøberg, 2004, Wertheim, 1997, Wertheim, 2006, and Schiebinger, 1989, in Sjøberg, 2004).

4.6.2. Today – five hundred years later!

Science is still clearly the domain of men, and the removal of women from this domain is even seen as natural by many, including both men and women (Sjøberg, 2004). Students and teachers, like other women and men, are part of society and share the same perceptions of MST and the stereotypical view of people in MST. Thus, it is perhaps not surprising that girls in the industrialised world are less interested than boys in MST education and careers. Changing this in the short term would require nothing less than a cultural revolution. Not changing it as soon as it is possible would be a catastrophic loss for humanity.

4.6.3. What to do?

The gender aspects are transversal and need to be given attention in <u>every</u> attempt to increase interest in MST education and careers. This includes <u>all of the recommendations</u> presented in sections 4.2-4.5.

Recommendations

Suggestions in the literature

OECD (2008) indicates that a good place to start is in science communication, including adapting pedagogy and school textbooks, e.g. by removing stereotyped images of MST.

My recommendations

In addition to the transversal gender aspects in all previous recommendations, I recommend the following as first steps:

Corporations & Employers **Universities**	- Promote female colleagues as role models in all external communication including employer branding. A considerable predominance of women in all external communication over a long period of time will undoubtedly be necessary in order to achieve gender balance in the long term. - Step up efforts to ensure equal opportunities between women and men in the employee offering. Consider promoting inequality in favour of women over a period of time in order to achieve equality in the long term.

Legislators	- Ban gender-stereotypical pedagogy and school textbooks - Task education agencies with following up this ban on gender-stereotypical pedagogy and school textbooks, and with supporting the implementation of non-gender-stereotypical pedagogy and school textbooks

4.7. Conclusions

This chapter has presented the main factors behind the proportional decline in choice of MST education, identified who is at fault and put forward recommendations on stakeholder action. It has also highlighted that gender aspects need to be given attention in every attempt to increase interest in MST education and careers. However, it has not been possible to determine the relative importance of the recommended actions.

The recommendations from sections 4.3-4.5 have been collected in a table on the next page. They need to be concretised at national and local levels along with carefully prepared implementation plans. Simplistic top-down decisions will not suffice, and are in many cases not even possible due to prevailing governance structures. The complex cultural differences between the worlds of schools, universities, legislators and corporations need to be handled with respect but overcome. Innovative funding streams enabling the commitment of relevant stakeholders, stakewatchers and stakekeepers need to be put in place.

		Corporations & Employers / Universities	Legislators
Image of maths, science and technology	**Science and technology needs are perceived to be fulfilled**	- Communicate the relevance of *your* MST to *further* societal development as well as how MST fits in with young people's values and concerns through the internet, television, newspapers, radio, in the class room etc. (As an example, the Volvo Group could communicate the relevance of its products in ensuring vital societal functions such at the distribution of provisions and the linked importance of developing sustainable technologies.)	- Encourage and fund communication of the relevance of MST to *further* societal development as well as how MST fits in with young people's values and concerns through the internet, television, newspapers, radio, in the class room etc.
	Certain specialisations may be perceived as a potential threat to society	N/A	N/A
Image of MST professionals and careers	**Jobs not perceived to be meaningful**	- Communicate why *your* science and technology careers are valuable, worthwhile and rewarding (e.g. through the internet, television, newspapers, radio, in the class room etc.)	- Task schools with communicating why science and technology careers are valuable, worthwhile and rewarding in and around the class room - Task education agencies with following up
	Lack of attractive role models	- Provide role models inside and outside school, attuned to young people's values and concerns - Work for the provision of role models in media	- Task schools with integrating provision of role models into science and technology education - Task education agencies with following up
	Lack of information and understanding of careers	- Work with schools to provide students, teachers, careers advisors and parents with accurate career information	- Task schools to work with corporations and employers to provide students, teachers, careers advisors and parents with accurate career information - Task education agencies with following up
	Job market perceived as unstable	- Work with employment agencies and statistical agencies to improve information about the job market	- Task employment agencies and statistical agencies with working with corporations and employers to improve information about the job market
	Careers perceived as unattractive	- Communicate salaries and job satisfaction rates - Investigate the relationship between the educational background of *your* managers and *their* career opportunities	N/A
MST education and curriculum	**Education is not seen as meaningful and does not sufficiently address students' values and concerns**	- Work with schools to provide meaningful life and career contexts attuned to young people's values and concerns, and to provide professional contacts	- Task schools with working with corporations, employers and universities to incorporate meaningful life and career contexts attuned to young people's values and concerns, and professional contacts into maths, science and technology education - Task schools and education agencies with developing a new vision of why education in maths, science and technology matters, and with ensuring that this vision is widely shared by teachers, schools and society and is relevant to young people's values and concerns
	Pedagogical innovation is required	N/A	- Task schools with implementing inquiry-based science education - Task education agencies with supporting the implementation of inquiry-based education and following it up
	Teachers are ill-equipped	- Work with schools conducting in-service training of MST teachers and universities educating MST teachers to ensure inclusion of tuition in new scientific and technological developments, and in how MST is relevant to your organisation and future societal development	- Task schools with conducting in-service training of non-MST-educated MST teachers to substantially raise their proficiency in MST subjects, or with replacing non-MST-educated MST teachers with teachers who are MST-educated - Task schools with working with corporations and universities to implement frequent in-service training of MST teachers in new scientific and technological developments, and in how MST is relevant to working life and *future* societal development *(See page 53 for two additional items)*

5. Current attempts to address the problem

This chapter aims to provide a brief overview of current attempts to address the problem and thereby the means to align possible subsequent proposals on corporate investment to increase maths, science and technology with ongoing activities across Europe – the ambition being to optimise the theoretical rate of return on any such investment. This will be done based on a literature review.

5.1. Conducted inquiries into current efforts

It is evident from the literature that many thousands of projects and initiatives targeting an increased interest in maths, science and technology education and careers exist across Europe. However, most of them are of relatively small scale, reaching out only to local youth, and most depend on the commitment of individual or small groups of enthusiasts. The latter is true regardless of whether or not the project or initiative is supported by a larger organisation.

5.1.1. Mappings of projects and initiatives

Despite the large number of references to projects and initiatives in the literature, no published, European-wide mappings of the same exist. However, Rocard *et al.* (2007) conducted an analysis of a selection of European projects and initiatives identifying two, Pollen and Sinus-Transfer, as particularly innovative and promising. (Pollen will be presented briefly in section 5.2.) In addition, the report Technopolis (European Commission, 2007) identifies 56 projects and initiatives across Europe within the limited scope of science mentoring and science ambassador schemes.

National mappings exist to some extent, but many are incomplete. Undoubtedly, one of the more extensive published mappings is the MoMoTech *(Monitoring von Motivationskonzepten für den Techniknachwuchs)* internet database, run by the German Academy of Science and Engineering and covering over one thousand projects and initiatives in Germany (MoMoTech, 2009). Teknikdelegationen (2009a) *Nyfiken på naturvetenskap och teknik*, a Swedish national mapping conducted by the government-appointed Teknikdelegationen (English translation: the Technology Delegation), is another. In Teknikdelegationen (2009a), 222 projects and initiatives are described and categorised into 59 with students as a primary target group, 58 where business participates, 7 events and festivals, 31 competitions, 16 science centres, 12 other centres and museums and 39 with teachers as a primary target group.

5.1.2. Cost and effect

In general, projects and initiatives aimed at increasing interest in maths, science and technology education and careers are poorly evaluated. However, many are, at least to some extent, able to show positive immediate effects on interest in maths, science and technology education and careers. Very few, the Jet-Net project, presented briefly in section 5.2, being one exception, are able to show that they have affected interest in the long term or subsequent choice of education or career. The former is often done by simply asking students to fill in a questionnaire describing an activity's effect on their interest immediately or soon after the activity is conducted. The latter is often due to difficulties in determining causality as well as the time-consuming nature of such an effort, but does not necessarily mean that they have not had a positive effect. Other projects and initiatives evaluate effect by proxy, e.g. by interviewing teachers on their perceptions of effects on interest in maths, science and technology education and careers. Some do not evaluate at all. The relationship between cost and effect of projects and initiatives is therefore difficult to investigate. In fact, no published comparative reports on the relationship between cost and effect have been found.

Similar conclusions are drawn specifically for science mentoring and science ambassador schemes by the European Commission (2007), conceding that the large majority "have failed to put in place a 'self evaluation' process allowing monitoring of the career paths chosen by children who have participated".

A Swedish report *Projekt utan effekt?* (English translation: *Projects with no effect?*) (Vetenskap och Allmänhet, 2007), looks into the evaluation of 26 Swedish projects and initiatives, also drawing conclusions analogous to the above. Although 65% of the analysed Swedish projects were evaluated, only 23% actually evaluated effects. The remaining 42% simply evaluated operational aspects of specific activities. None of the evaluations looked into the relationship between cost and effect.

Thus, when decisions are made on continuing an ongoing project or initiative, they are often based on gut feeling of success or, at best, available theoretical research on elements that are believed to lead to success. Decisions are typically not based on significant long term quantitative data.

5.1.3. Society is not learning from previous efforts

It is evident that society is not learning from previous efforts; perhaps it does not want to for fear of the efforts being exposed as unsuccessful. In addition to the lack of adequate evaluation, and despite common targets, projects and initiatives are not learning from and communicating with each other. This is something that is being identified as critical by a growing body of research and number of policymakers; school/business aspects are, in fact, the topic of a recent European Round Table of Industrialists proposal for a European Coordinating Body (see 5.5.3). For example:

OECD (2008c) states that

> "The actual impact of the various actions on both young people's attitudes and their choices of studies and careers is poorly evaluated, and communication between the various stakeholders is often inadequate. Follow-on actions need to engage all persons who are concerned by declining interest in science. A network of stakeholders (linking educational resource centres, the business community, science and technology education specialists, and student and teacher communities), should be established to share information on best practises between countries and the various communities involved."

Rocard *et al.* (2007) state that "Teachers are key players in the renewal of science education. Among other methods, being part of a network allows them to improve the quality of their teaching and supports their motivation" and that "The articulation between national activities and those funded at the European level must be improved…". Johansson and Mouwitz (2007) argue that there is a need to "support and coordinate all the positive forces promoting better mathematics learning and teaching".

5.2. Typography

Among the multitude of projects and initiatives aimed at increasing interest in maths, science and technology education and careers, three different types emerge and are described in this typography. A single project or initiative may very well belong to more than one type.

5.2.1. Adventure- or experience-oriented

Adventure- or experience-oriented projects and initiatives appear to be the most common type, encompassing both extensive operations such as science centres open to the public on a daily basis, and festivals and competitions reoccurring on a annual basis, as well as smaller one-off activities such as CSI murder investigation afternoons for students, explosive chemistry experiments in the classroom or science ambassador meetings with students. Although each of these deserve a more complex analysis in themselves, and some serve a purpose wider than increasing interest in maths, science and technology education and careers, one central feature common to all of them is to inspire, excite and enthuse young people about certain aspects of maths, science and technology.

5.2.2. Pedagogical renewal and teacher development

The second type that emerges is pedagogical renewal and pedagogical renewal through teacher development. This type encompasses projects equipping teachers with the necessary tools and know-how to move from deductive to inquiry-based science education, science mentoring schemes, tutoring and coaching of younger students by older students and competence development programmes for teachers. Again, each of these deserve a more complex analysis in themselves, and some serve a purpose wider than increasing interest in maths, science and technology education and careers. However, one central feature common to all of them is to innovate or complement current teaching methods. Two projects of this type have received so much attention in Europe that they are worth mentioning specifically: *Pollen* and *Intize*.

Pollen

Pollen promotes the use of inquiry-based science education through the provision of classroom resources and teacher training. Pollen is composed of 12 national partners: *Le Laboratoire de Didactique des Sciences Physiques* in Belgium, *Project 2000+* in Estonia, *La main à la pâte* in France, *Natlab* in Germany, *Apor Vilmos Katolikus Föiskola* in Hungary, *Consorzio Innovazione Formazione Ricerca Educativa* in Italy, *AMSTEL Institue* in the Netherlands, *Ciência Viva* in Portugal, *P.A.U. Education* in Spain, *University of Ljubljana* in Slovenia, *Naturvetenskap och teknik för alla* in Sweden and *the Regional Science Learning Centre from East Midlands* in the United Kingdom (Pollen, 2009).

Intize and XplainY

Intize provides upper secondary school students in Göteborg, Sweden, with free private maths tutoring with local university students acting as tutors and mentors. In a similar manner, upper secondary school students tutor secondary school students. Intize is part of a network of similar organisations elsewhere in Sweden and in Norway called XplainY (Intize, 2009).

5.2.3. Linking school subjects to “real” (working) life

The third type that emerges comprises projects and initiatives linking school subjects to “real” (working) life. Essentially, this encompasses school and business/employer collaboration through which school subjects are set into life and career contexts that are relevant and meaningful to students, through which role models are provided for students, and through which career information is provided for students, teachers and careers advisors. Six projects of this type have received so much attention in Europe that they are worth mentioning specifically: *Jet-Net* in the Netherlands, *Wissensfabrik* in Germany, *C.Génial* in France, *Science Team K* in Denmark, *Næringsliv i skolen* in Norway and *MATENA* in Sweden. Unless otherwise indicated below, the projects match the above generic profile well.

Jet-Net (Netherlands)

Jet-Net is a Dutch national platform for school and business collaboration created jointly by the Dutch government, schools and businesses in the Netherlands. The platform supports and stimulates the development of cooperation programmes between individual schools and companies (Jet-Net, 2009).

Wissensfabrik (Germany)

Wissensfabrik is a German umbrella organisation encompassing projects and initiatives aimed at improving education (mainly maths, science and technology) and entrepreneurship. Many projects are about providing locally adapted tools that assist teachers in reaching the targets set up by the curriculum (Wissensfabrik, 2009).

C.Génial (France)

C.Génial is a French foundation established by Areva, EADS, France Telecom, Schlumberger, Technip and SNCF (C.Génial, 2009).

Science Team K (Denmark)

Science Team K was a Danish collaborative effort in the years 2003-2007 between schools, businesses, and local government in the Danish Municipality of Kalundborg incorporating training of teachers, networking between institutions and support to new education equipment (Dansk Naturvidenskabsformidling, 2009).

Næringsliv i skolen (Norway)

Næringsliv i skolen is a Norwegian programme providing guest lessons, company visits, thematic projects, mentorships and shadowing days in formalised, legally binding, partnerships between schools and businesses. Activities are based on curriculum requirements and needs expressed by teachers. The formal agreements support long term commitment and continuity (Næringslivets hovedorganisasjon, 2009).

MATENA (Sweden)

MATENA is a Swedish programme being developed to encourage and support *effective* collaboration between schools and businesses. MATENA coordinators will act as intermediaries in local clusters of individual schools and companies wanting to develop their collaboration. Teachers will be offered training programmes on how to use business as a pedagogical tool in and around the classroom.

5.3. National strategies

A number of European countries have either developed or are developing national strategies for maths, science and technology education. The following are four prominent examples.

5.3.1. Denmark: National Centre for Science, Technology and Medical Education

A Danish government-appointed working group presented proposals for a Danish national strategy on science, technology and medical education in 2008. As a result, in November 2008 the Danish government allocated DKK 65 million over the period 2009-2012 for the establishment of a national centre for science, technology and medical education (Undervisningsministeriet, 2009).

The centre is currently being set up, and has been tasked with (Undervisningsministeriet, 2009):

- supporting the renewal of pedagogy and educational content
- developing in-service training for teachers
- creating better interaction between formal education and informal learning environments such as private and public companies, museums and science centres
- contributing to the creation of knowledge sharing networks for formal and informal educators so that their experience can be disseminated in a structured manner
- engaging in corresponding international knowledge sharing networks
- collecting and disseminating experiences from practice and research in science, technology and medical education

5.3.2. Netherlands: Platform Bèta Techniek

The Dutch government's national strategy for science and technology, *Deltaplan Science and Technology*, resulted in the creation of the *Platform Bèta Techniek* in 2004. The platform is an independent foundation funded by the government with EUR 60 million per year. Its target is to increase the number of MST graduates by 15% by 2010. Work is carried out according to performance-innovation agreements with schools who participate voluntarily. If the schools reach their targets, they receive grants to use as they choose (Platform Bèta Techniek, 2009).

To assist schools in reaching their targets, the platform has a number of support programmes (Platform Bèta Techniek, 2009):

- *VTB* supporting pedagogical development and innovation in primary school
- *Universum* supporting pedagogical development and innovation in secondary and upper secondary school
- *Ambitie* supporting pedagogical development and innovation in vocational education
- *Sprint* supporting pedagogical development and innovation in higher education
- *Jet-Net* supporting school and business collaboration as presented in section 5.3.3

The platform also supports teacher development and teacher exchanges between upper secondary school and higher education.

5.3.3. Norway

The Norwegian government presented a 4-year national strategy for mathematics, science and technology education, *Et felles løft for realfagene*, in 2006. Since then, annual action plans have been designed, executed and followed up (Kunnskapsdepartementet, 2009).

The main themes of the strategy include (Kunnskapsdepartementet, 2009):

- creating a national meeting place for science in working life and education
- encouraging local cooperation and interaction between business and education
- increasing tuition time for MST in primary and secondary school
- in-service MST training for teachers and nursery school staff
- establishing a programme for development of good practice in teaching MST, including practical approaches and the use of ICT

Norway has a national centre for recruitment of maths, science and technology students called *Renate*. The centre was established by the Norwegian government in 1998 and given a reinforced mandate, linking to the national strategy, in 2007 (Renate, 2009).

5.3.4. Sweden: Teknikdelegationen and Matematikdelegationen

The Swedish Government appointed *the Swedish Technology Delegation* in July 2008. The delegation is chaired by Leif Johansson, CEO Volvo Group, and consists of representatives from academia, industry and employer/employee organisations (Teknikdelegationen, 2009b).

The delegation is tasked with (Teknikdelegationen, 2009b):

- analysing MST and ICT workforce demand
- highlighting and strengthening current efforts to increase interest and participation in tertiary education in MST and ICT

- proposing long-term efforts, including how to conduct, monitor and evaluate work, with the aim of increasing interest and participation in tertiary education in MST and ICT

The Swedish Technology Delegation must present its findings to the Swedish Minister of Higher Education and Research by April 30th, 2010.

In 2004, *the Swedish Mathematics Delegation*, appointed by the Swedish Government and tasked with proposing an action plan to increase interest in and develop mathematics education, submitted four main proposals valued at SEK 2.5 billion over five years (SOU, 2004):

"…

- Support and develop activities to increase interest in and provide greater insight into the value, role and significance of mathematics in everyday and working life, science and society
- Train qualified teachers in mathematics at all levels for all children, young people and adults
- Support and coordinate all the positive forces promoting better mathematics learning and teaching
- Clarify and develop aims, goals, content and assessment in mathematics for the entire education system

…"

5.3.5. United Kingdom: STEM Programme and National STEM Centre

In 2004, the United Kingdom Government published a 10-year Science and Innovation Framework "… which aims to make Britain the most attractive location in the world for science, research and development, and innovation, with a view to attracting the best scientists to meet this goal" (United Kingdom Department for Education and Skills, 2006). In the same year, a Science, Technology, Engineering and Mathematics (STEM) mapping review identified over 470 STEM initiatives supported by the United Kingdom Government. In 2006, the STEM Programme Report (United Kingdom Department for Education and Skills, 2006) was published, putting forward proposals for a national STEM strategy. The main message of the STEM Programme Report was the need to "… rationalise and improve the delivery of the current plethora of STEM initiatives…", improving value for money and being cost neutral. A government-appointed National STEM Director is currently responsible for implementing the proposals. Among other activities, this has lead to the establishment of a National STEM Centre, due to open in September 2009, responsible for bringing "together the best teaching resources from the past 25 years, making them accessible to all schools and colleges – either online where possible or in person; it will also be a focal point for STEM activity, ensuring that all partners are working together" (Science Learning Centres, 2009).

5.4. *European strategy*

Education, particularly primary, secondary and upper secondary school education, is formally and principally of national concern within the European Union. The European Commission has a very limited mandate to push educational policy. Nevertheless, key strategic agreements between EU member states, such as the *Lisbon Agenda*, aim to drive European competitiveness by moving towards a knowledge economy and emphasising the importance of education in general, and MST education in particular, in achieving this aim. Although the Lisbon Agenda is certainly a European strategy with elements concerning the issue at hand, Europe lacks a coherent long-term strategy to increase interest in mathematics, science and technology education and careers. Having said that, three key players are moving in a similar direction, perhaps towards such a strategy: the European Commission, the current troika France, the Czech Republic and Sweden, and the European Round Table of Industrialists.

5.4.1. European Commission

The Lisbon benchmark on MST targets a 15% increase in the total number of graduates in MST from 2000 to 2010. The European Commission's 2008 progress report concludes that the benchmark was passed in 2004, and that the increase is currently more than 29% (European Commission, 2008). In line with conclusions from chapter 3, the Lisbon benchmark on MST is seen by many, including me, to be insufficient. This view also appears to be shared by the Commission, as it continues to give MST education priority through:

- Ongoing exchange of national good practice through a MST cluster of member state experts, run by DG Education and Culture
- Recent focus on MST in the University Business Forum. In relation to this, the Commission recently communicated that it would explore how a European coordinating body and initiatives such as European Schoolnet could promote school and business collaboration (European Commission, 2009). See in relation to proposals from the European Round Table of Industrialists in section 5.4.3.
- Activities, including EU calls for proposals, following up the previously referenced Rocard report (Rocard *et al.*, 2007), run by DG Education and Culture and DG Research

5.4.2. EU Presidency: France and Czech Republic

The latest presidencies, France and the Czech Republic, have both to some extent addressed increasing interest in maths, science and technology education.

- France held a presidency conference in Grenoble on science education highlighting many of the challenges discussed in this thesis (Ministère Éducation Nationale, 2008)

– The Czech Republic held a presidency conference in Prague on partnerships between academia and industry. Ondřej Liška, the Czech minister of education, argued that school and business collaboration can influence young people to choose maths, science and technology careers (Czech Presidency of the European Union, 2009).

It remains to be seen whether the third part of the current EU presidency trio, Sweden, follows lead.

5.4.3. European Round Table of Industrialists

Following research activities and external and internal discussions, the European Round Table of Industrialists brought together high-level representatives from academia, government and business through a stakeholder engagement event, *Inspiring the Next Generation*, in Brussels on October 2nd 2008. Participants such as José Manuel Barroso, President of the European Commission, Jorma Ollila, Chairman of ERT, Nokia and Royal Dutch Shell, and Leif Johansson, Vice Chairman of ERT and CEO Volvo Group addressed the issue of increasing interest in MST education and careers emphasising and providing support in response to the need for increased collaboration between schools and business in order to link school subjects to working life.

ERT has proposed that a *European Coordinating Body* be established to coordinate and leverage on school business partnerships across Europe, and that this body be run by European Schoolnet.

European Coordinating Body

- a European Round Table of Industrialists and European Schoolnet proposal

The coordinating body would work with national partners to operate

- an observatory of practice; *including*
  - evaluation of current partnerships
  - needs analysis to identify gaps in current partnerships
  - research
    - annual synthesis report of relevant published research
    - interviews
    - focus groups
- an online repository of good practice
- coordination and support activities; *including*
  - a community platform
  - coordination meetings
  - school business matching tools
  - special interest groups
  - professional development
- dissemination and stimulation activities; *including*
  - a multilingual web portal in 8 languages
  - European level campaigns and conferences

5.5. Conclusions

On the one hand, this chapter has shown that there are a huge *number of activities* ongoing across Europe targeting an increased interest in MST education and careers, though the total *amount of activity*, e.g. in terms of investment, is difficult to assess. On the other hand,

- most activities are poorly evaluated in terms of cost and effect or at too early a stage to show any results;
- there is a lack of coherence between and coordination of activities at all levels in society;
- society is not learning from previous efforts; *and*
- there is evident that a fair amount of rationalisation is needed.

Thus, any corporate investment should be made in partnership with other stakeholders and local, national or European coordinating bodies in order to ensure cost-effectiveness and encourage overall improvement of the above.

6. Corporate options and incentives to respond

Chapter 2 shows that in many countries, the base from which the Volvo Group is dependent on being able to acquire talented personnel in MST is shrinking, and that in some countries the rate of decline is rapid. Chapters 3 and 4 show that private and public corporations and employers, university management and faculty as well as legislators are the only true stakeholders with the power, urgency and legitimacy needed to positively affect the decline. This is a fundamental conclusion as it limits corporate options and expels the notion that the decline is a matter for others, e.g. schools, to resolve. A second important observation from chapter 4 is that the relative importance of the recommended actions cannot be determined. It can only be assumed that the likelihood of successful results increases with the quantity and quality of efforts undertaken. Chapter 5 adds the perspective of other efforts to tackle the decline. Finally, in this chapter I attempt to assess whether the conclusions of previous chapters warrant a Volvo Group corporate response by analysing corporate options and incentives to respond from a financial perspective.

6.1. Method

The assessment is achieved by presenting a business case based on accepted economic measurements and investment calculus, as described by the literature and referenced where applicable, complemented by my own assumptions and models. My assumptions and models aim to be conservative, in the sense that I have played down the risk of economic loss as a result of a workforce deficit as well as the potential positive effect that a corporate response might incur. My models are simplistic. Nevertheless, I believe that the results build to a realistic assessment upon which the Volvo Group can and should make a decision on whether or not and how to respond.

The business case addresses three aspects:

- Economic value of human capital in maths, science and technology (here: engineers – see delimitations)
- Expected loss of net income in 2010-2025 as a result of the forecast workforce deficit
- Corporate options set in relation to the maximum investment that still provides a positive return on investment

6.1.1. Delimitations

The business case is delimited to engineers and Sweden because of data limitations. However, the method can be reused in other markets, for other employee categories and/or by other companies, provided that additional data is made available.

6.2. Economic value of an engineer

6.2.1. Theory

HEVA

The traditional, but outdated, measurement of the financial contribution of an employee to a company used by many governments and businesses is *sales per employee*. The measurement is simplistic and does not take into account a number of complex aspects such as the alternative cost of invested capital and alternative employment arrangements such as part time employees and consultants (Fitz-enz, 2000). Fitz-enz (2000) proposes the measurement ‘Human Economic Value Added’, an expansion of the widely accepted economic measurement ‘Economic Value Added’, to improve the validity of results.

HEVA = ([Net operating profit after tax] – [Cost of capital]) / [Full time equivalents]

Augustsson *et al.* (2009) go one step further by suggesting a weighted HEVA taking into account the relative importance of different employee categories. They achieve this by multiplying HEVA by the average salary in the employee category being assessed divided by the average salary in the whole employee population.

$$HEVA_{weighted} = HEVA \times ([\text{Average salary in the employee category being assessed}] / [\text{Average salary in the whole employee population}])$$

HEVA is problematic in the sense that it is a measurement of the contribution of *all* immaterial assets not included in the balance sheet, to the net operating profit after tax. Although human capital is such an asset, so, for instance, is brand value, and it is impossible to distinguish them from each other. Nevertheless, I will use HEVA as one of two inputs on the economic value of human capital.

Total Contribution Margin

Another way to look at the economic value of human capital in a large company with a relatively fixed total cost, such as the Volvo Group, is to look at the total contribution margin of an additional employee.

Total Contribution Margin (TCM) = Total Revenue (TR) – Total Variable Cost (TVC)

This method is accurate if the workforce deficit is small, but becomes less so as the deficit grows.

6.2.2. Application and results

HEVA

The Volvo Group operates in a cyclical market. In order to achieve a more realistic measurement of the financial contribution of an employee to the Group over time, I will create a seven-year average of HEVA, applying global figures and neglecting inflation. An average taken over a longer period would include 1998-2001 and thus the unfair effects of restructuring costs and income from the divestment of subsidiaries. I will determine the weighting factor for an engineer employed in Sweden from the Swedish figures for 2008, neglecting possible future variations over time.

$$HEVA_{weighted,\ final} = ((HEVA_{2002} + \ldots + HEVA_{2008}) / 7) \times ([\text{Average engineer salary in Sweden, 2008}] / [\text{Average salary in the whole employee population in Sweden, 2008}])$$

With the exception of the weighting factor, the definitions used in the calculation presented in appendix 2, section 9.1, correspond to those used by AB Volvo (2009, p. 143, 145 & 151). The data behind the weighting factor have been provided by AB Volvo Corporate HR, but are not presented due to confidentiality restrictions.

The weighted HEVA seven-year average arrives at SEK 31,583 per annum.

Total Contribution Margin

The total contribution margin for an average engineer is SEK 655,600 per annum based on Volvo Technology's internal hourly rate, an assumed number of billable hours and an assumed average salary.

Hourly rate	SEK 800
Number of billable hours per annum	1,640
Total Revenue (TR)	**SEK 1,312, 000**
Salary per month	SEK 40,000
Social costs (35%) per month	SEK 14,000
Holiday pay	SEK 8,400
Total Variable Cost (TVC)	**SEK 656,400**
Total Contribution Margin (TCM = TR - TVC)	**SEK 655,600**

Conclusion

An engineer's true economic value is likely to be somewhere between the weighted HEVA seven-year average and the total contribution margin, i.e. SEK 200,000–SEK 500,000. For the purposes of the following business case calculations, it will be set to the average of the two estimates, SEK 343,591 per annum for 2008.

6.3. Expected loss of net income 2010-2025

6.3.1. Model

I will establish the expected loss of net income for the Volvo Group 2010-2025 on the basis of the Swedish National Agency for Higher Education's forecast on the supply and demand of Bachelor of Science-level (in Swedish: högskoleingenjörer) and Master of Science-level engineers (in Swedish: civilingenjörer) in Sweden. The two groups will be combined into one group of engineers, as the Volvo Group is likely to recruit employees from the other category if one of them is in deficit. The forecasts are presented in figures 41-44.

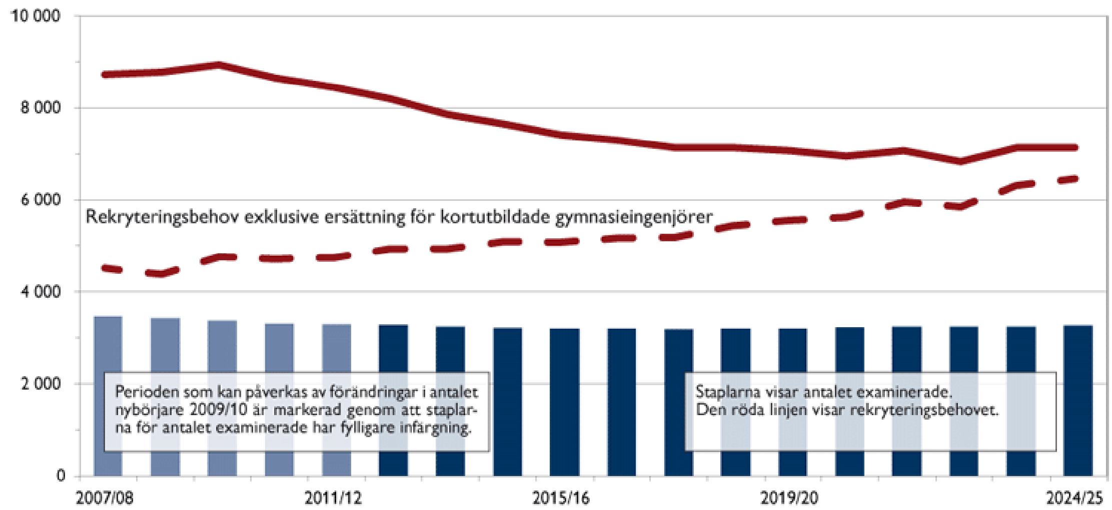

Figure 41 Forecast recruitment needs (red line) and graduation numbers (bars) of *Bachelor of Science-level* engineers (Source: Högskoleverket, 2009a)

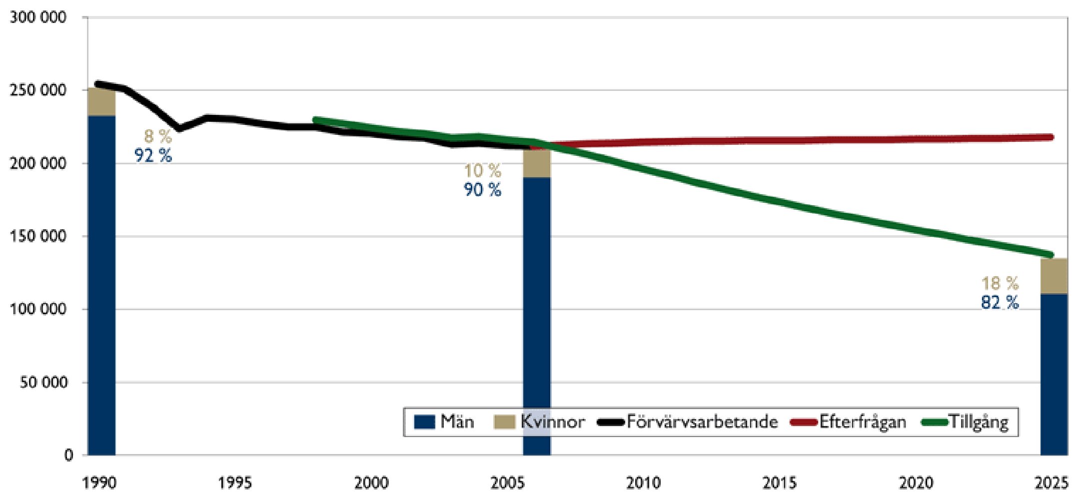

Figure 42 Forecast supply (green line) and demand (red line) of *Bachelor of Science-level* engineers (Source: Högskoleverket, 2009)

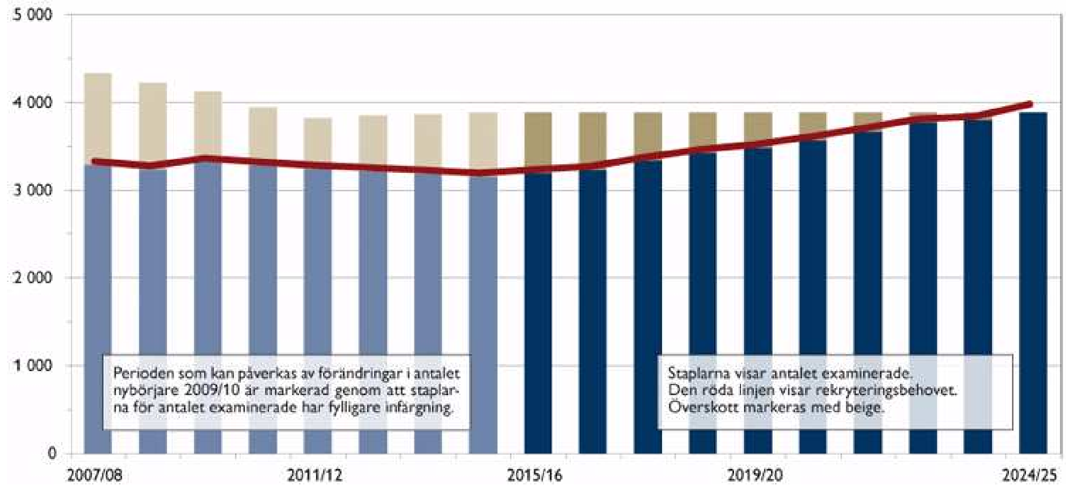

Figure 43 Forecast recruitment needs (red line) and graduation numbers (bars) of *Master of Science-level* engineers (Source: Högskoleverket, 2009a)

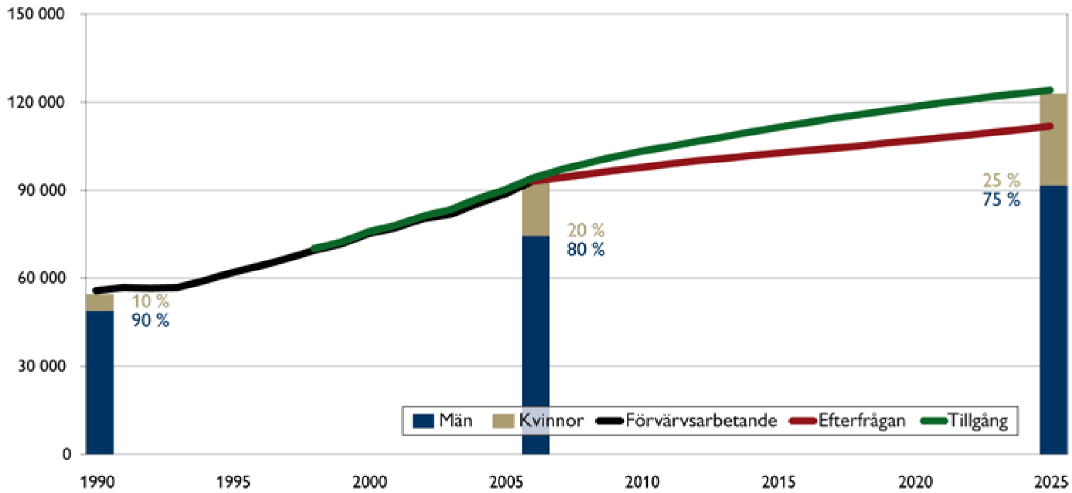

Figure 44 Forecast supply (green line) and demand (red line) of *Master of Science-level* engineers (Source: Högskoleverket, 2009)

I will determine the Volvo Group's nominal share of the national engineer deficit by spreading the national deficit proportionally between current engineer employers according to the 2008 distribution. This assumes even growth of current engineer employers in the future. In order to take into account the effects of the current financial crises and the cyclical nature of the Volvo Group's market, the model will take into account two market downturns, each two years long, by setting the Group's final share of the national engineer deficit to zero for the years 2008, 2009, 2010, 2015, 2016, 2021 and 2022. Finally, the expected loss of net income for the Volvo Group 2008-2025 will be determined by multiplying the economic value of an engineer by the Volvo Group's final share of the national engineer deficit.

[Expected loss of net income for the Volvo Group] = [Economic value of an engineer] x [0 for 2008, 2009, 2010, 2015, 2016, 2021 and 2022] *x ([Number of engineers in Sweden*

employed by the Volvo Group in 2008] / [Total number of engineers in Sweden in 2008]) x [National engineer deficit]

Each year is adjusted for inflation.

6.3.2. Results

The model shows that the accumulated expected loss of net income for the Volvo Group 2008-2025 amounts to approximately SEK 1770 million, net present value. The annual expected loss of net income (NPV) is presented in figure 45.

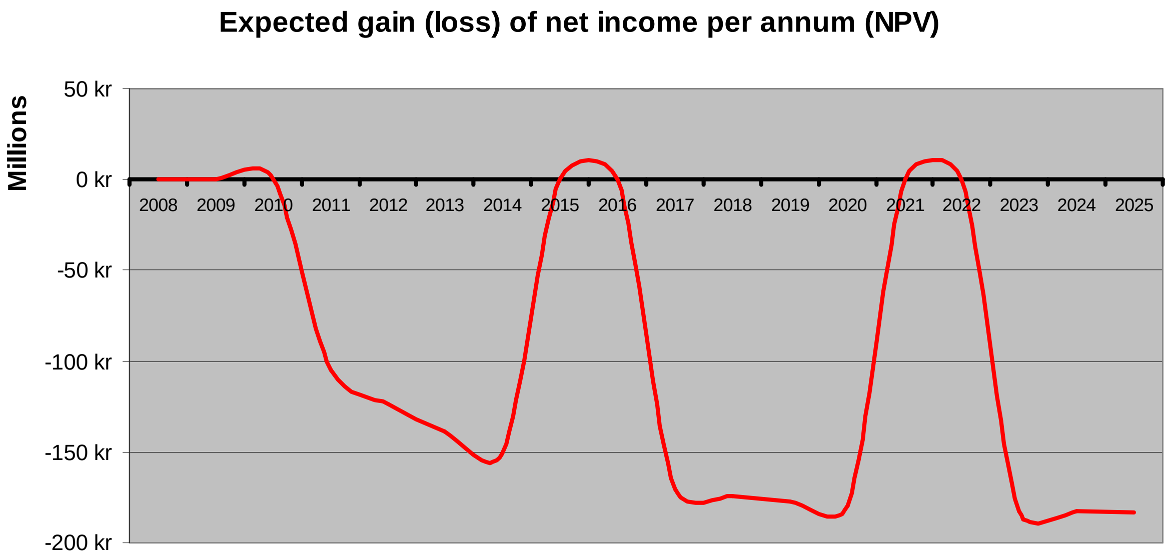

Figure 45

6.4. Corporate options set in relation to return on investment (ROI)

Four possible options are envisaged and presented below. Ultimately, apart from the first, each can be implemented to a different extent, by itself and/or jointly with others. Rationalising the organisation or moving it abroad is not seen as a possible option as the need is predefined for this thesis and the possibility of rationalising or moving abroad, thereby removing need, is consequently dismissed. Employing non-educated personnel and educating them in-house is also not seen as a possible option because employers are not likely to be able to build sufficient capacity in the relatively short period 2010-2025. Nor is importing the required white and blue collar workers an option, as current trends indicate that the net flow of workers into (+) and out of (-) Europe will be negative during the next decades, mostly due to the ongoing massive boom in several Asian economies.

In general, any investment where *[Accumulated investment] + [Accumulated net expected gain (loss) of net income] < [Accumulated gross expected gain (loss) of net income]* is a sound investment.

6.4.1. Do nothing and rely on others to act

The most obvious and straightforward option is perhaps to do nothing at all, hoping that others will act. The motive would be to eliminate the cost of investment. This is a high-risk option; if others do not act, the Volvo Group can expect to lose net income amounting to approximately SEK 1,770 million (NPV) over the period 2010-2025. If others do act, depending on how and to what extent, the effect may still be insufficient. Furthermore, other companies who act are likely to strengthen their relative attractiveness as employers, leading to increased difficulties for the Volvo Group in recruiting any engineers that are or become available.

6.4.2. Lobby government

The second most obvious and straightforward option is to lobby the government to execute the recommendations in chapter 4 on improving the image of MST, MST professionals and MST careers as well as improving MST education and curriculum. The cost of investment would be low. This is a medium-risk option; lobbying the government may not be sufficient if employers do not do their part.

6.4.3. Strengthen employee offering and employer branding effort to ensure relative attractiveness as employer

A third option is to strengthen the employee offering, for instance by increasing salaries and improving career-development opportunities, as well as the employer branding effort to ensure successful and correct communication of the employee offering. The aim would be to ensure that the Volvo Group is the most attractive employer and thereby able to recruit any engineers that are or become available.

A detailed analysis of this option is outside the scope of this thesis. However, it is evident that although the initial cost of investment might be low, it is likely to rise substantially. Strengthening the employee offering by raising salaries once by as little as 5% would incur huge cost in excess of the expected loss of net income if nothing is done. Thus, this is a high risk option; competing with other companies to have the best employee offering and the best employer branding results in circumstances when a workforce deficit is growing is likely to lead to high and increasing costs throughout 2011-2025.

6.4.4. Partner with other companies in collaborating with schools, universities and other stakeholders, stakewatchers and stakekeepers to secure quality and quantity of an educated workforce

A forth option is to partner with other companies in collaborating with schools to secure the quality and quantity of an educated workforce by taking part in activities that put MST into meaningful life and career contexts, provide role models and provide career information in accordance with the recommendations in chapter 4.

This option requires the Volvo Group to commit employee time to regularly recurring activities in and around school education. Due to long lead times and potential free rider problems, such an investment is only likely to be sound if a substantial number of other companies make an equivalent investment. This would also allow the Volvo Group's costs to be minimised as the total cost would be shared by many.

Model expansion

In order to fully understand the investment requirements (of this option), cash flow differences (between acting on this option and not acting at all) and the investments' expected effects on the number of students who choose engineering education, a deeper analysis is required. To that point, I have expanded the model presented in section 6.3 based on the following assumptions:

- The first step is to determine where/when additional engineers might be recruited. The (full) recruitment potential at every stage is assumed to be static and equal to that of the class of 2009, born in 1987 and presented in figure 46. In 1996, at the start of Secondary School stage 1 (in Swedish: mellanstadiet), the class had 111,000 students (the whole population in the age group) in the pipeline with the possibility of becoming engineers. In 2002, at the start of Upper Secondary School (in Swedish: gymnasiet), the group in the pipeline had shrunk to 18,000 students due to the students' own structural choices of educational programmes. These 18,000 include the Upper Secondary School (in Swedish: gymnasiet) programmes 'Naturvetenskap' (in English: Science) and 'Teknik' (in English: Technology). In 2009, at the end of University, the group in the pipeline had shrunk to 7,000 students, again due to the students' own structural choices of educational programmes, in this case, including dropouts. These 7,000 include Bachelor of Science-level (in Swedish: högskoleingenjörer) and Master of Science-level engineers (in Swedish: civilingenjörer). The (full) recruitment potential at every stage is thus equal to the drop in the number of students in the pipeline at the intersection following the stage in question. The drop between Secondary School stage 1 and Secondary School stage 2 (in Swedish: högstadiet) as a result of emotional choice, i.e. intended structural choice, is assumed to be half of that between Secondary School stage 1 and Upper Secondary School. Students who are part of the (full) recruitment potential are hereafter called *potentials*.
- However, it is not reasonable to believe that all *potentials* can be recruited. Recruiting from Secondary School stage 2 is, based on previous conclusions, likely to be the

easiest, followed by Secondary School stage 1 and finally Upper Secondary School. Therefore, the realistic maximum recruitment potential is assumed to be 12.5% of the full recruitment potential at Secondary School stage 1, 15% of the full recruitment potential at Secondary School stage 2 and 10% of the full recruitment potential at Upper Secondary School. The percentages reflect my assumption that the maximum recruitment potential is likely to be in the range 5-20% for all three levels, with Secondary School stage 2 being the easiest to recruit from, Secondary School stage 1 being slightly more difficult to recruit from and Upper Secondary School being the most difficult to recruit from. I base my assumption on research showing that young people form their attitudes towards science education prior to the age of 13-15 (Osborne and Dillon, 2008 and OECD 2008c).

- Commitment of employee time, hereafter called *investment*, is made during the last year of Secondary School stage 1 with a 10-year delay of effect, during the last year of Secondary School stage 2 with a 7-year delay of effect and/or during the last year of Upper Secondary School with a 4-year delay of effect.
- The workforce deficit is completely eliminated in order to ensure that no free rider problems emerge. This is achieved in the four scenarios that will be analysed and presented where 100%, 50%, 25% or 10% of the current engineer employers share the total cost of investment according to their current share of the engineer workforce.
- The required investment per potential increases linearly from SEK 0 at a 0% success rate (the percentage of successful recruitments out of the maximum recruitment potential) up to SEK 11,910 at a 100% success rate irrespectively of school stage. It is set to a level that generates a total return on investment (ROI) equal to SEK 0 in the 10% scenario and adjusted for inflation each year. Thus, the 25%, 50% and 100% scenarios generate an increasingly positive return on investment.
- Annual interest calculated for costing purposes is 9% and annual inflation is 3%

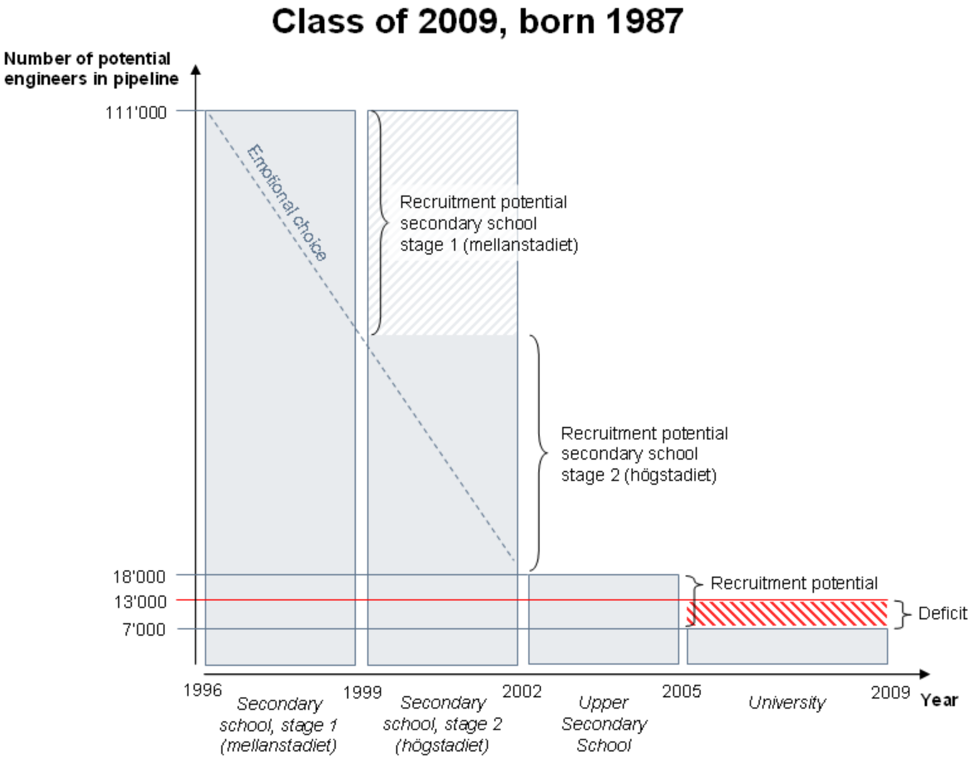

Figure 46

As a result of the assumptions in the expanded model, the optimum investment strategy is, in the following order, (1) to minimise the accumulated workforce deficit as swiftly as possible, (2) to invest in Secondary School stage 2, (3) to invest in Upper Secondary School and (4) to invest in Secondary School Stage 1. The strategy is implemented for the four scenarios in the extended model calculations presented in appendix 2, section 9.2, and yields the following scenario results.

Scenario results

The net value present (NVP) of the return on investment (ROI) over the period 2010-2025 in the four scenarios is SEK 836 million in the 100% scenario, SEK 743 million in the 50% scenario, SEK 557 million in the 25% scenario and SEK 0 in the 10% scenario. The net value present (NVP) of the required investments during 2010-2025 is SEK 93 million in the 100% scenario, SEK 186 million in the 50% scenario, SEK 372 million in the 25% scenario and SEK 929 million in the 10% scenario. The annual required investments are presented in figure 47. The first investments are made in 2010. No investments are required after 2018 as the delayed effects of investment compensate for the workforce production deficit during the whole period 2008-2025.

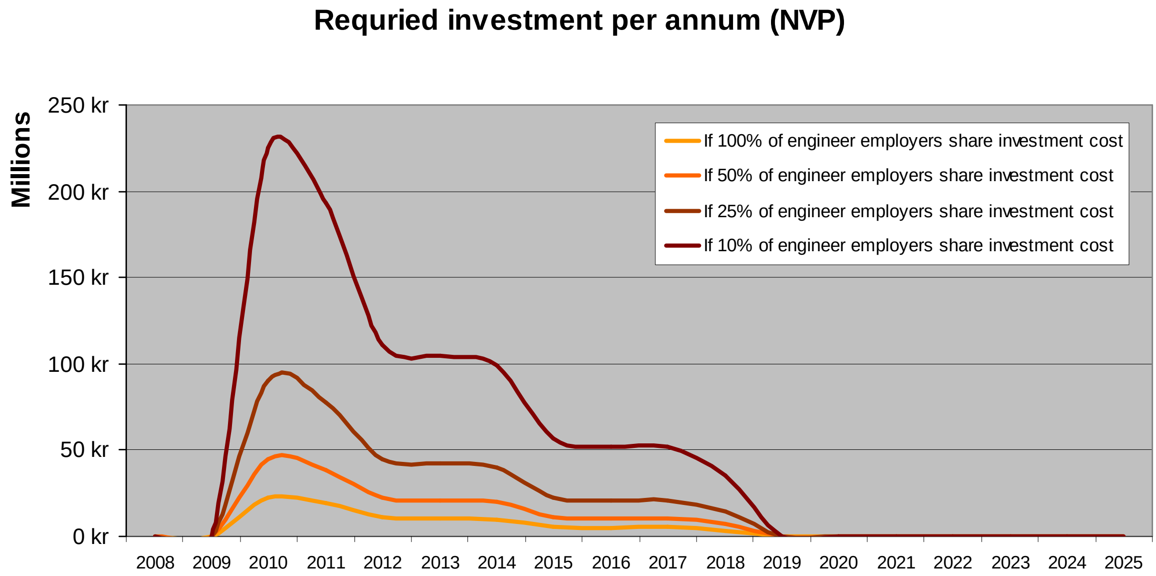

Figure 47

The investments result in the net expected gain (loss) of net income presented in figure 48 and the cash flow difference presented in figure 49.

Following any of the four scenarios would result in the deficit being eliminated by 2021, as shown by figure 50. The figure also shows that the Volvo Group's gross workforce deficit, i.e. the workforce deficit if no investment is made, will have reached 1,281 engineers by 2025. If that deficit existed today, 22% of the Group's engineer positions in Sweden would be vacant.

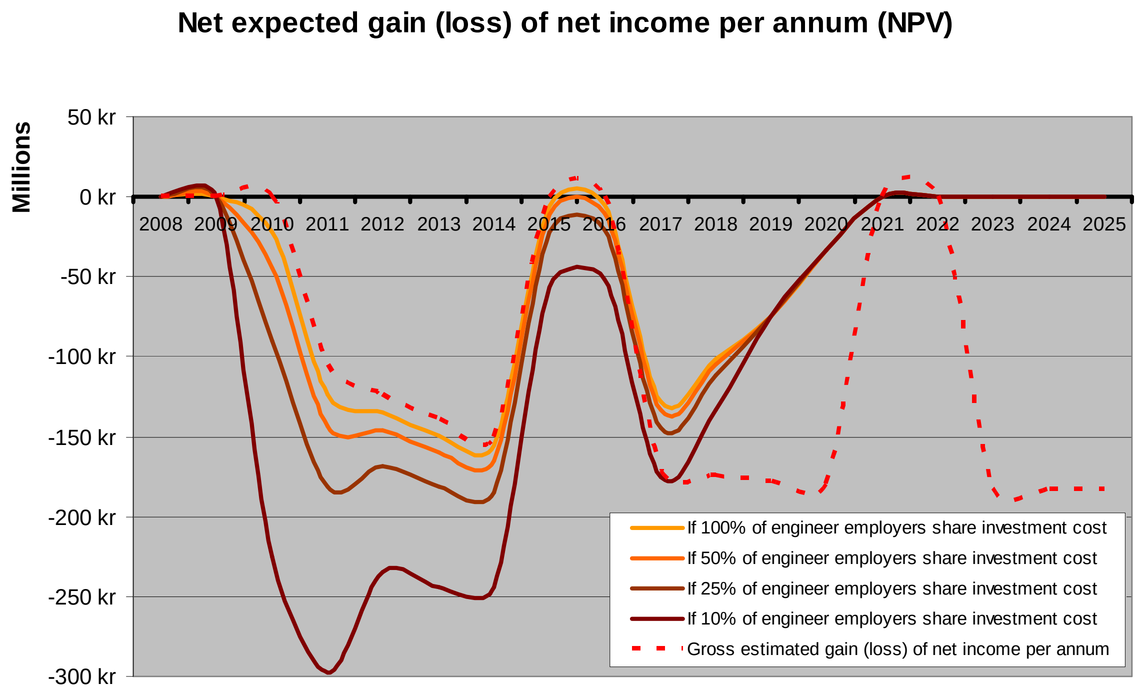

Figure 48

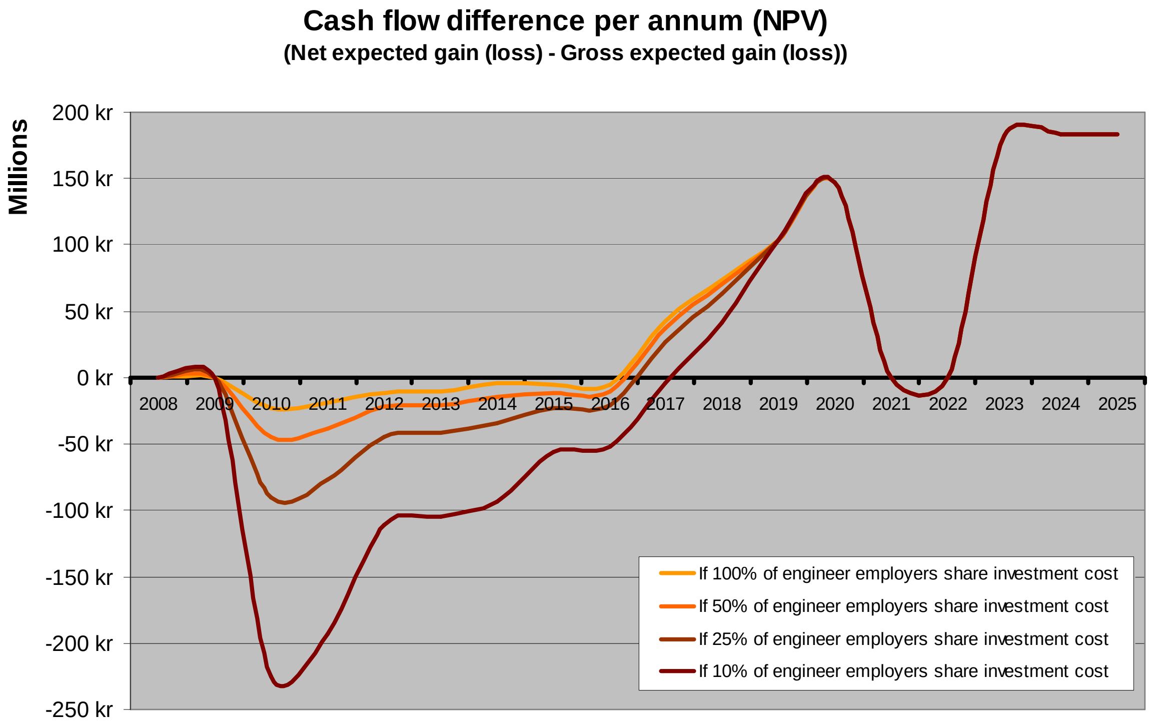

Figure 49

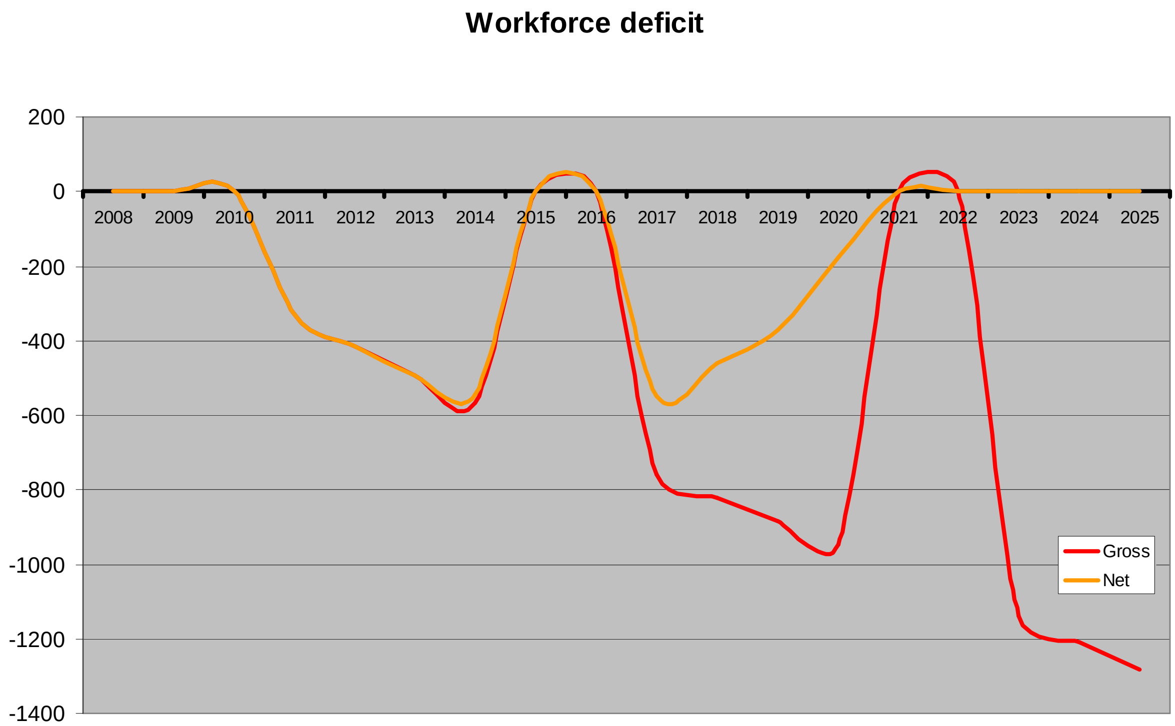

Figure 50

The optimal investment strategy, based on current assumptions, is shown in figures 51 and 52. As the required investment per potential is set to a level that generates a total return on investment (ROI) equal to SEK 0 in the 10% scenario, this is essentially equivalent to the maximum required investment per potential that still generates a non-negative return on investment (ROI) in the 10% scenario. Can it be assumed that the investments will have the modelled effects?

On average, according to the model, the class of 2009 had 13 potentials during the last year of Secondary School stage 1 and Secondary School stage 2, and 18 potentials during the last year of Upper Secondary School. Thus, a required investment per potential set to SEK 11,910 equals approximately SEK 155,000, 194 hours or 12% of a full-time position per class of 30 students at Secondary School stages 1 and 2 and approximately SEK 214,000, 268 hours or 16% of a full-time position per class of 30 students at Upper Secondary School. This appears to be more than sufficient to put MST into meaningful life and career contexts, provide role models and provide career information in accordance with the recommendations in chapter 4. It is likely that the investment per potential could be lowered.

The required investment per potential appears to stabilise at around half of the initial required investment per potential once the workforce production backlog is eliminated (see figure 51 years

2015-2018 for Secondary School stage 2). Though 6% of a full-time position per class of 30 students should still be sufficient, it is likely to be close to the lower boundary reflecting that the relationship between investment and effect is, in reality, likely to be non-linear.

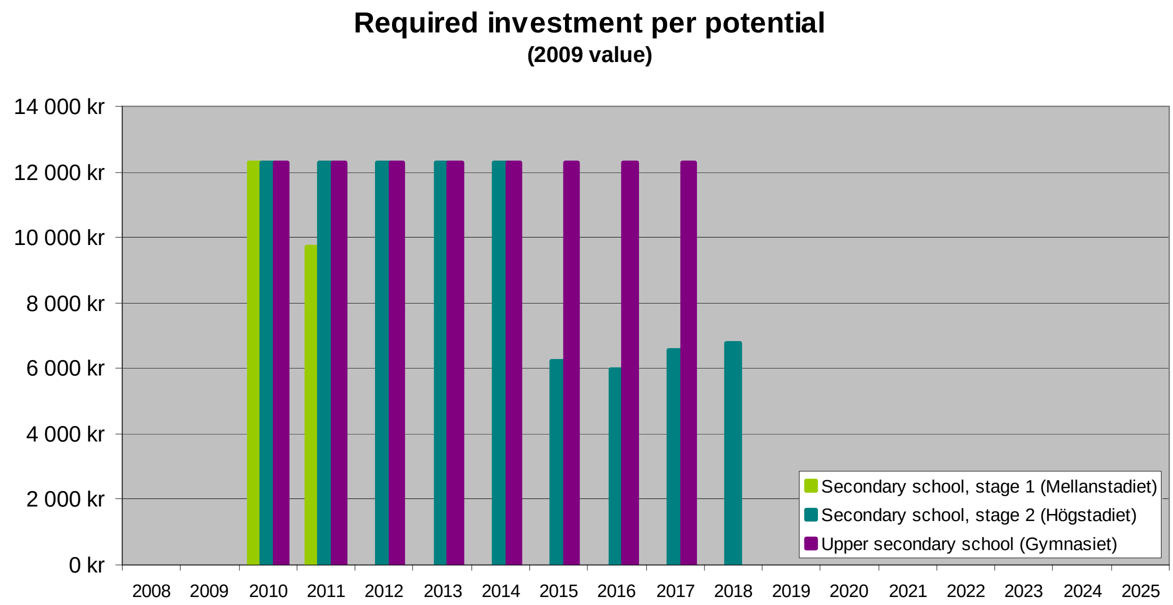

Figure 51

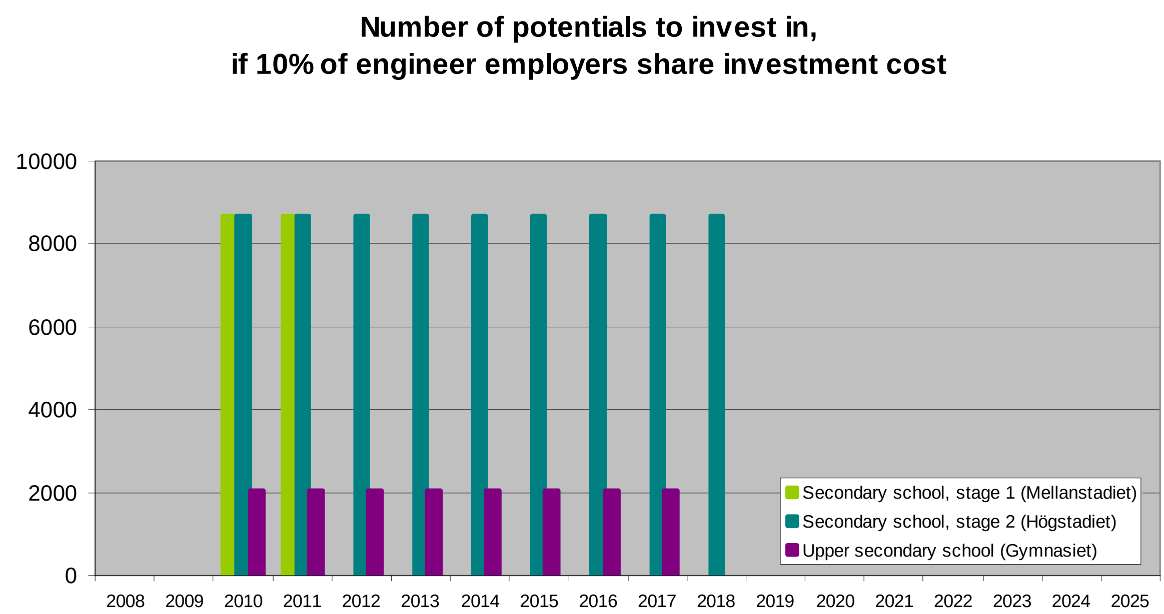

Figure 52

What happens if the backlog is removed?

It may also be interesting to see what happens to the results if the backlog is removed, i.e. if the annual workforce production deficit is set to 0 for 2008-2016 as opposed to what is forecast by the Swedish

National Agency for Higher Education. The net value present (NVP) of the return on investment (ROI) in the four scenarios becomes SEK 322 million in the 100% scenario, SEK 286 million in the 50% scenario, SEK 215 million in the 25% scenario and SEK 0 in the 10% scenario. The required investment is presented in figure 53.

As shown in figure 54, the required investment per potential stabilises around SEK 6,000 which equals approximately SEK 78,000, 98 hours or 6% of a full-time position per class of 30 students at Secondary School stage 2. Though this appears to be sufficient to put MST into meaningful life and career contexts, provide role models and provide career information in accordance with the recommendations in chapter 4, it is likely to be close to the lower boundary, again reflecting that the relationship between investment and effect is, in reality, likely to be non-linear.

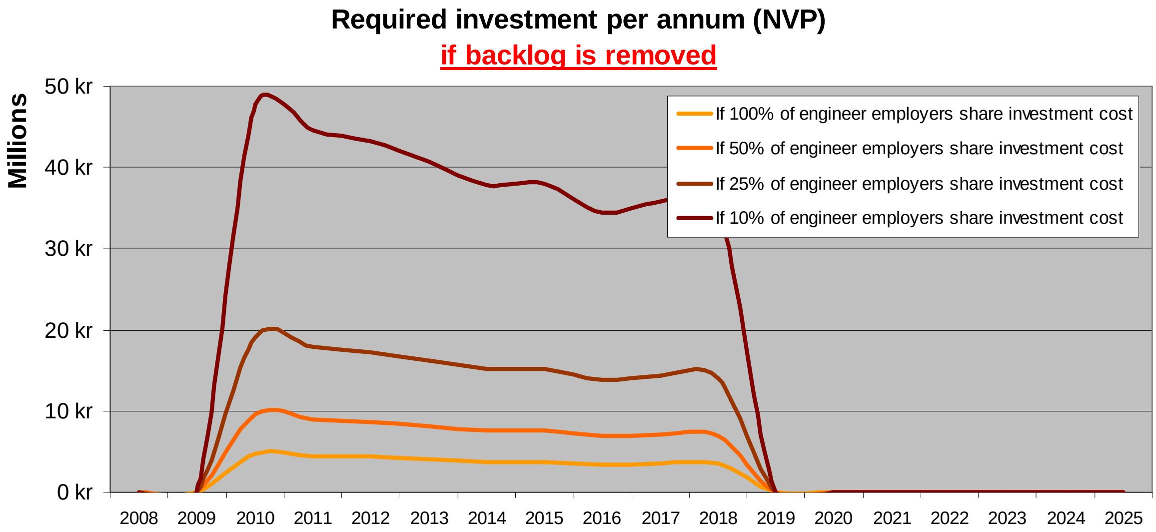

Figure 53

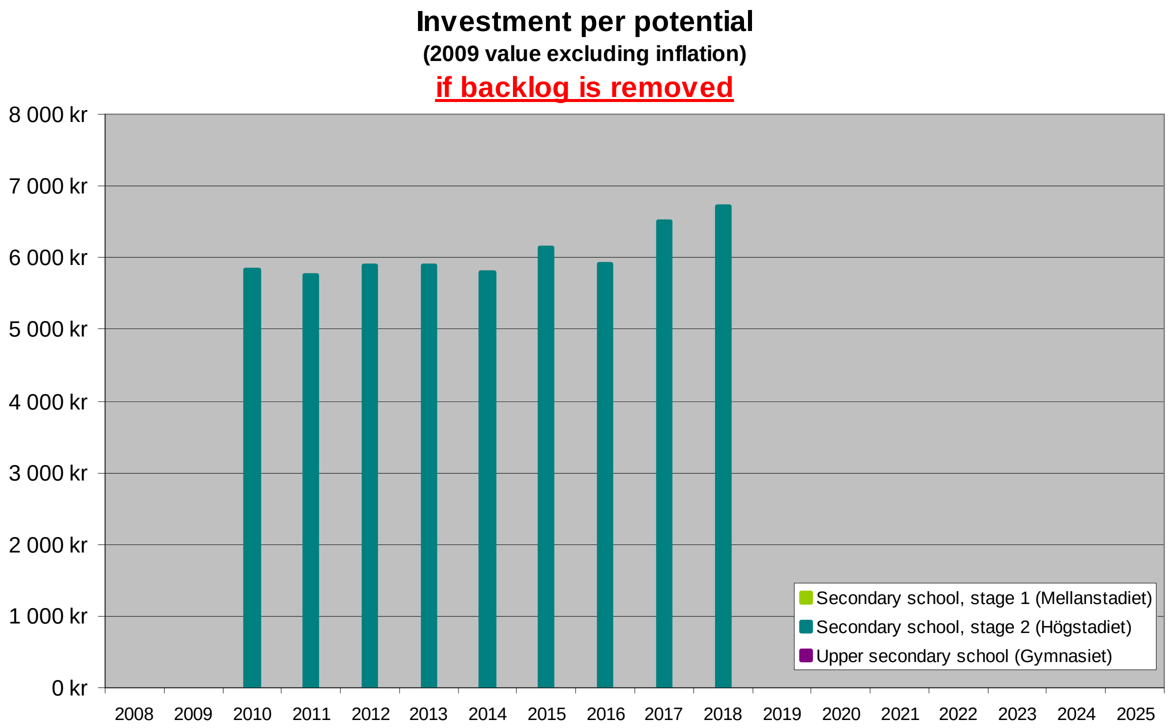

Figure 54

Prerequisites

Chapter 5 shows that an external system of coordination and support is necessary to enable and ensure the effectiveness of school business partnership. In addition to administrative motives, both teachers and company employees need support in understanding how business can be used as pedagogical tool in and around the classroom. For the Volvo Group in Sweden, this makes cooperation with the Swedish programme MATENA an absolute prerequisite for any in-kind investment in school to increase interest in MST education and careers.

My model has shown that a backlog in workforce production is now unavoidable as there is a time delay in the effect of investment. The Swedish Government should consider short-term legislative and tax incentives to encourage companies' commitment and ensure that the necessary high initial annual investments are made to eliminate the backlog as swiftly as possible. Short-term incentives are likely to be even more important for small and medium-sized companies who may not have the capacity to act in a long-term manner irrespective of any positive long-term return on investment (ROI).

Other ways of viewing and making such an investment

In addition to the return on investment included in my model, several surplus returns should be considered, valued and factored into a final decision. Perhaps the most obvious is that suppliers would suffer from a workforce deficit and thus benefit from it being eliminated. Company commitment is also likely to result in (Maignan *et al.*, 1999)

- Competence development of involved co-workers in a general social sense as well as more specifically in the methods of leadership, teamwork, communication etc.
- Improved job satisfaction of involved co-workers as many want to contribute to society and societal development.
- Improved brand image including corporate social responsibility (CSR) aspects.

The company may benefit from organising and encouraging a certain amount of company commitment as voluntary work.

Conclusion

Although clearly financially viable, this is a medium-risk option. Partnering with other companies in collaborating with schools, universities and other stakeholders, stakewatchers and stakekeepers to secure quality and quantity of an educated workforce may not be sufficient if the Swedish Government does not do its part.

6.5. Conclusions

Doing nothing and relying on others to act is financially out of the question. In the short term, strengthening the employee offering and employer branding effort to ensure the Volvo Group's relative attractiveness as an employer will be necessary since a backlog in workforce production is now unavoidable. To avoid a prolonged workforce deficit, the Volvo Group should

- lobby the Swedish Government to execute the recommendations in chapter 4 on improving the image of MST, MST professionals and MST careers, and on improving MST education and curriculum, *and*
- partner with other companies in collaborating with schools to secure the quality and quantity of an educated workforce by taking part in activities that put MST into meaningful life and career contexts, provide role models and provide career information.

In theory, the latter should be done in accordance with the optimal investment strategy presented in figures 51 and 52 as soon as a minimum of 10% of current engineer employers are prepared to share the total investment cost. As more companies are encouraged to join, the number of potentials invested in by the Volvo Group should be reduced accordingly. Until the 10% level can be met, the Volvo Group should promote this type of school business partnership by participating in small pilots at a handful of the Group's main business locations in Sweden. In reality, this level of school business partnership will take time to establish and is dependent on many external factors outside of the Group's direct control. Nevertheless, this business case has shown that the effort should be undertaken.

The Volvo Group faces similar challenges in France and Japan. Urgent attempts should be made to construct the same type of model for them as I have done for Sweden.

7. Conclusions

The Volvo Group must strengthen its employee offering and employer branding effort in Sweden to ensure the Group's relative attractiveness as an employer, as a backlog in the workforce production of engineers is now unavoidable. To avoid a prolonged workforce deficit, the Volvo Group should

- Lobby the Swedish Government[1] to execute the recommendations in chapter 4 on improving the image of maths, science and technology (MST), MST professionals and MST careers as well as improving MST education and curriculum, *and*
- partner with other companies[2] in collaborating with schools to secure the quality and quantity of an educated workforce, by taking part in activities that put MST into meaningful life and career contexts, provide role models and provide career information.

Doing nothing and relying on others to act is financially out of the question as the Volvo Group would be likely to loose net income amounting to SEK 1,770 million (net value present) over the period 2010-2025 in Sweden alone, provided the Swedish National Agency for Higher Education's forecast is accurate. Statistics from Eurostat and OECD indicate similar trends, but are not sufficiently comprehensive to allow the same detailed level of conclusion.

In theory, school business partnership should be built across Sweden in accordance with the optimal investment strategy presented in chapter 6 as soon as a minimum of 10% of current engineer employers are prepared to share the total investment cost. As more companies are encouraged to join, the number of potentials invested in by the Volvo Group should be reduced accordingly. Until the 10% level can be met, the Volvo Group should promote school business partnership by participating in small pilots at a handful of the Group's main business locations in Sweden. In reality, the required level of school business partnership will take time to establish, and is dependent on many external factors outside of the Group's direct control. Nevertheless, the business case in chapter 6 shows that the effort should be undertaken.

School business partnership, in Sweden and elsewhere in Europe, should be built in cooperation with local, national or European coordinating bodies in order to ensure cost effectiveness and encourage improvement of the fact that most of the huge number of activities currently being undertaken in Sweden and across Europe to promote increased interest in MST education and careers

---

[1] The Swedish Technology Delegation (see section 5.3.4) is due to present its findings by April 30th 2010. Volvo Group CEO Leif Johansson's position as chairman of the Delegation gives the Volvo Group a unique opportunity to convey these important messages to the Delegation and thus by extension hopefully to the Swedish Government.

[2] The Volvo Group's existing commitment to the Swedish programme MATENA (see section 5.2.3) should be utilised as far as it is possible.

- are poorly evaluated in terms of cost and effect or at too early a stage to show any results
- lack coherence and coordination with other similar activities at all levels in society
- do not learn from others' previous efforts

The Volvo Group faces similar challenges in France and Japan. Urgent attempts should be made to construct the same type of business case for those countries as I have done for Sweden.
In fact, although Europe and most of the analysed countries have experienced increases in the absolute number of graduates from MST tertiary education over the period 1998-2006, negative demographic trends, a stabilisation of access to tertiary education and drops in the proportion of students choosing MST are likely to have a negative or, in some cases, very negative impact on absolute numbers in the years to come. At the same time, and despite the current financial crisis, demand is likely to increase, creating a workforce deficit in many of the analysed countries. Negative attitudes to education and work in science and technology among Europe's though further support this conclusion. The question is not whether there is a problem, but rather how big the problem is. Unfortunately, due to a lack of better workforce demand forecasts, a good answer cannot be provided.

The main factors behind the proportional decline in choice of MST education are:

- Image of maths, science and technology
    - Science and technology needs are perceived to be fulfilled
    - Certain specialisations may be perceived as a threat to society
- Image of MST professionals and careers
    - Jobs not perceived to be meaningful
    - Lack of attractive role models
    - Lack of information and understanding of careers
    - Job market perceived as unstable
    - Careers perceived as unattractive
- MST education and curriculum
    - Education is not seen as meaningful and does not sufficiently address student's values and concerns
    - Pedagogical innovation is required
    - Teachers are ill-equipped

Significant transversal gender aspects exist in each of these factors.

The issue is complex and engages many stakeholders of various categories. However, only the following can be categorised as "real" or definitive stakeholders:

- Private and public corporations and employers

- University management and faculty
- Legislators
- Science centres, museums and exhibitions

Schools are not “real” or definitive stakeholders, which is a critical conclusion as it expels the notion that the problems are for them alone to resolve. The reason is that, although there are exceptions, the general picture is that schools see their role as preparing and equipping their students for prosperous lives as democratic citizens rather than providing employers with personnel.

Thus, it is up to European private and public corporations and employers, universities and legislators to act on recommendations on how to tackle the factors listed above, concretising them at national and local levels along with carefully prepared implementation plans. In doing so, they need to give the transversal gender aspects special attention. Simplistic top-down decisions will not suffice, and are in many cases not even possible due to prevailing governance structures. The complex cultural differences between the worlds of schools, universities, legislators and corporations need to be handled with respect, but also need to be overcome. Europe’s young depend on it.

8. APPENDIX 1: Country profiles

8.1. Belgium

8.1.1. Supply

Demography

Belgium can expect a 12% decrease in the total population of 18-year-olds from 1990 to 2020, as illustrated by figure 55. The actual change from 1990 to 2008 was an 8% decrease, and the projected change from 2008 to 2020 is a 4% decrease. The linear trend over the period 1990-2025 is, however, insignificant (<3%).

The primary trend for the development indicator on demography (D-I) is the linear trend over the period 1990/1993-2025/2030, which generates the preliminary indicator value 0 for Belgium. The secondary trend (D-II) is the projected change from 2005/2008 to 2020. This does not affect the analysis, and sets the final development indicator on demography for Belgium to 0.

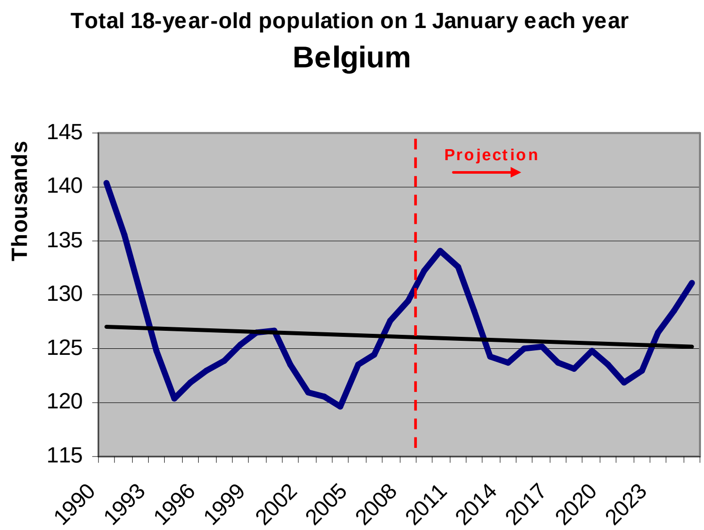

Figure 55 (Data source: Eurostat, 2009a; Eurostat, 2009b)

Educational attainment

The final development indicator on educational attainment for Belgium is set to 1. (See 2.3.2 Educational attainment for a general analysis)

Choice of MST education

Upper secondary school

No additional data has been found. (See sections 2.2.2 Data sources and 2.3.3. Choice of MST education)

Tertiary education

Belgium experienced a 7.0% increase in the number of graduates from mathematics, science and technology tertiary education (ISCED 5 & 6) from 1998 to 2006, as illustrated by figure 56.

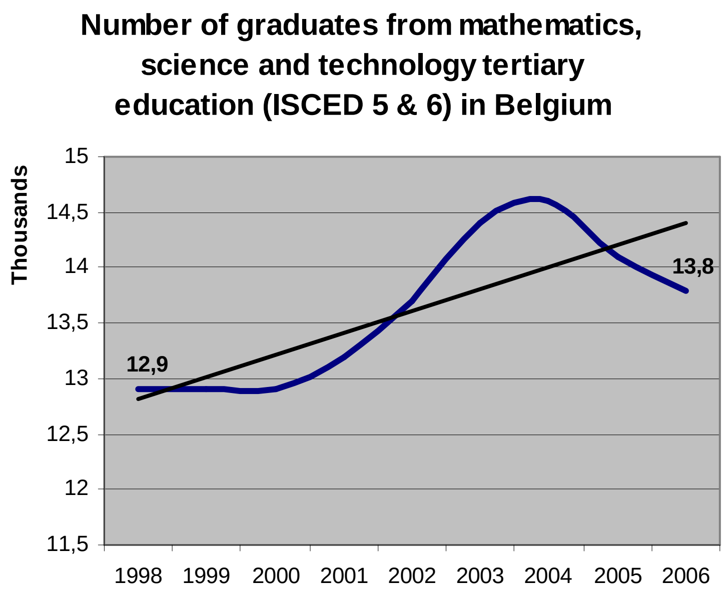

Figure 56 (Data source: Eurostat, 2009f)

As demography and educational attainment have already been accounted for, it is more interesting to look at choice of MST education in relation to the total student population. Figure 57 shows a 1.1 percentage unit or 5.8% decrease in the relative share of graduates from mathematics, science and technology tertiary education (ISCED 5 & 6) among the total population of tertiary graduates in Belgium from 1998 to 2006.

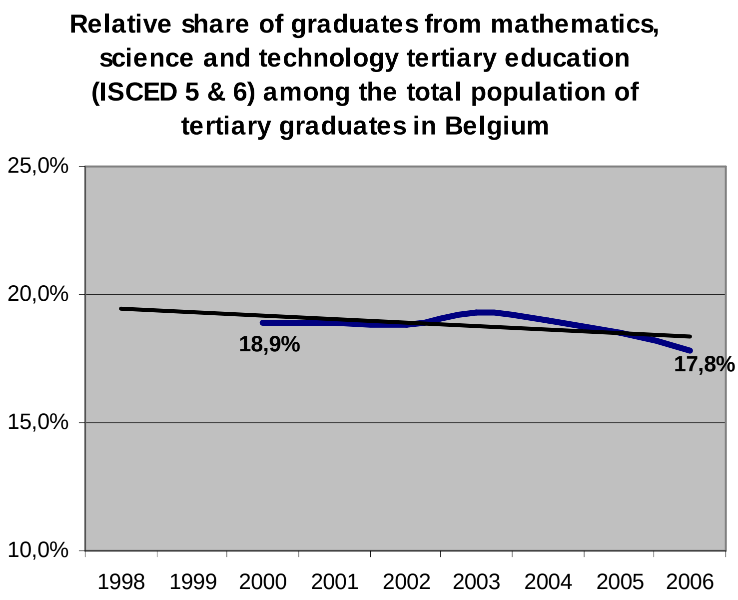

Figure 57 (Data source: Eurostat, 2009f)

Figure 58 shows a 2.0 percentage unit or 9.5% decrease in the relative share of students enrolled in mathematics, science, computing, engineering, manufacturing and construction tertiary education (ISCED 5 & 6) among the total population of tertiary students in Belgium from 1998 to 2006.

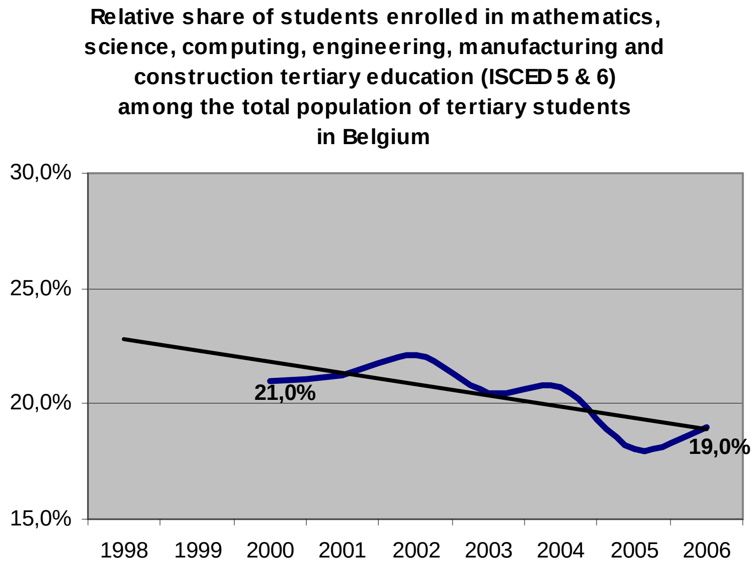

Figure 58 (Data source: Eurostat, 2009f)

The primary trend for the development indicator on choice of MST education (M-I) is the combined average of the changes in the percentage of graduates from mathematics, science and technology tertiary education and the percentage of students enrolled in mathematics, science, computing, engineering manufacturing and construction tertiary education, which generates the preliminary indicator value -2 for Belgium. The secondary trend (M-II) is not applicable, which sets the final development indicator on choice of MST education for Belgium to -2.

Supply development indicator

The assigned development indicators for Belgium are illustrated in figure 59 together with the combined indicator for Belgium constructed according to section 2.2.4. Belgium is facing a somewhat negative trend in the supply of human resources in MST. This is due to a very negative trend in choice of MST education, partly counterbalanced by a positive trend in educational attainment.

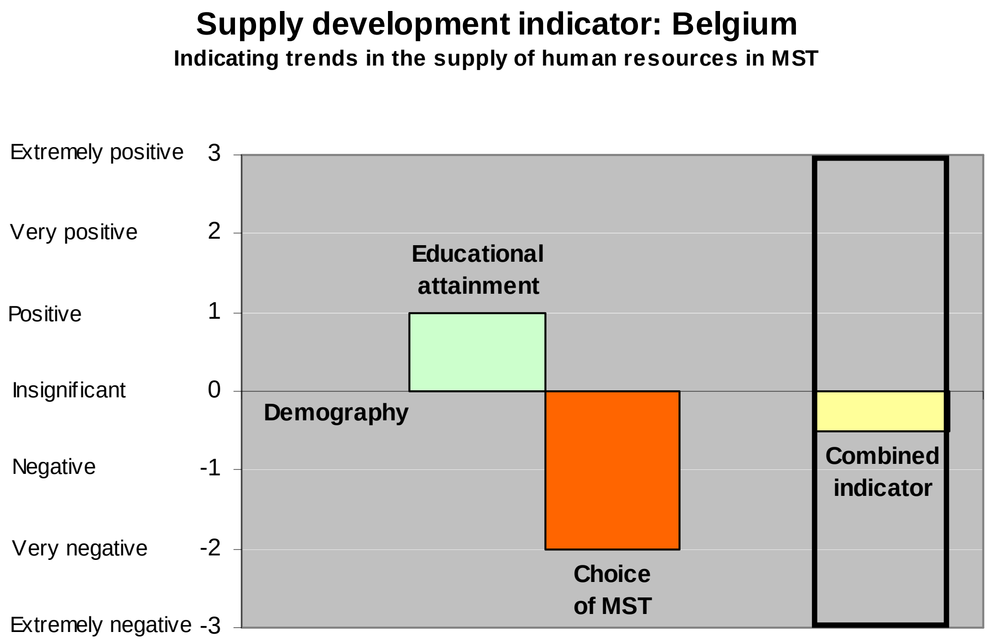

Figure 59

8.1.2. Demand

Age pyramid (See 2.4 for a general analysis)

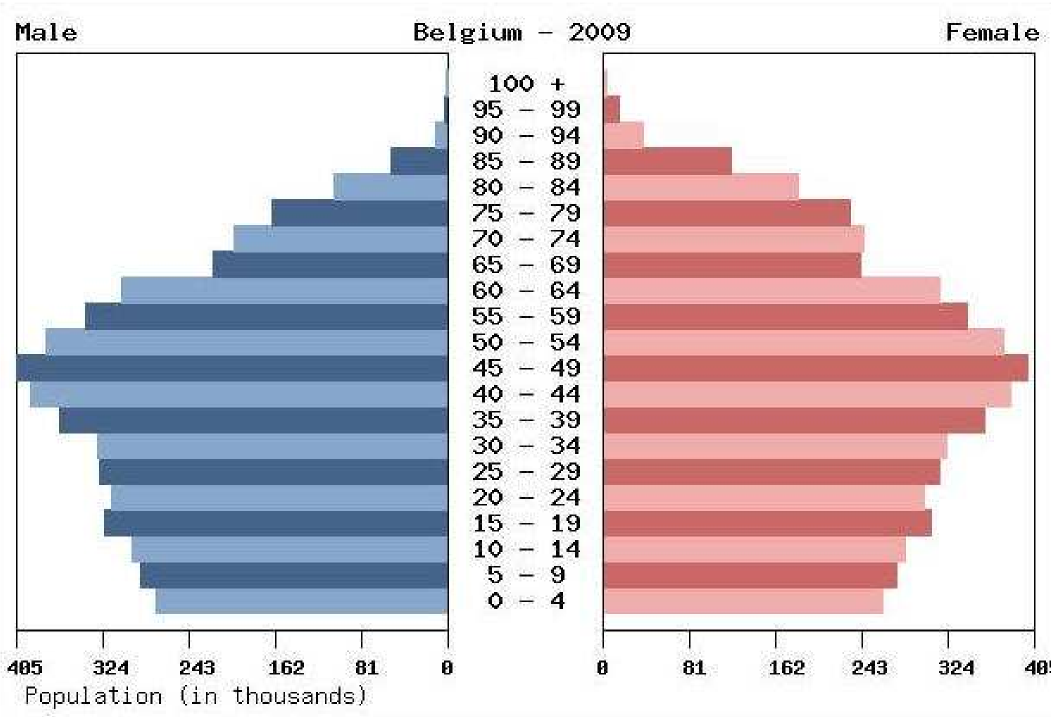

Figure 60 (Source: U.S. Census Bureau, 2009)

8.2. *Finland*

8.2.1. Supply

Demography

Finland can expect a 5% decrease in the total population of 18-year-olds from 1990 to 2020, as illustrated by figure 61. The actual change from 1990 to 2008 was a 7% increase, and the projected change from 2008 to 2020 is an 11% decrease. The linear trend over the period 1990-2025 is negative (~5%).

The primary trend for the development indicator on demography (D-I) is the linear trend over the period 1990/1993-2025/2030, which generates the preliminary indicator value -1 for Finland. The secondary trend (D-II) is the projected change from 2005/2008 to 2020. This does not affect the analysis, and sets the final development indicator on demography for Finland to -1.

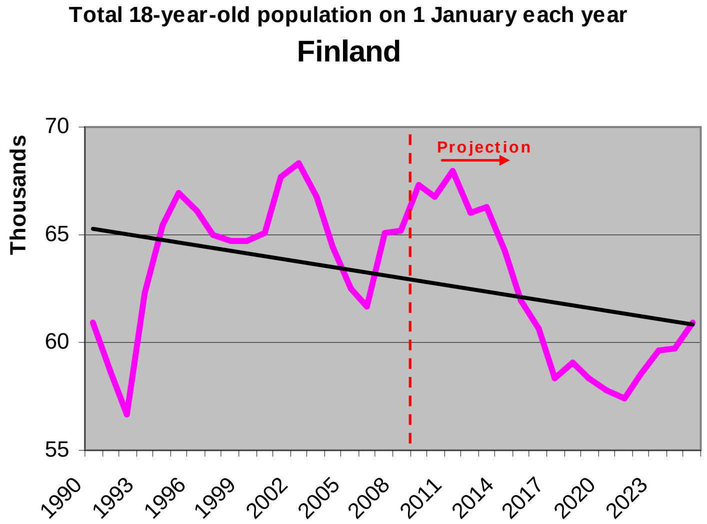

Figure 61 (Data source: Eurostat, 2009a; Eurostat, 2009b)

Educational attainment

The final development indicator on educational attainment for Finland is set to 1. (See 2.3.2 Educational attainment for a general analysis)

Choice of MST education

Upper secondary school

No additional data has been found. (See sections 2.2.2 Data sources and 2.3.3. Choice of MST education)

Tertiary education

Finland experienced a 16.7% increase in the number of graduates from mathematics, science and technology tertiary education (ISCED 5 & 6) from 1998 to 2006, as illustrated by figure 62.

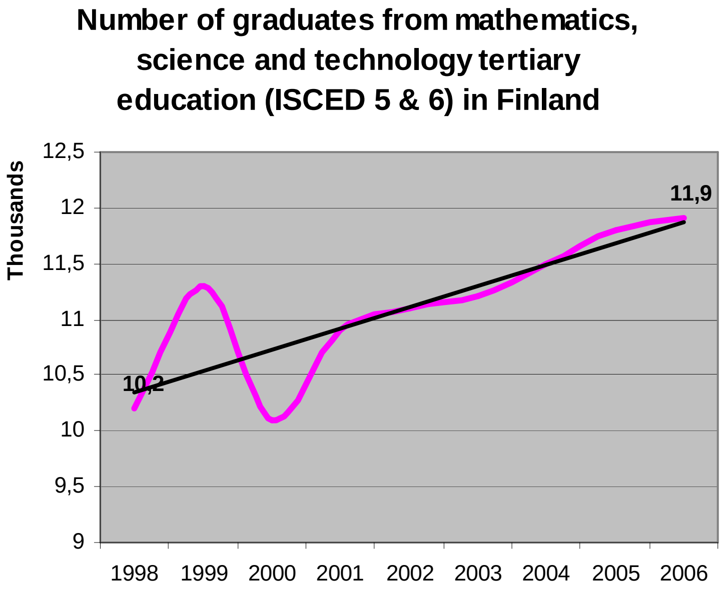

Figure 62 (Data source: Eurostat, 2009f)

As demography and educational attainment have already been accounted for, it is more interesting to look at choice of MST education in relation to the total student population. Figure 63 shows a 3.3 percentage unit or 12.6% increase in the relative share of graduates from mathematics, science and technology tertiary education (ISCED 5 & 6) among the total population of tertiary graduates in Finland from 1998 to 2006.

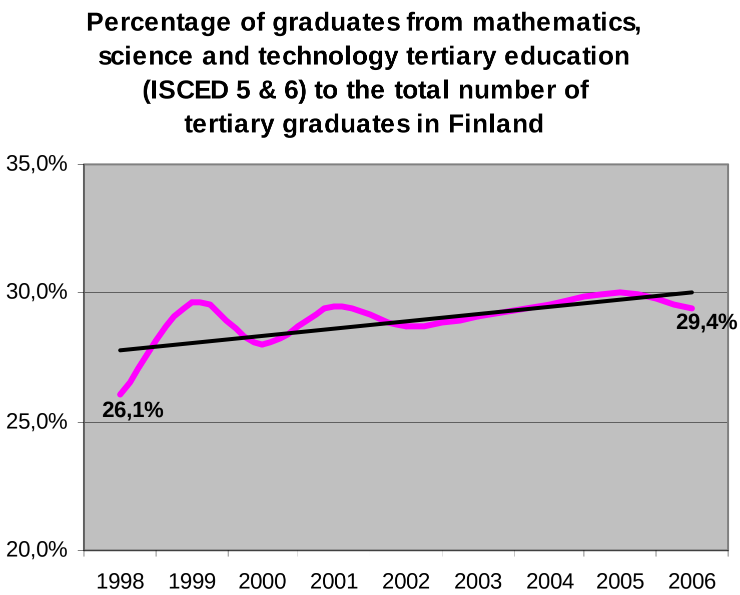

Figure 63 (Data source: Eurostat, 2009f)

Figure 64 shows a 3.0 percentage unit or 8.7% increase in the relative share of students enrolled in mathematics, science, computing, engineering, manufacturing and construction tertiary education (ISCED 5 & 6) among the total population of tertiary students in Finland from 1998 to 2006.

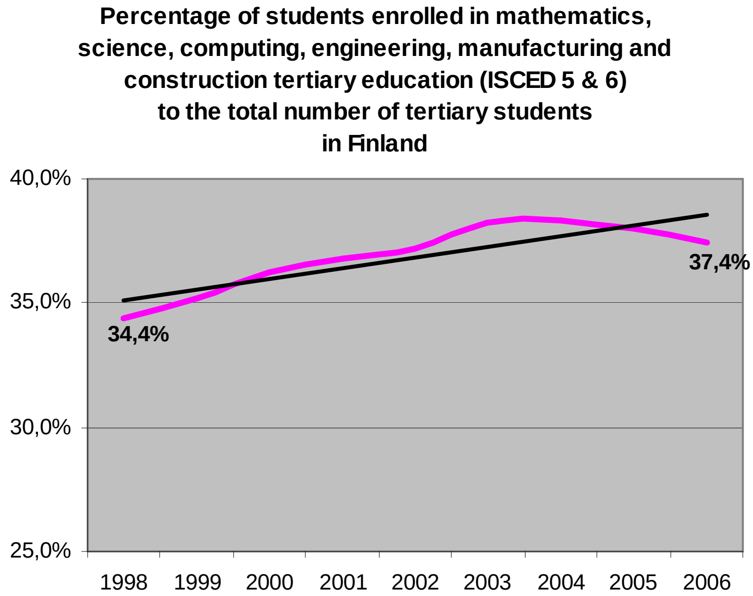

Figure 64 (Data source: Eurostat, 2009f)

The primary trend for the development indicator on choice of MST education (M-I) is the combined average of the changes in the percentage of graduates from mathematics, science and technology tertiary education and the percentage of students enrolled in mathematics, science, computing, engineering manufacturing and construction tertiary education, which generates the preliminary indicator value 2 for Finland. The secondary trend (M-II) is not applicable, which sets the final development indicator on choice of MST education for Finland to 2.

Supply development indicator

The assigned development indicators for Finland are illustrated in figure 65 together with the combined indicator for Finland constructed according to section 2.2.4. Finland is facing a positive trend in the supply of human resources in MST. The most important contributing factor is a very positive trend in choice of MST education.

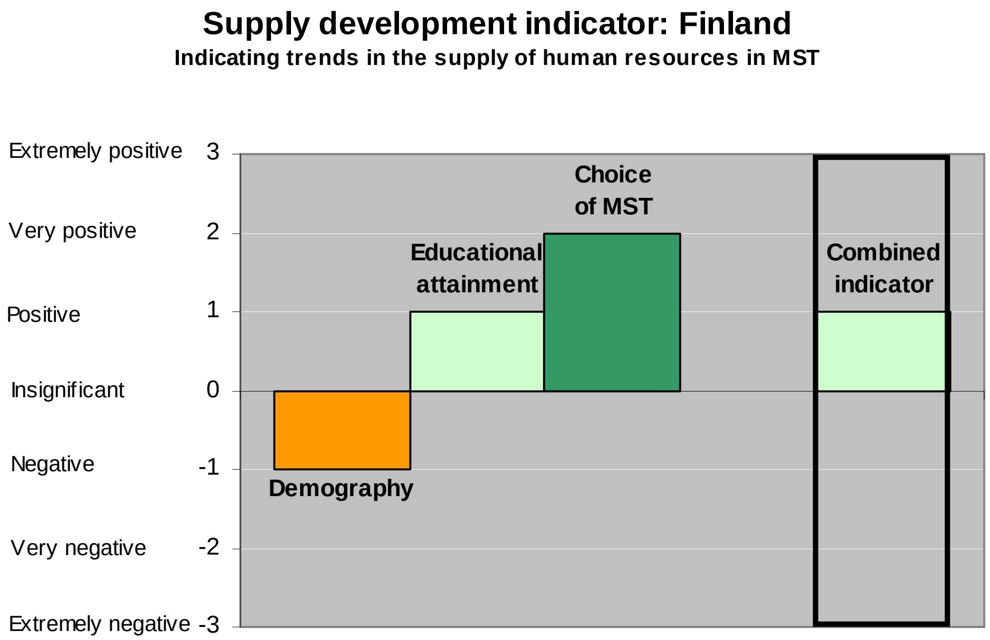

Figure 65

8.2.2. Demand

Age pyramid (See 2.4 for a general analysis)

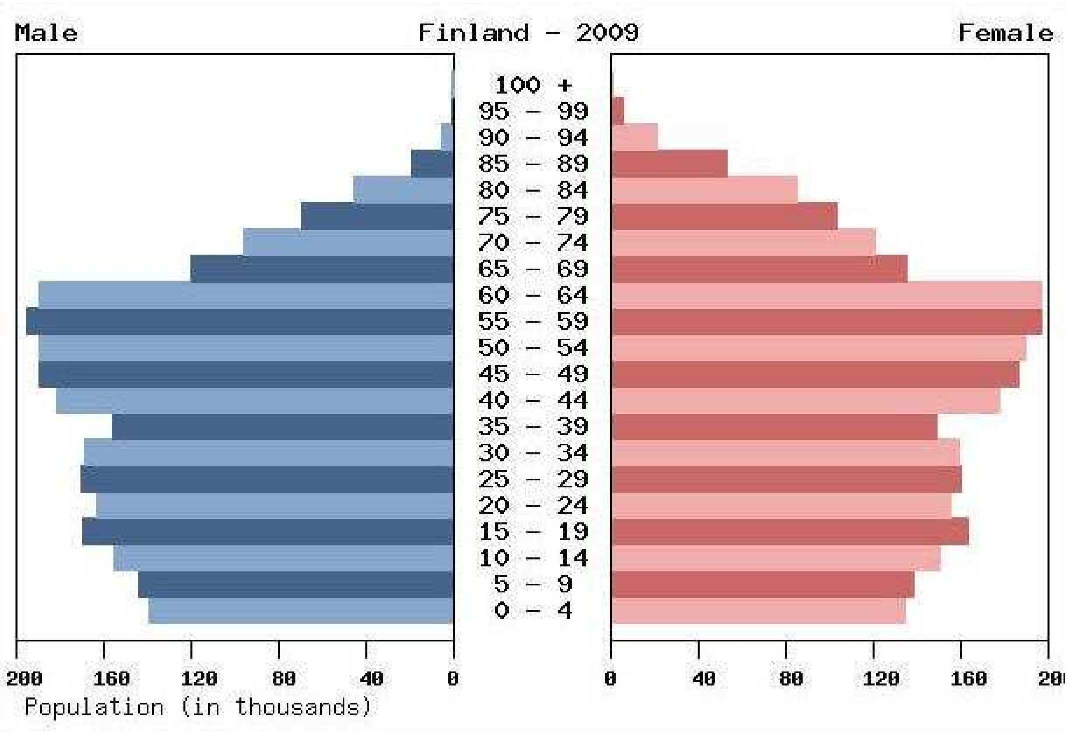

Figure 66 (Source: U.S. Census Bureau, 2009)

8.3. France

8.3.1. Supply

Demography

France can expect an 11% decrease in the total population of 18-year-olds from 1990 to 2020, as illustrated by figure 67. The actual change from 1990 to 2008 was a 12% decrease, and the projected change from 2008 to 2020 is a 1% increase. The linear trend over the period 1990-2025 is negative (~5%).

The primary trend for the development indicator on demography (D-I) is the linear trend over the period 1990/1993-2025/2030, which generates the preliminary indicator value -1 for France. The secondary trend (D-II) is the projected change from 2005/2008 to 2020. This does not affect the analysis, and sets the final development indicator on demography for France to -1.

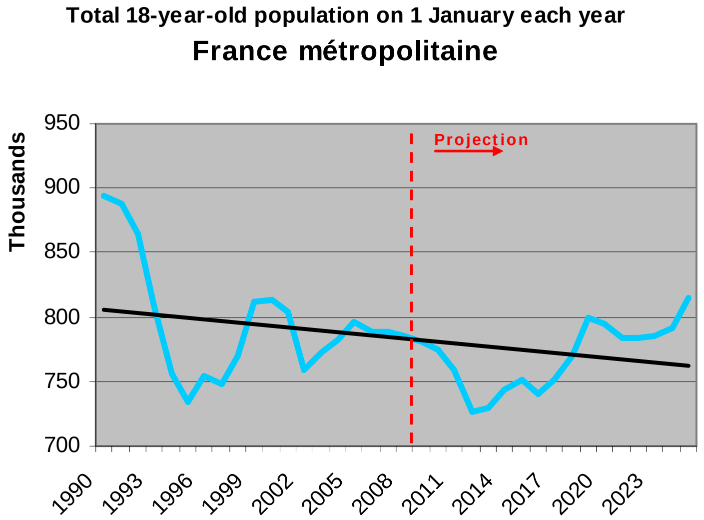

Figure 67 (Data source: Eurostat, 2009a; Eurostat, 2009b)

Educational attainment

The final development indicator on educational attainment for France is set to 1. (See 2.3.2 Educational attainment for a general analysis)

Choice of MST education

Upper secondary school

No additional data has been found. (See sections 2.2.2 Data sources and 2.3.3. Choice of MST education)

Tertiary education

France experienced an 11,5% increase in the number of graduates from mathematics, science and technology tertiary education (ISCED 5 & 6) from 1998 to 2006, as illustrated by figure 68.

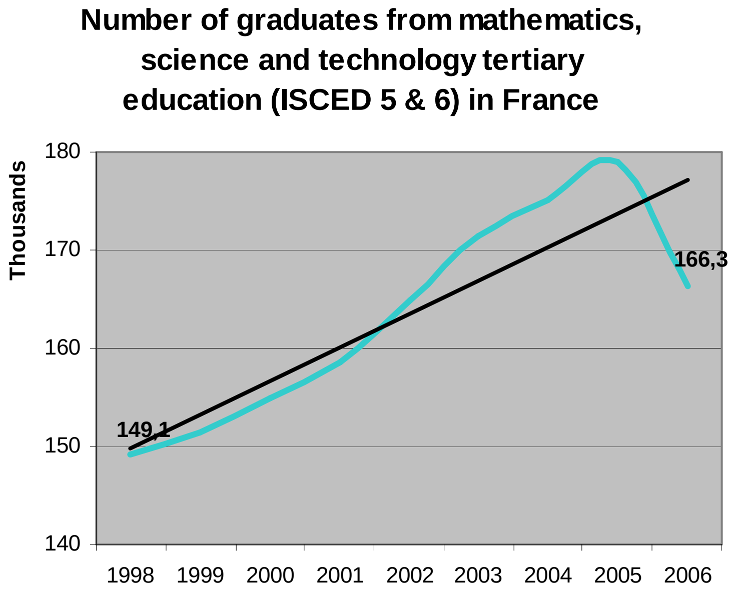

Figure 68 (Data source: Eurostat, 2009f)

As demography and educational attainment have already been accounted for, it is more interesting to look at choice of MST education in relation to the total student population. Figure 69 shows a 4.9 percentage unit or 16.0% decrease in the relative share of graduates from mathematics, science and technology tertiary education (ISCED 5 & 6) among the total population of tertiary graduates in France from 1998 to 2006.

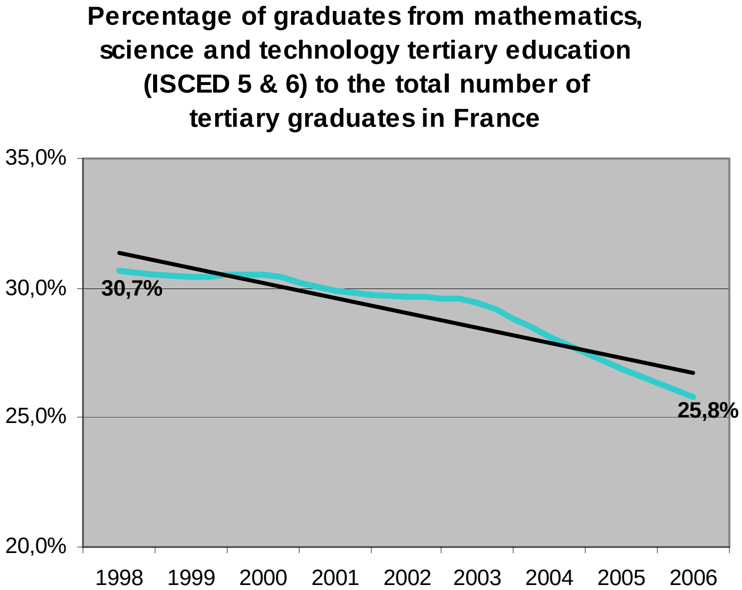

Figure 69 (Data source: Eurostat, 2009f)

The primary trend for the development indicator on choice of MST education (M-I) is the combined average of the changes in the percentage of graduates from mathematics, science and technology tertiary education and the percentage of students enrolled in mathematics, science, computing, engineering manufacturing and construction tertiary education, which generates the preliminary indicator value -3 for France. The secondary trend (M-II) is not applicable, which sets the final development indicator on choice of MST education for France to -3.

Supply development indicator

The assigned development indicators for France are illustrated in figure 70 together with the combined indicator for France constructed according to section 2.2.4. France is facing a negative trend in the supply of human resources in MST. The most important contributing factor is an extremely negative trend in choice of MST education.

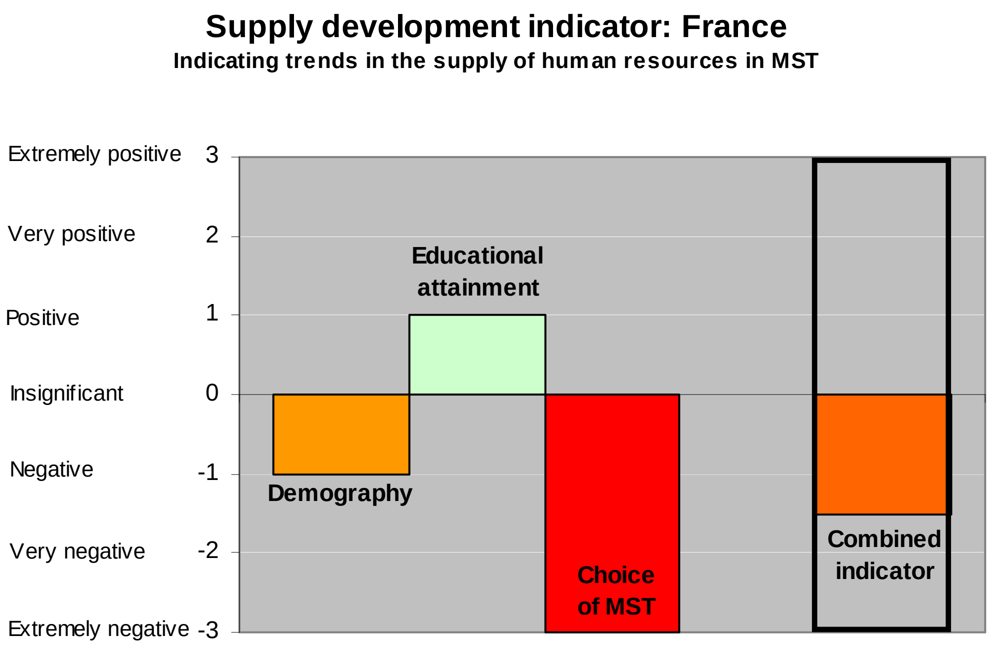

Figure 70

8.3.2. Demand

Age pyramid (See 2.4 for a general analysis)

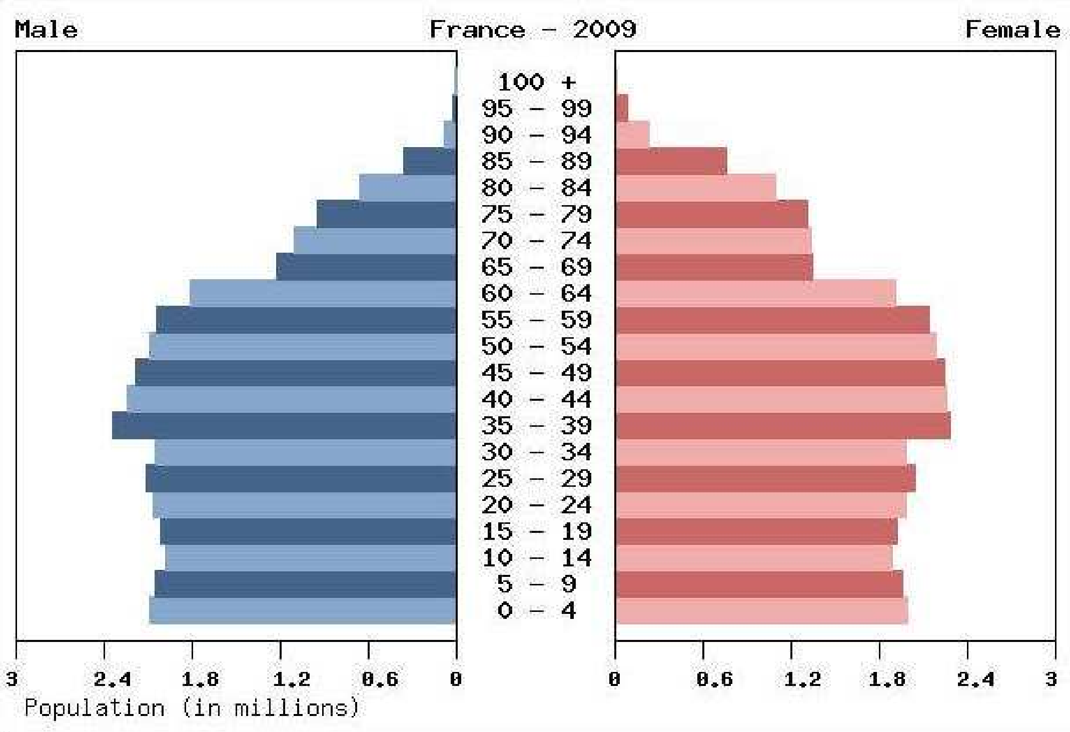

Figure 71 (Source: U.S. Census Bureau, 2009)

8.4. *Germany*

8.4.1. Supply

Demography

Germany can expect a 26% decrease in the total population of 18-year-olds from 1990 to 2020, as illustrated by figure 72. The actual change from 1990 to 2008 was a 6% decrease, and the projected change from 2008 to 2020 is a 21% decrease. The linear trend over the period 1990-2025 is extremely negative (~20%).

The primary trend for the development indicator on demography (D-I) is the linear trend over the period 1990/1993-2025/2030, which generates the preliminary indicator value -3 for Germany. The secondary trend (D-II) is the projected change from 2005/2008 to 2020. This does not affect the analysis, and sets the final development indicator on demography for Germany to -3.

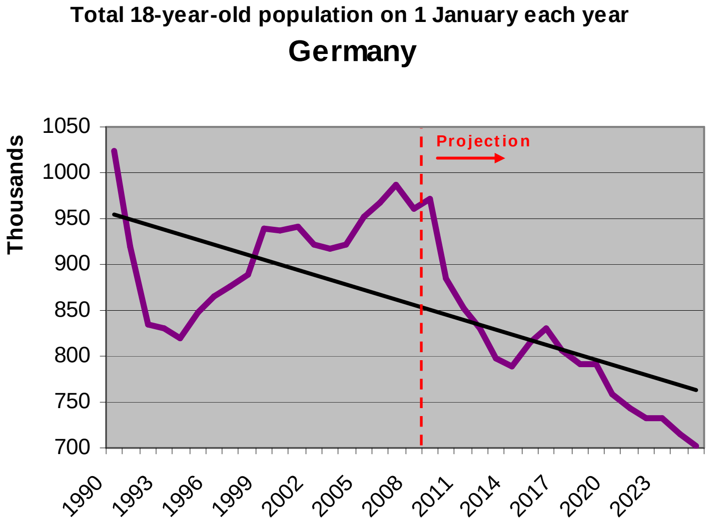

Figure 72 (Data source: Eurostat, 2009a; Eurostat, 2009b)

Educational attainment

The final development indicator on educational attainment for Germany is set to 1. (See 2.3.2 Educational attainment for a general analysis)

Choice of MST education

Upper secondary school

No additional data has been found. (See sections 2.2.2 Data sources and 2.3.3. Choice of MST education)

Tertiary education

Germany experienced a 13.0% increase in the number of graduates from mathematics, science and technology tertiary education (ISCED 5 & 6) from 1998 to 2006, as illustrated by figure 73.

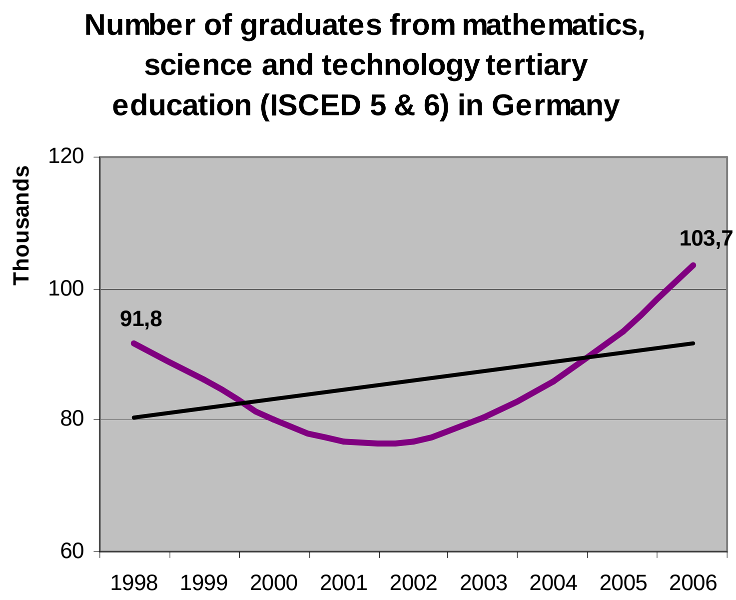

Figure 73 (Data source: Eurostat, 2009f)

As demography and educational attainment have already been accounted for, it is more interesting to look at choice of MST education in relation to the total student population. Figure 74 shows a 3.5 percentage unit or 12.2% decrease in the relative share of graduates from mathematics, science and technology tertiary education (ISCED 5 & 6) among the total population of tertiary graduates in Germany from 1998 to 2006.

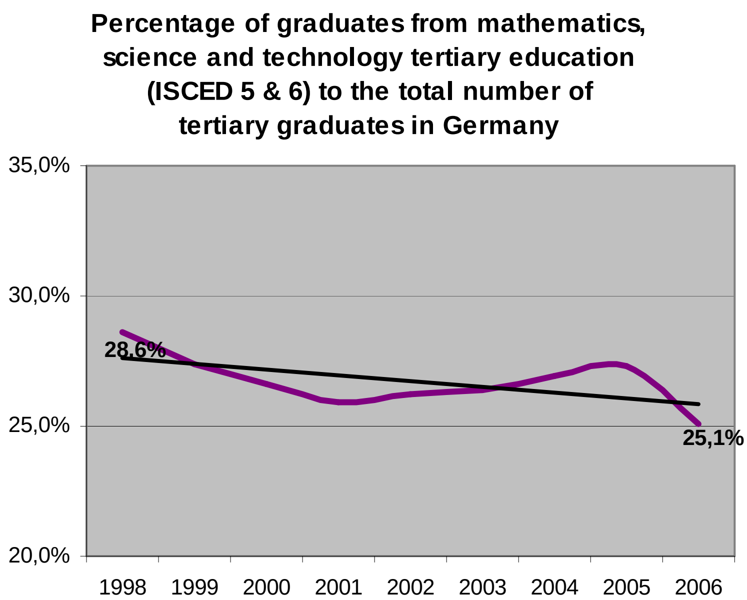

Figure 74 (Data source: Eurostat, 2009f)

Figure 75 shows a 2.4 percentage unit or 8.4% increase in the relative share of students enrolled in mathematics, science, computing, engineering, manufacturing and construction tertiary education (ISCED 5 & 6) among the total population of tertiary students in Germany from 1998 to 2006.

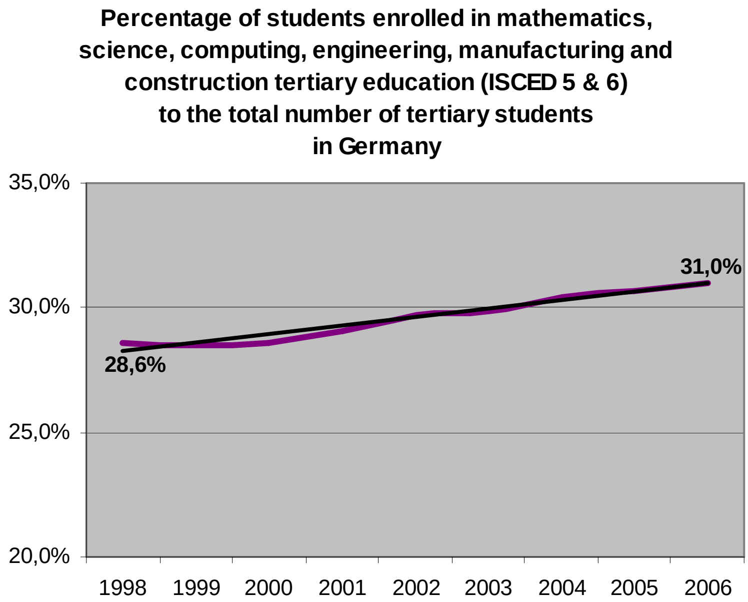

Figure 75 (Data source: Eurostat, 2009f)

The primary trend for the development indicator on choice of MST education (M-I) is the combined average of the changes in the percentage of graduates from mathematics, science and technology tertiary education and the percentage of students enrolled in mathematics, science, computing, engineering manufacturing and construction tertiary education, which generates the preliminary indicator value -1 for Germany. The secondary trend (M-II) is not applicable, which sets the final development indicator on choice of MST education for Germany to -1.

Supply development indicator

The assigned development indicators for Germany are illustrated in figure 76 together with the combined indicator for Germany constructed according to section 2.2.4. Germany is facing a negative trend in the supply of human resources in MST. The most important contributing factor is an extremely negative trend in demography.

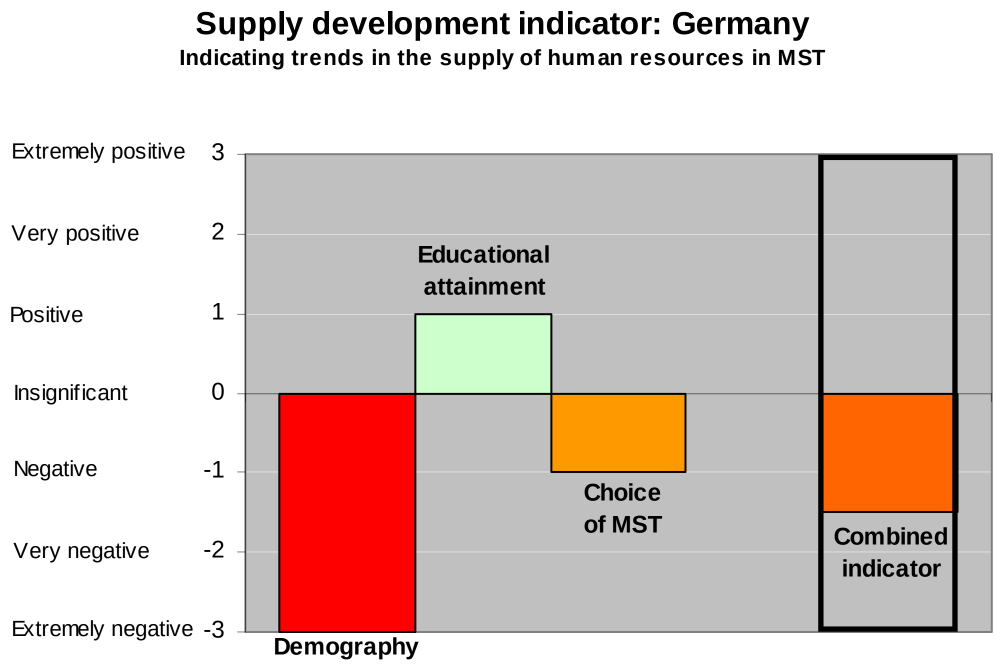

Figure 76

8.4.2. Demand

Age pyramid (See 2.4 for a general analysis)

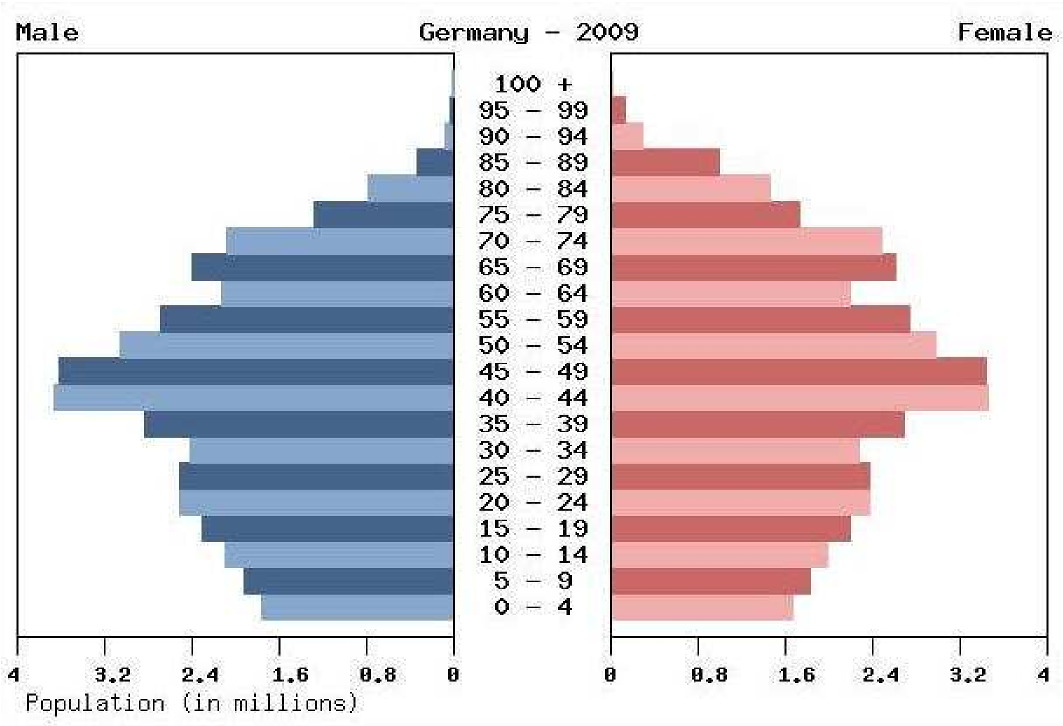

Figure 77 (Source: U.S. Census Bureau, 2009)

8.5. *Ireland*

8.5.1. Supply

Demography

Ireland can expect a 2% increase in the total population of 18-year-olds from 1990 to 2020, as illustrated by figure 78. The actual change from 1990 to 2008 was a 12% decrease, and the projected change from 2008 to 2020 is a 17% increase. The linear trend over the period 1990-2025 is positive (~5%).

The primary trend for the development indicator on demography (D-I) is the linear trend over the period 1990/1993-2025/2030, which generates the preliminary indicator value 2 for Ireland. The secondary trend (D-II) is the projected change from 2005/2008 to 2020. The large increase affects the analysis by +1, and sets the final development indicator on demography for Ireland to 2.

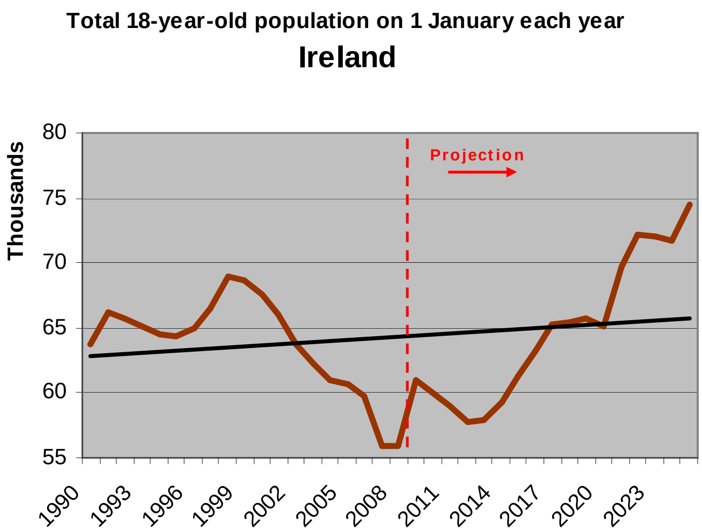

Figure 78 (Data source: Eurostat, 2009a; Eurostat, 2009b)

Educational attainment

The final development indicator on educational attainment for Ireland is set to 1. (See 2.3.2 Educational attainment for a general analysis)

Choice of MST education

Upper secondary school

No additional data has been found. (See sections 2.2.2 Data sources and 2.3.3. Choice of MST education)

Tertiary education

Ireland experienced a 17.7% increase in the number of graduates from mathematics, science and technology tertiary education (ISCED 5 & 6) from 1998 to 2006, as illustrated by figure 79.

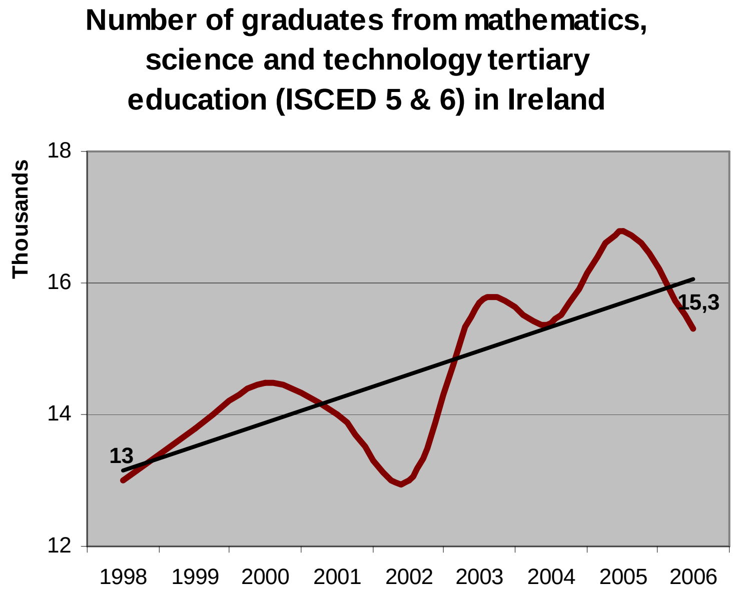

Figure 79 (Data source: Eurostat, 2009f)

As demography and educational attainment have already been accounted for, it is more interesting to look at choice of MST education in relation to the total student population. Figure 80 shows a 6.2 percentage unit or 19.3% decrease in the relative share of graduates from mathematics, science and technology tertiary education (ISCED 5 & 6) among the total population of tertiary graduates in Ireland from 1998 to 2006.

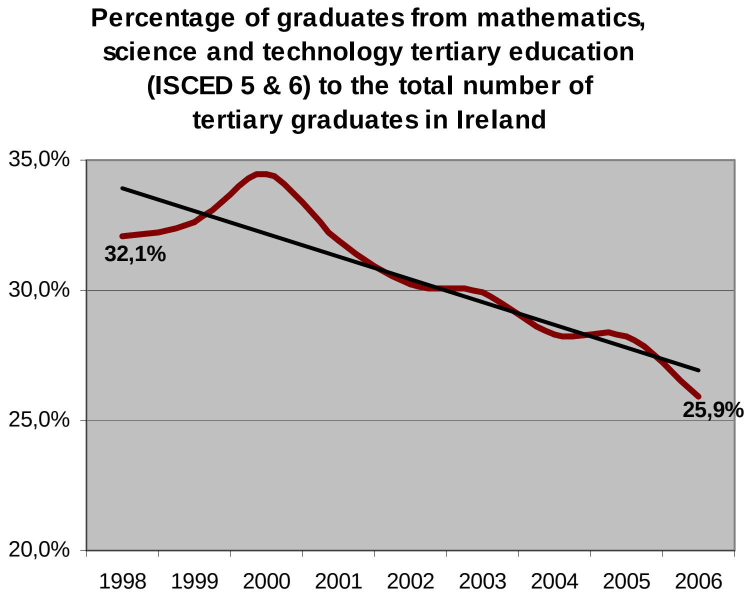

Figure 80 (Data source: Eurostat, 2009f)

Figure 81 shows a 8.2 percentage unit or 23.9% decrease in the relative share of students enrolled in mathematics, science, computing, engineering, manufacturing and construction tertiary education (ISCED 5 & 6) among the total population of tertiary students in Ireland from 1998 to 2006.

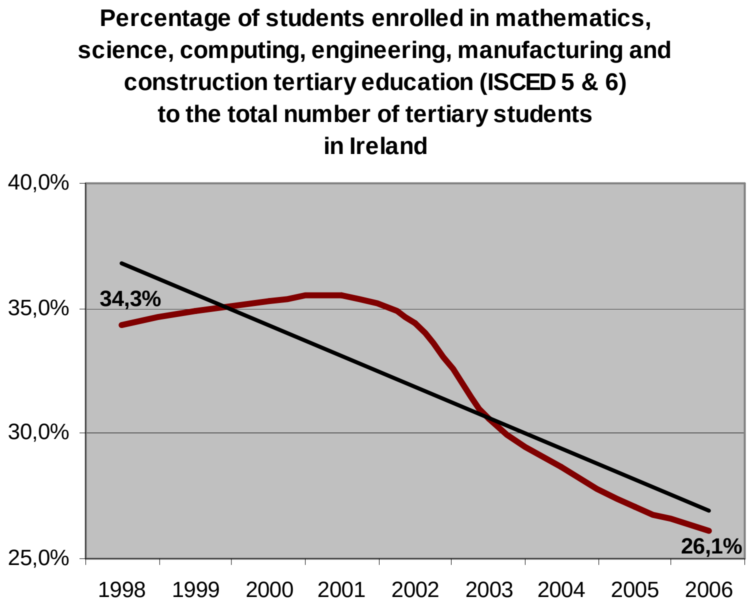

Figure 81 (Data source: Eurostat, 2009f)

The primary trend for the development indicator on choice of MST education (M-I) is the combined average of the changes in the percentage of graduates from mathematics, science and technology tertiary education and the percentage of students enrolled in mathematics, science, computing, engineering manufacturing and construction tertiary education, which generates the preliminary indicator value -3 for Ireland. The secondary trend (M-II) is not applicable, which sets the final development indicator on choice of MST education for Ireland to -3.

Supply development indicator

The assigned development indicators for Ireland are illustrated in figure 82 together with the combined indicator for Ireland constructed according to section 2.2.4. Ireland is not facing any significant trend in the supply of human resources in MST. However, the combined indicator hides an extremely negative trend in choice of MST education, which has been counterbalanced by a very positive trend in demography and a positive trend in educational attainment.

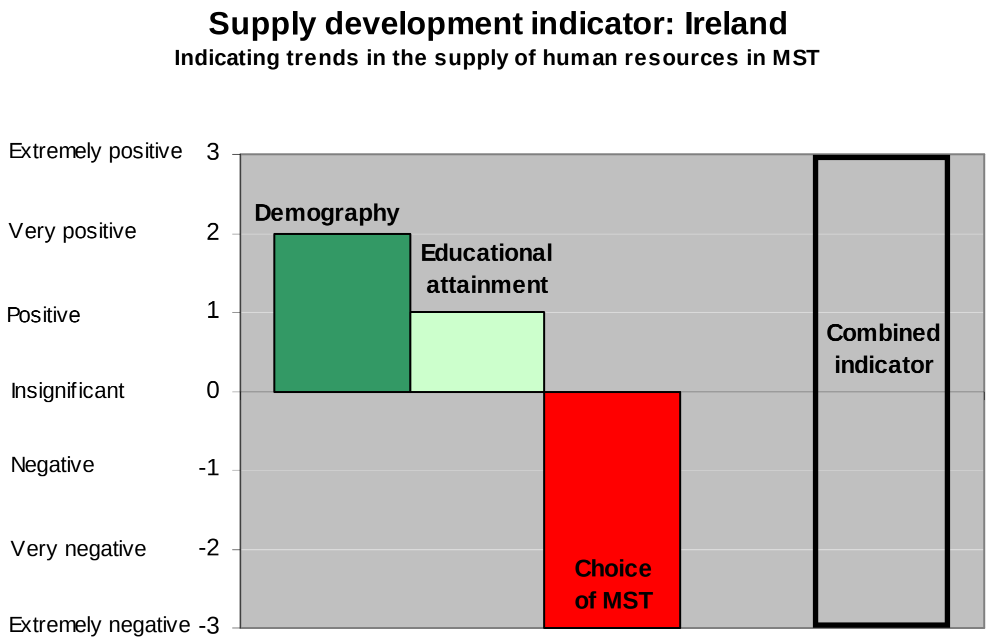

Figure 82

8.5.2. Demand

Age pyramid (See 2.4 for a general analysis)

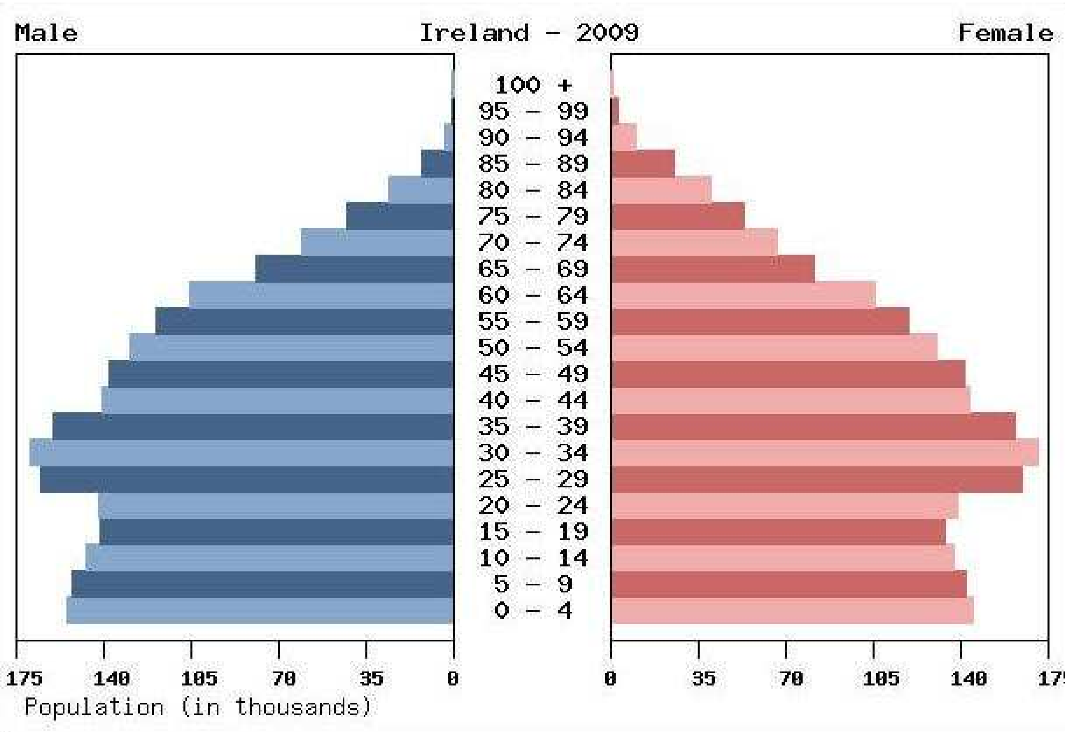

Figure 83 (Source: U.S. Census Bureau, 2009)

8.6. *Italy*

8.6.1. Supply

Demography

Italy can expect a 35% decrease in the total population of 18-year-olds from 1990 to 2020; as illustrated by figure 84. The actual change from 1990 to 2008 was a 34% decrease, and the projected change from 2008 to 2020 is a 3% decrease. The linear trend over the period 1990-2025 is extremely negative (~35%).

The primary trend for the development indicator on demography (D-I) is the linear trend over the period 1990/1993-2025/2030, which generates the preliminary indicator value -3 for Italy. The secondary trend (D-II) is the projected change from 2005/2008 to 2020. The stabilisation affects the analysis by +1, and sets the final development indicator on demography for Italy to -2.

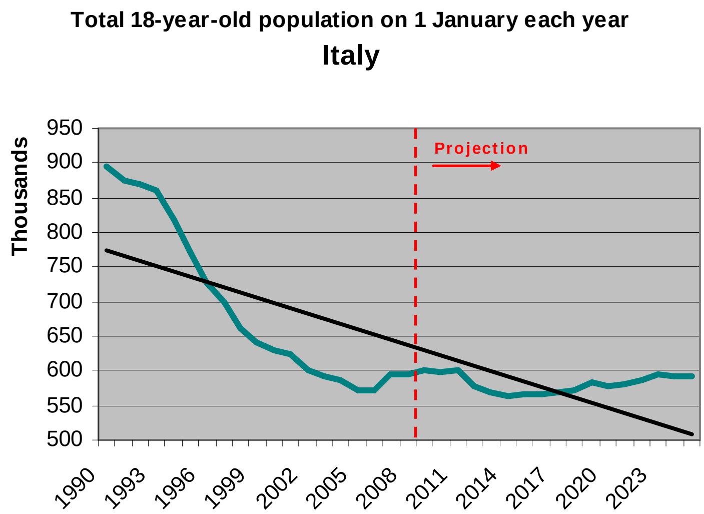

Figure 84 (Data source: Eurostat, 2009a; Eurostat, 2009b)

Educational attainment

The final development indicator on educational attainment for Italy is set to 2. (See 2.3.2 Educational attainment for a general analysis)

Choice of MST education

Upper secondary school

No additional data has been found. (See sections 2.2.2 Data sources and 2.3.3. Choice of MST education)

See section 3.2.3. No additional data has been found.

Tertiary education

Italy experienced a 1.5 percentage unit or 6.2% decrease in the relative share of graduates from mathematics, science and technology tertiary education (ISCED 5 & 6) among the total population of tertiary graduates from 1998 to 2006, as illustrated by figure 85.

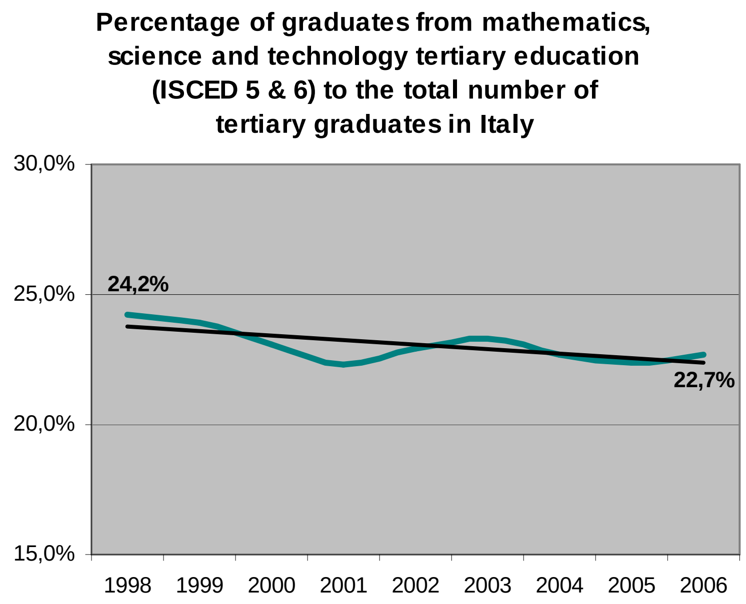

Figure 85 (Data source: Eurostat, 2009f)

Figure 86 shows a 3.6 percentage unit or 13.2% decrease in the relative share of students enrolled in mathematics, science, computing, engineering, manufacturing and construction tertiary education (ISCED 5 & 6) among the total population of tertiary students in Italy from 1998 to 2006.

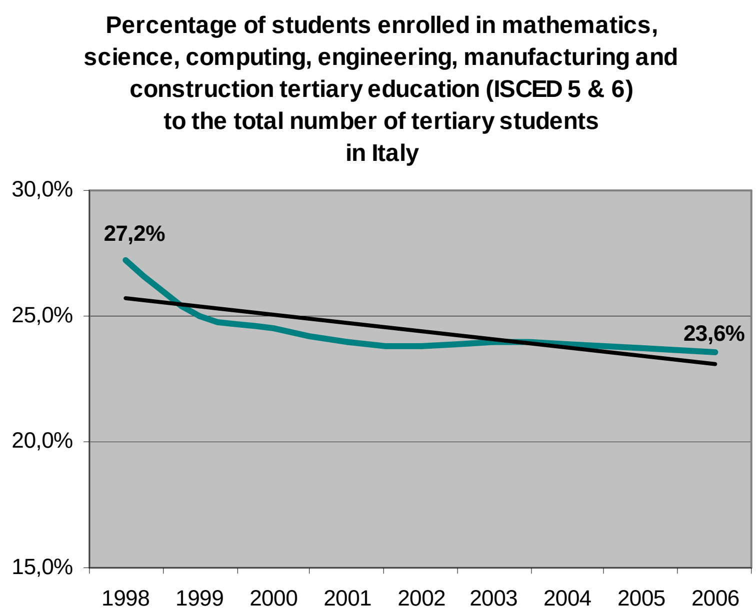

Figure 86 (Data source: Eurostat, 2009f)

The primary trend for the development indicator on choice of MST education (M-I) is the combined average of the changes in the percentage of graduates from mathematics, science and technology tertiary education and the percentage of students enrolled in mathematics, science, computing, engineering manufacturing and construction tertiary education, which generates the preliminary indicator value -2 for Italy. The secondary trend (M-II) is not applicable, which sets the final development indicator on choice of MST education for Italy to -2.

Supply development indicator

The assigned development indicators for Italy are illustrated in figure 87 together with the combined indicator for Italy constructed according to section 2.2.4. Italy is facing a negative trend in the supply of human resources in MST. Very negative trends in demography and choice of MST education are both contributing factors which are somewhat counterbalanced by a very positive trend in educational attainment.

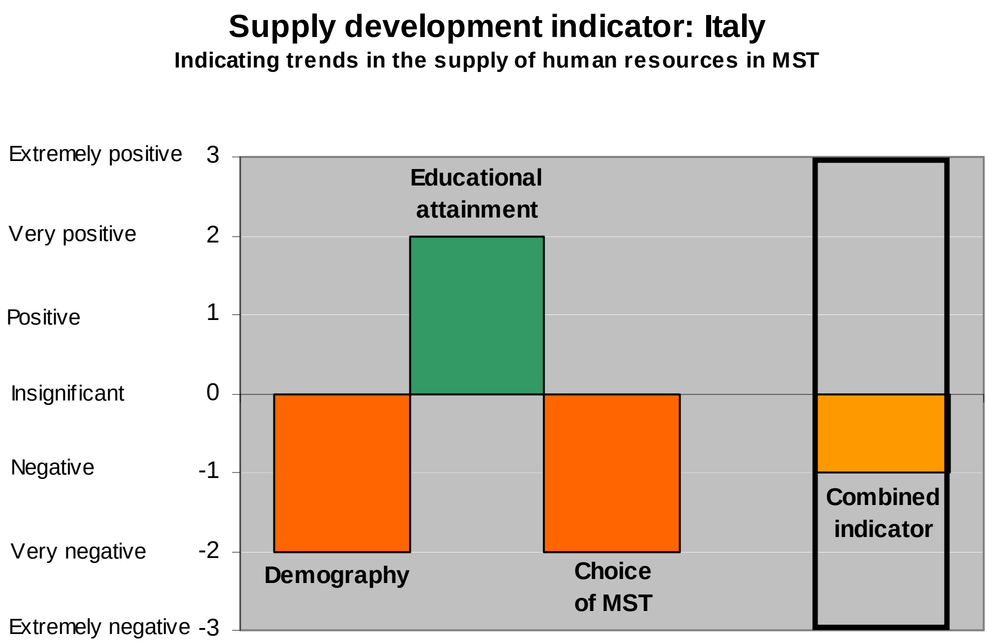

Figure 87

8.6.2. Demand

Age pyramid (See 2.4 for a general analysis)

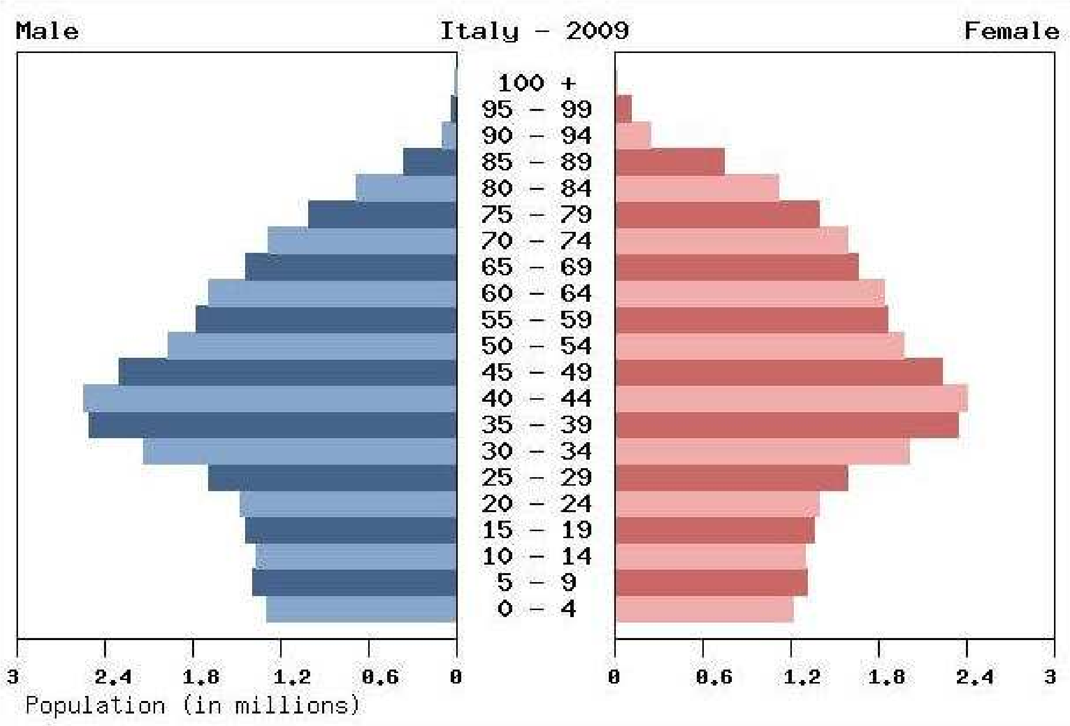

Figure 88 (Source: U.S. Census Bureau, 2009)

8.7. Netherlands

8.7.1. Supply

Demography

The Netherlands can expect a 15% decrease in the total population of 18-year-olds from 1990 to 2020, as illustrated by figure 89. The actual change from 1990 to 2008 was a 17% decrease, and the projected change from 2008 to 2020 is a 2% increase. The linear trend over the period 1990-2025 is, however, insignificant (<3%).

The primary trend for the development indicator on demography (D-I) is the linear trend over the period 1990/1993-2025/2030, which generates the preliminary indicator value 0 for the Netherlands. The secondary trend (D-II) is the projected change from 2005/2008 to 2020. This does not affect the analysis, and sets the final development indicator on demography for the Netherlands to 0.

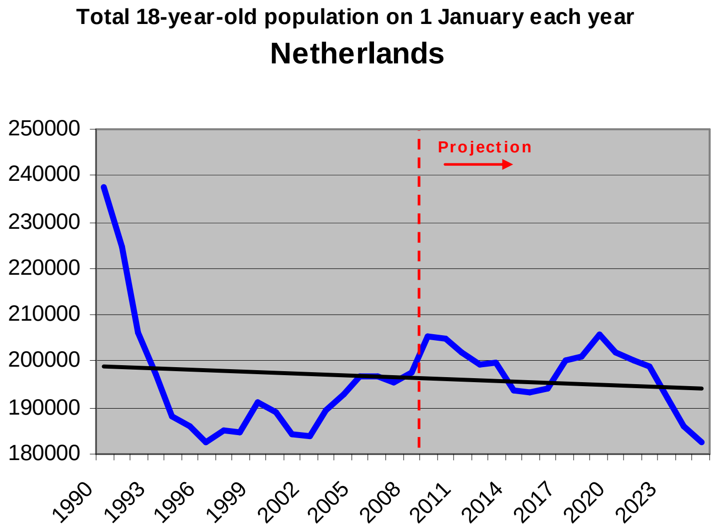

Figure 89 (Data source: Eurostat, 2009a; Eurostat, 2009b)

Educational attainment

The final development indicator on educational attainment for the Netherlands is set to 1. (See 2.3.2 Educational attainment for a general analysis)

Choice of MST education

Upper secondary school

No additional data has been found. (See sections 2.2.2 Data sources and 2.3.3. Choice of MST education)

Tertiary education

The Netherlands experienced a 29.4% increase in the number of graduates from mathematics, science and technology tertiary education (ISCED 5 & 6) from 1998 to 2006, as illustrated by figure 90.

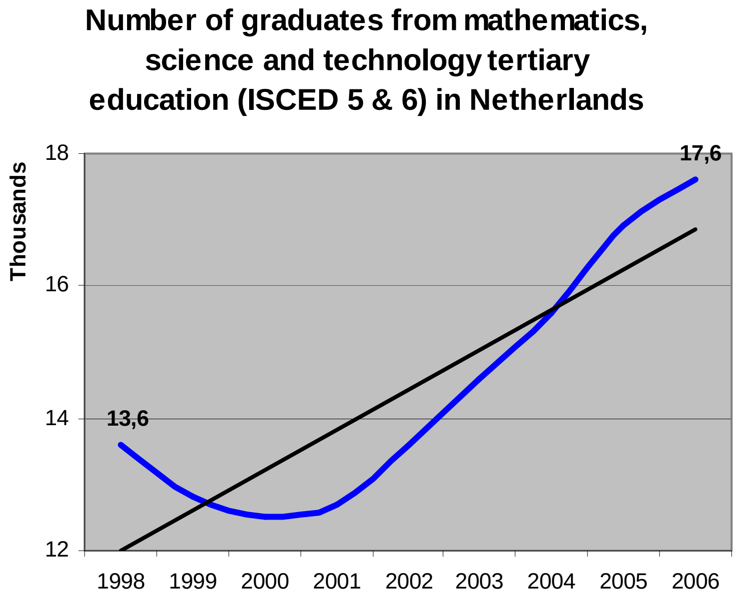

Figure 90 (Data source: Eurostat, 2009f)

As demography and educational attainment have already been accounted for, it is more interesting to look at choice of MST education in relation to the total student population. Figure 91 shows a 1.9 percentage unit or 11.2% decrease in the relative share of graduates from mathematics, science and technology tertiary education (ISCED 5 & 6) among the total population of tertiary graduates in the Netherlands from 1998 to 2006.

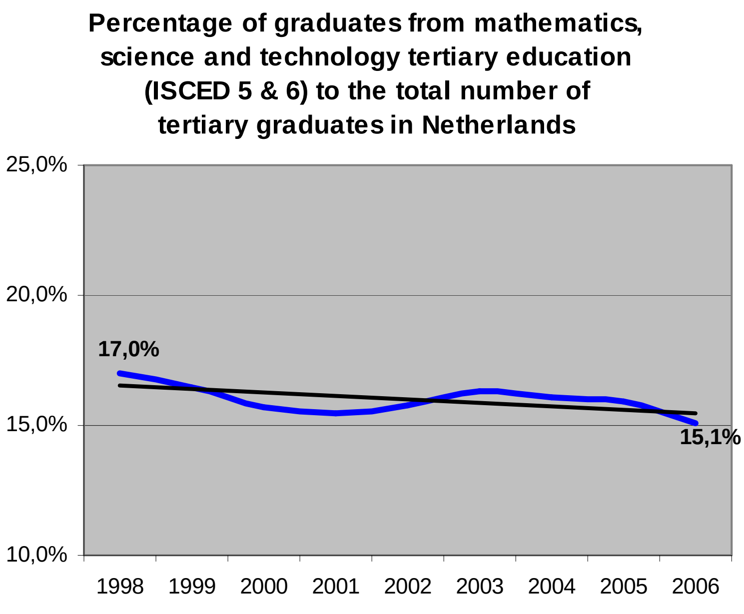

Figure 91 (Data source: Eurostat, 2009f)

Figure 92 shows a 2.2 percentage unit or 12.8% decrease in the relative share of students enrolled in mathematics, science, computing, engineering, manufacturing and construction tertiary education (ISCED 5 & 6) among the total population of tertiary students in the Netherlands from 1998 to 2006.

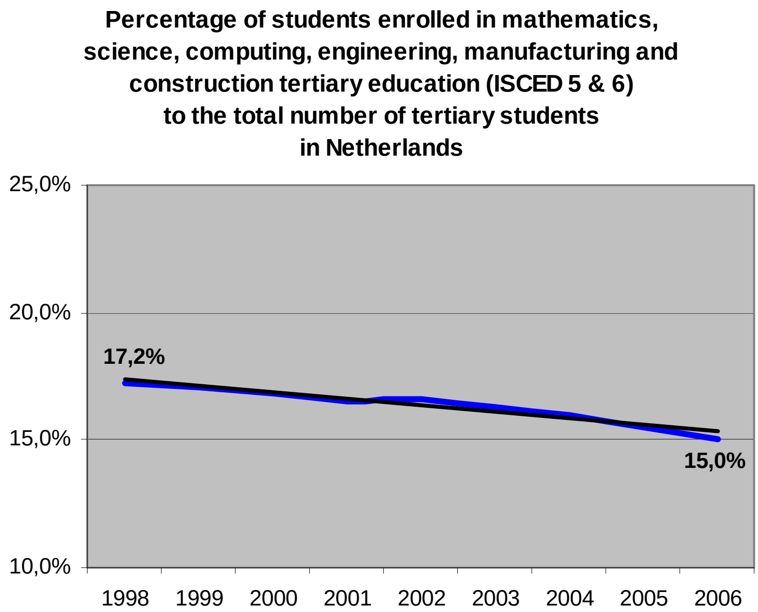

Figure 92 (Data source: Eurostat, 2009f)

The primary trend for the development indicator on choice of MST education (M-I) is the combined average of the changes in the percentage of graduates from mathematics, science and technology tertiary education and the percentage of students enrolled in mathematics, science, computing, engineering manufacturing and construction tertiary education, which generates the preliminary indicator value -2 for the Netherlands. The secondary trend (M-II) is not applicable, which sets the final development indicator on choice of MST education for the Netherlands to 0.

Supply development indicator

The assigned development indicators for the Netherlands are illustrated in figure 93 together with the combined indicator for the Netherlands constructed according to section 2.2.4. The Netherlands is facing a somewhat negative trend in the supply of human resources in MST. This is due to a very negative trend in choice of MST education, partly counterbalanced by a positive trend in educational attainment.

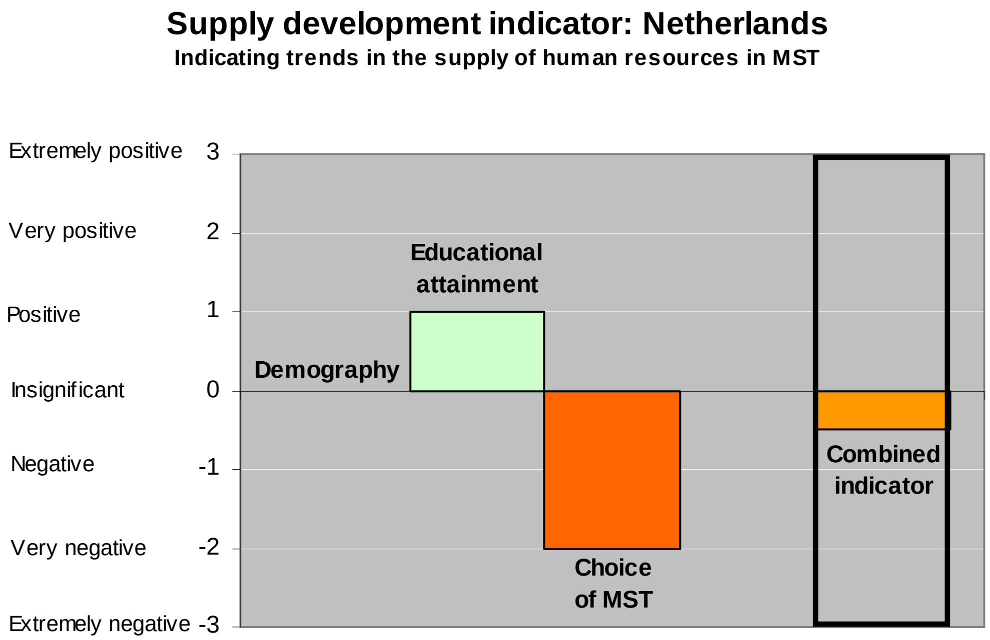

Figure 93

8.7.2. Demand

Age pyramid (See 2.4 for a general analysis)

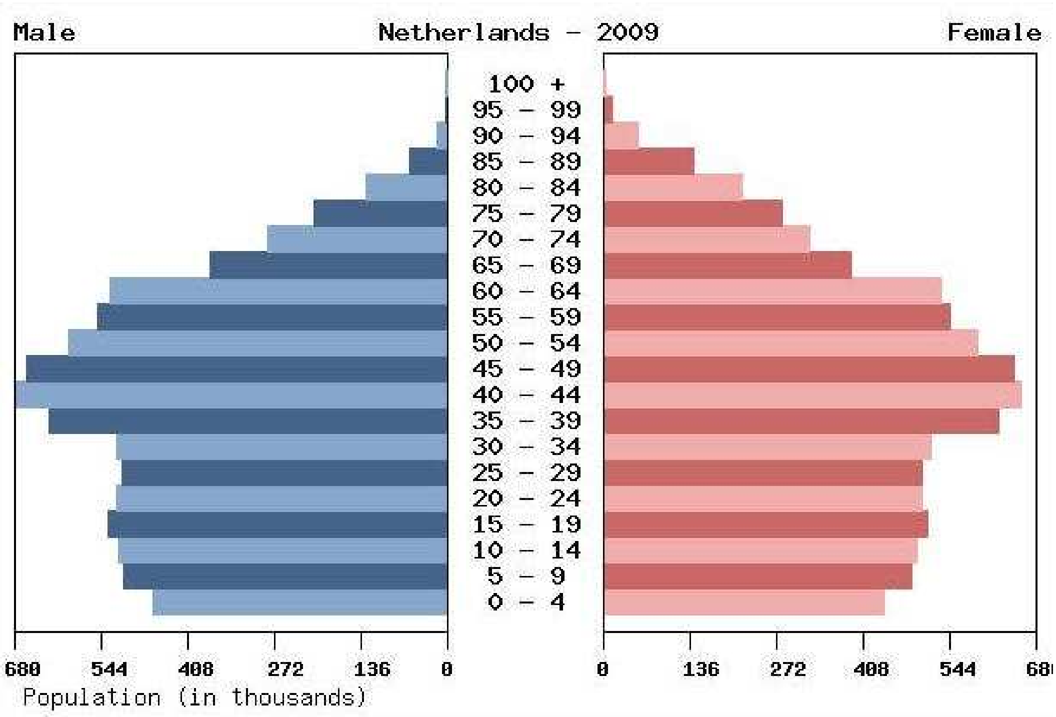

Figure 94 (Source: U.S. Census Bureau, 2009)

8.8. *Poland*

8.8.1. Supply

Demography

Poland can expect a 33% decrease in the total population of 18-year-olds from 1990 to 2020, as illustrated by figure 95. The actual change from 1990 to 2008 was a 3% increase, and the projected change from 2008 to 2020 is a 35% decrease. The linear trend over the period 1990-2025 is extremely negative (~50%).

The primary trend for the development indicator on demography (D-I) is the linear trend over the period 1990/1993-2025/2030, which generates the preliminary indicator value -3 for Poland. The secondary trend (D-II) is the projected change from 2005/2008 to 2020. This does not affect the analysis, and sets the final development indicator on demography for Poland to -3.

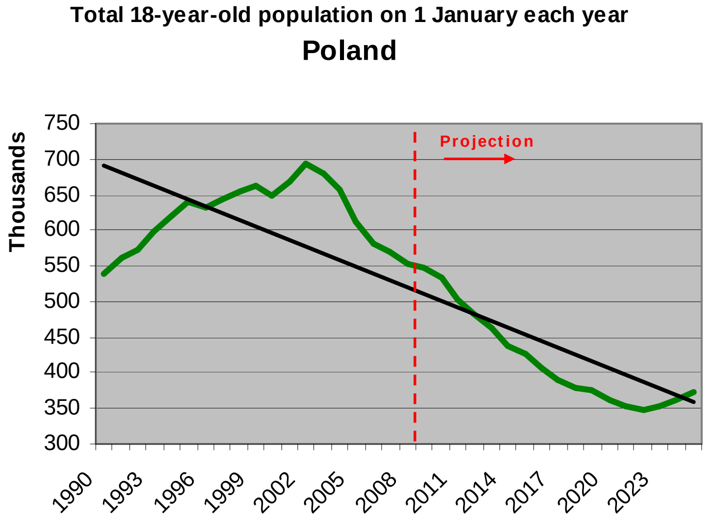

Figure 95 (Data source: Eurostat, 2009a; Eurostat, 2009b)

Educational attainment

The final development indicator on educational attainment for Poland is set to 2. (See 2.3.2 Educational attainment for a general analysis)

Choice of MST education

Upper secondary school

No additional data has been found. (See sections 2.2.2 Data sources and 2.3.3. Choice of MST education)

Tertiary education

Poland experienced a 208.3% increase in the number of graduates from mathematics, science and technology tertiary education (ISCED 5 & 6) from 1998 to 2006, as illustrated by figure 96.

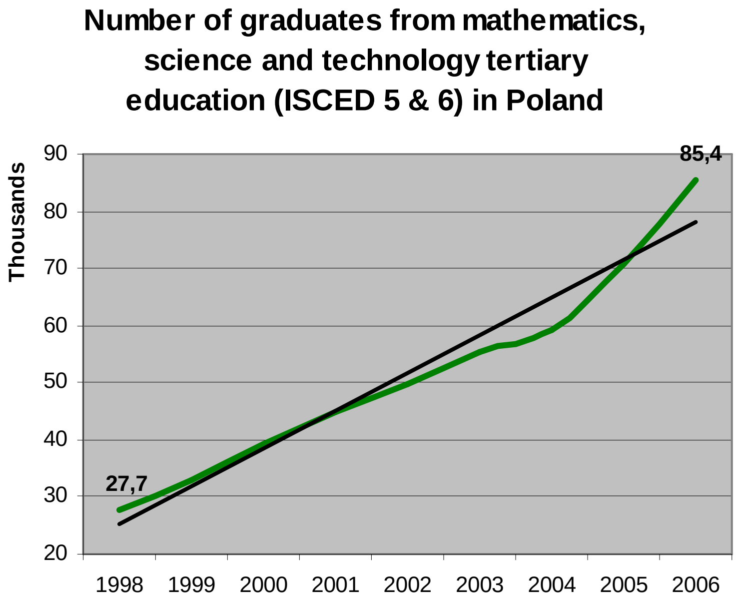

Figure 96 (Data source: Eurostat, 2009f)

As demography and educational attainment have already been accounted for, it is more interesting to look at choice of MST education in relation to the total student population. Figure 97 shows a 1.8 percentage unit or 11.9% increase in the relative share of graduates from mathematics, science and technology tertiary education (ISCED 5 & 6) among the total population of tertiary graduates in Poland from 1998 to 2006.

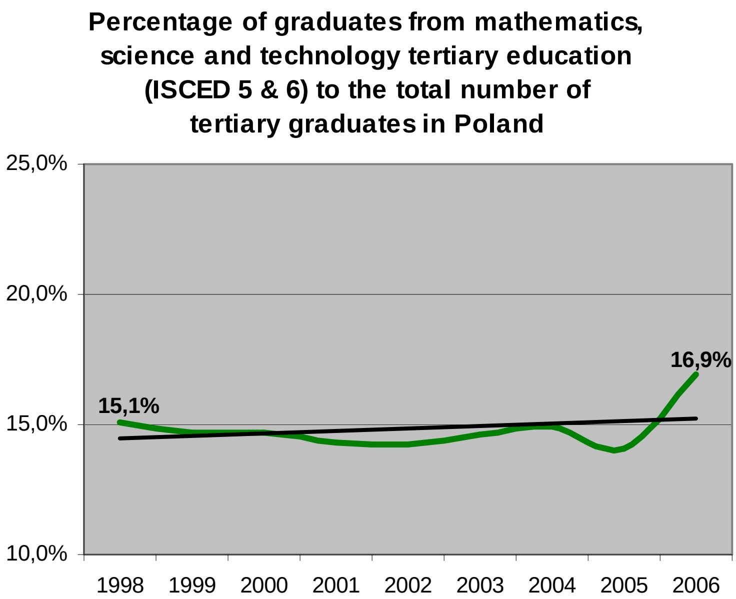

Figure 97 (Data source: Eurostat, 2009f)

Figure 98 shows a 1.3 percentage unit or 6.2% increase in the relative share of students enrolled in mathematics, science, computing, engineering, manufacturing and construction tertiary education (ISCED 5 & 6) among the total population of tertiary students in Poland from 1998 to 2006.

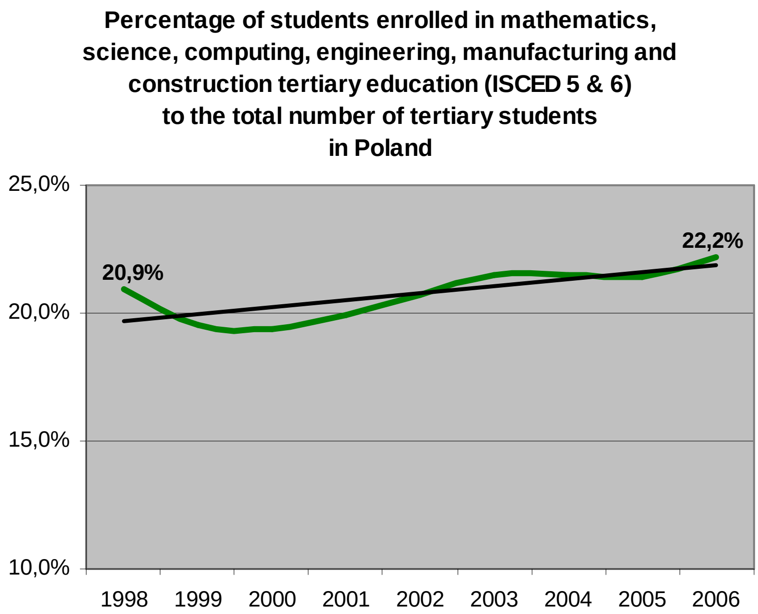

Figure 98 (Data source: Eurostat, 2009f)

The primary trend for the development indicator on choice of MST education (M-I) is the combined average of the changes in the percentage of graduates from mathematics, science and technology tertiary education and the percentage of students enrolled in mathematics, science, computing, engineering manufacturing and construction tertiary education, which generates the preliminary indicator value 2 for Poland. The secondary trend (M-II) is not applicable, which sets the final development indicator on choice of MST education for Poland to 2.

Supply development indicator

The assigned development indicators for Poland are illustrated in figure 99 together with the combined indicator for Poland constructed according to section 2.2.4. Poland is facing a somewhat positive trend in the supply of human resources in MST. This is due to very positive trends in educational attainment and choice of MST, counterbalanced by an extremely negative trend in demography.

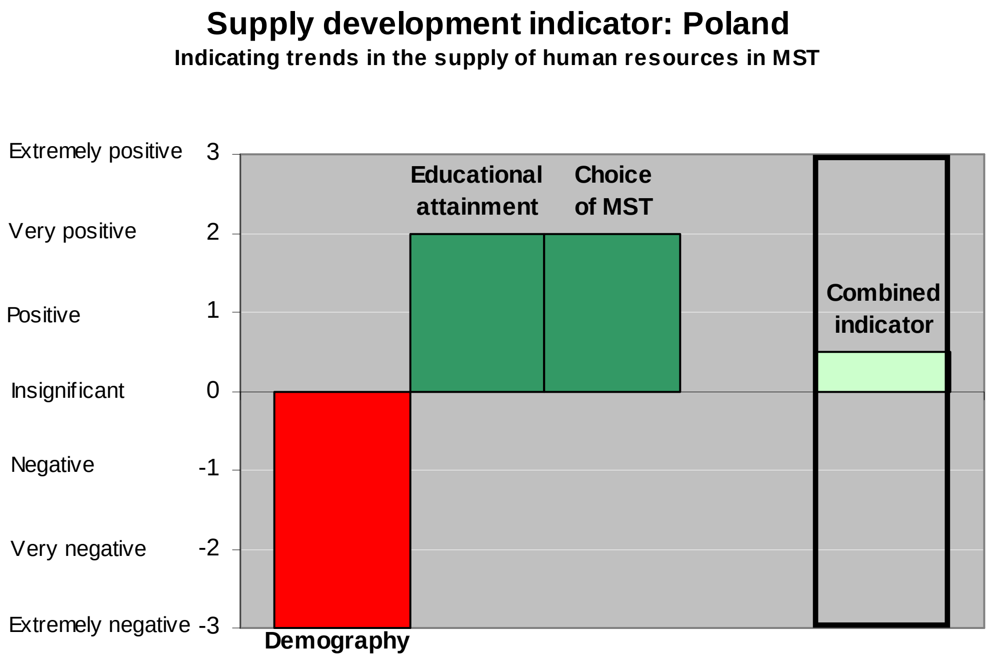

Figure 99

8.8.2. Demand

Age pyramid (See 2.4 for a general analysis)

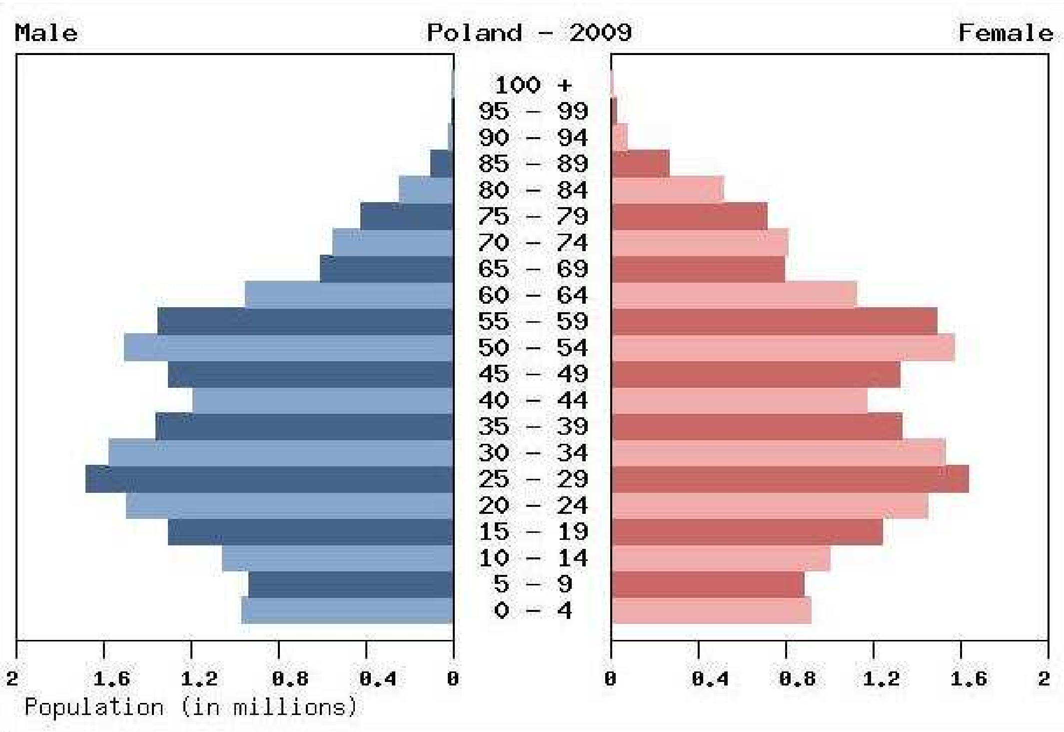

Figure 100 (Source: U.S. Census Bureau, 2009)

8.9. *Sweden*

8.9.1. Supply

Demography

Sweden can expect a 13% decrease in the total population of 18-year-olds from 1990 to 2020, as illustrated by figure 101. The actual change from 1990 to 2008 was an 8% increase, and the projected change from 2008 to 2020 is a 20% decrease. The linear trend over the period 1990-2025 is, however, insignificant (<3%).

The primary trend for the development indicator on demography (D-I) is the linear trend over the period 1990/1993-2025/2030, which generates the preliminary indicator value 0 for Sweden. The secondary trend (D-II) is the projected change from 2005/2008 to 2020. The very large decrease affects the analysis by -2, and sets the final development indicator on demography for Sweden to -2.

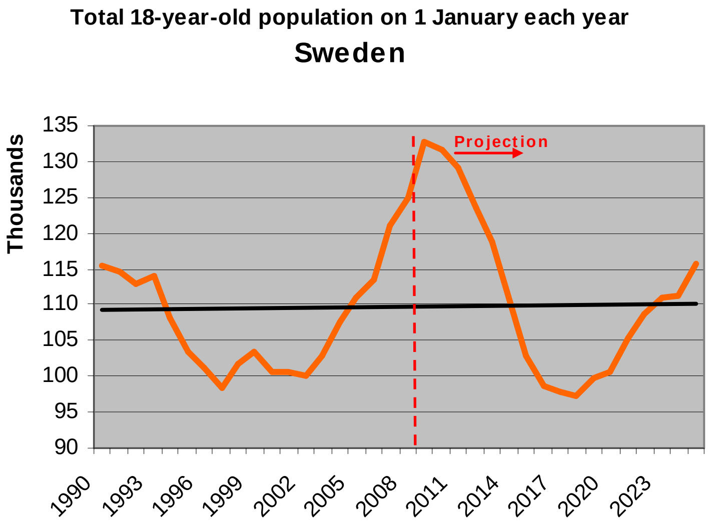

Figure 101 (Data source: Eurostat, 2009a; Eurostat, 2009b)

Educational attainment

The final development indicator on educational attainment for Sweden is set to 1. (See 2.3.2 Educational attainment for a general analysis)

Choice of MST education

Upper secondary school

Sweden has provided additional data on applications and admissions to science and technology preparatory upper secondary school education during 1996-2008. The data is presented in figures 102-105 and exposes extremely negative trends, in absolute numbers as well as in relation to the total student population. Figure 105 shows a 7.5 percentage unit or 35.3% decrease in the relative share of applicants to science and technology preparatory upper secondary school education among the total number of upper secondary school applicants in Sweden from 2000 to 2008.

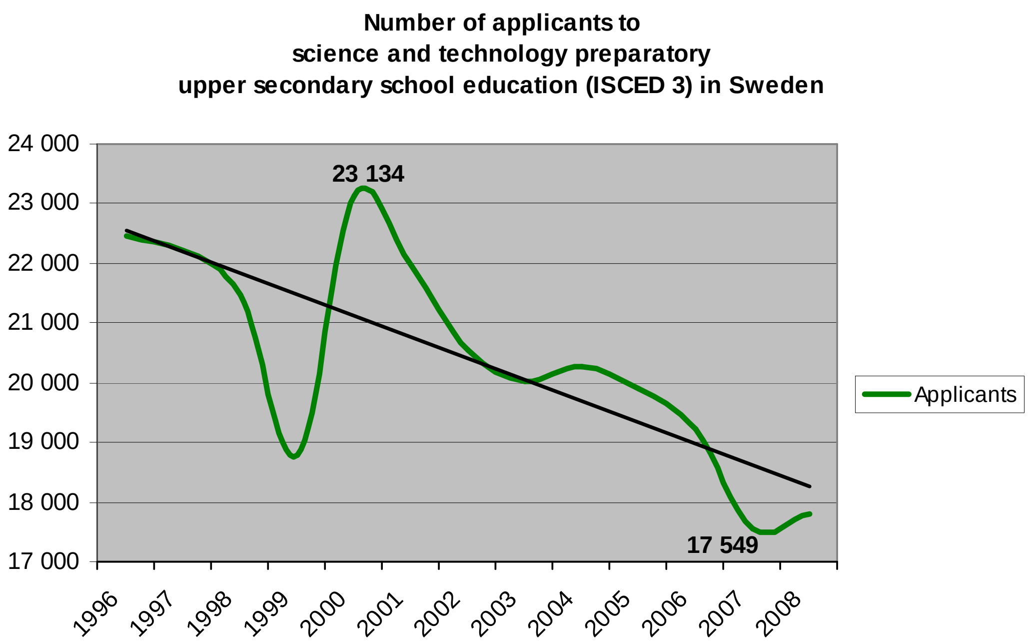

Figure 102 (Data source: Skolverket, 2006a-j; Skolverket, 2007; Skolverket, 2008; Skolverket, 2009)

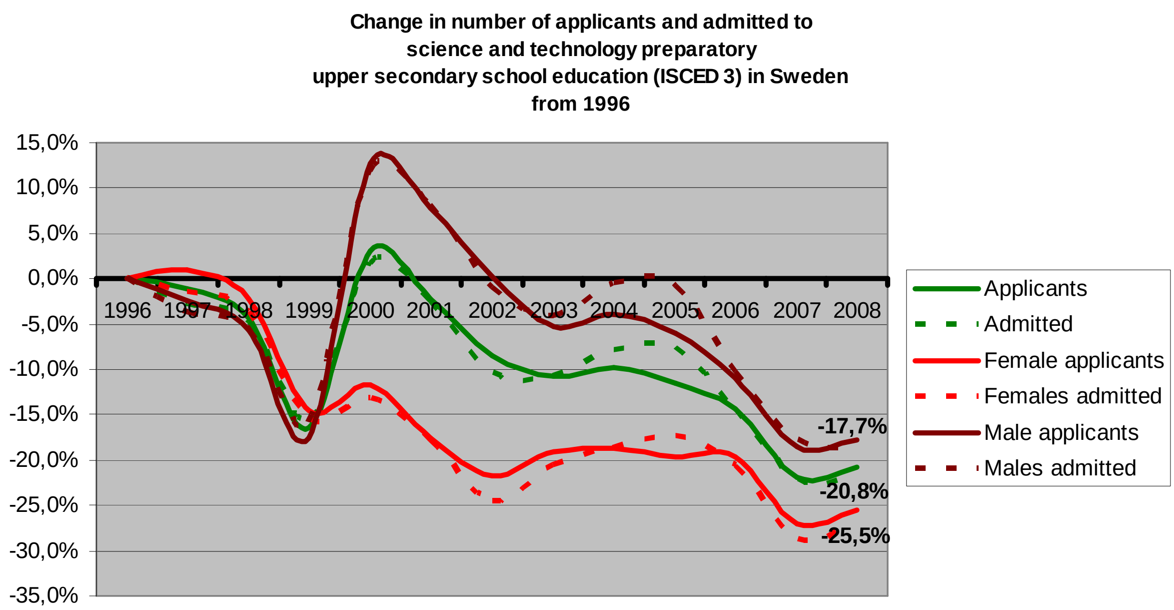

Figure 103 (Data source: Skolverket, 2006a-j; Skolverket, 2007; Skolverket, 2008; Skolverket, 2009)

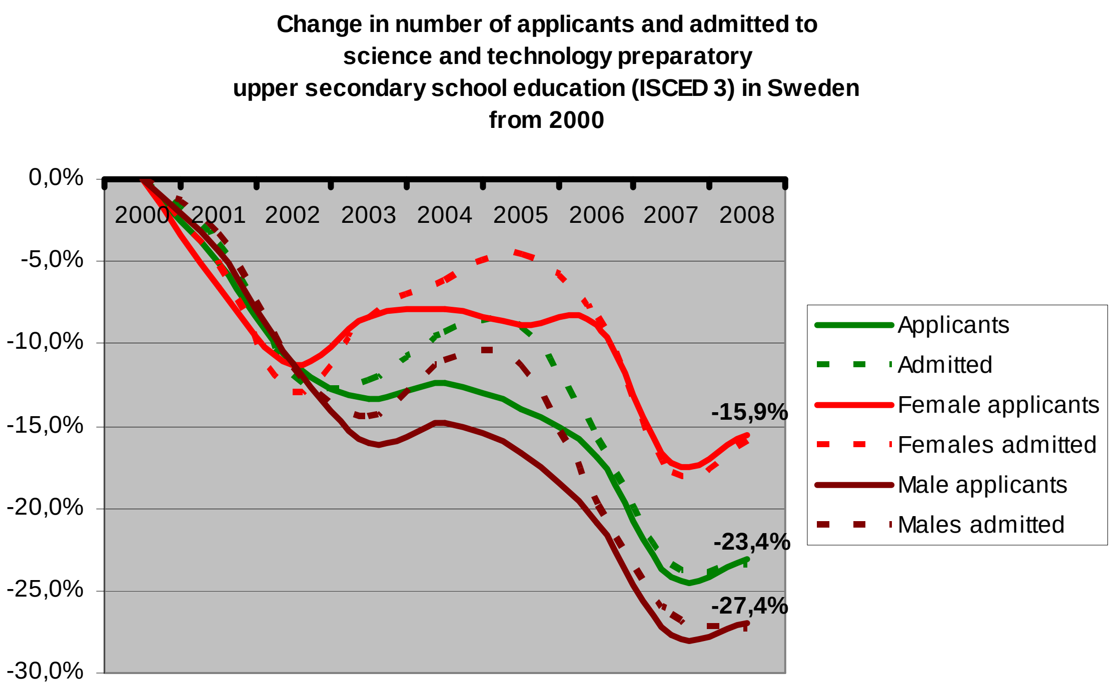

Figure 104 (Data source: Skolverket, 2006a-j; Skolverket, 2007; Skolverket, 2008; Skolverket, 2009)

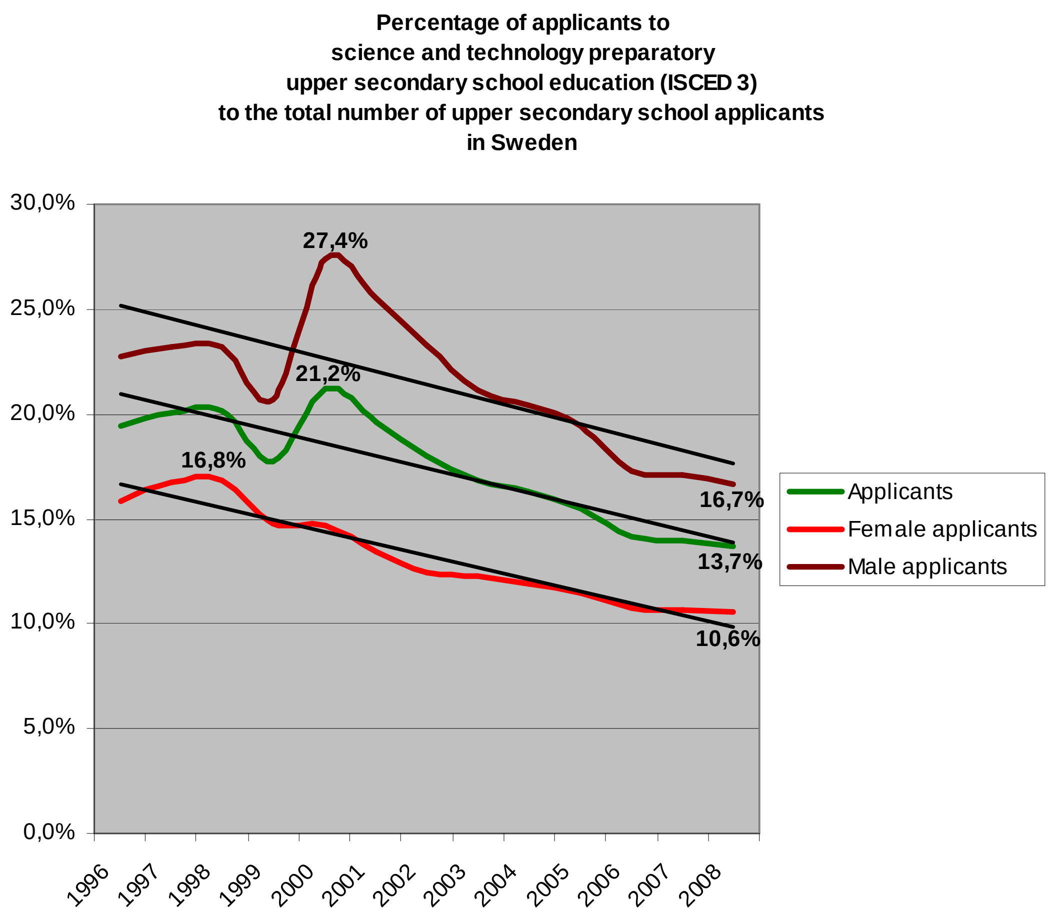

Figure 105 (Data source: Skolverket, 2006a-j; Skolverket, 2007; Skolverket, 2008; Skolverket, 2009)

Tertiary education

Sweden experienced a 78.9% increase in the number of graduates from mathematics, science and technology tertiary education (ISCED 5 & 6) from 1998 to 2006, as illustrated by figure 106.

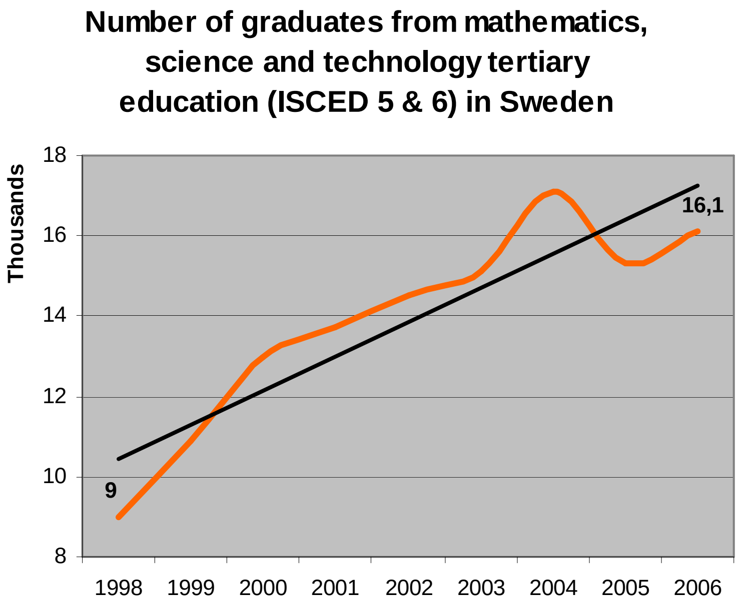

Figure 106 (Data source: Eurostat, 2009f)

As demography and educational attainment have already been accounted for, it is more interesting to look at choice of MST education in relation to the total student population. Figure 107 shows a 0.2 percentage unit or 0.8% decrease in the relative share of graduates from mathematics, science and technology tertiary education (ISCED 5 & 6) among the total population of tertiary graduates in Sweden from 1998 to 2006.

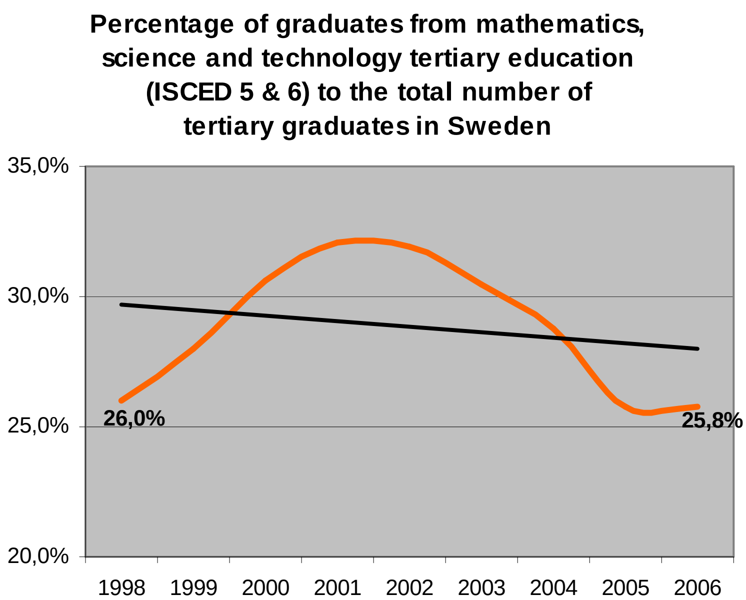

Figure 107 (Data source: Eurostat, 2009f)

Figure 108 shows a 4.3 percentage unit or 14.2% decrease in the relative share of students enrolled in mathematics, science, computing, engineering, manufacturing and construction tertiary education (ISCED 5 & 6) among the total population of tertiary students in Sweden from 1998 to 2006.

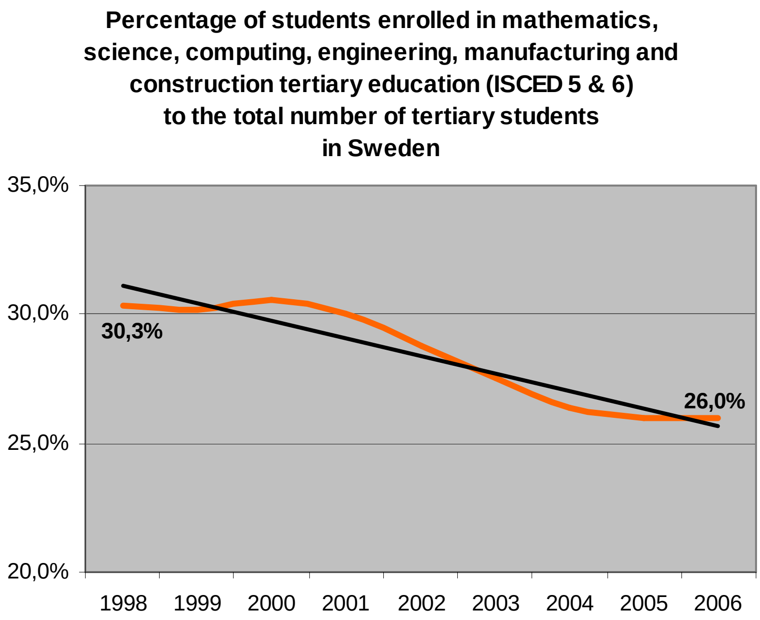

Figure 108 (Data source: Eurostat, 2009f)

Sweden has also provided additional data on applications to tertiary engineering education in Sweden during 2001-2009. The data is presented in figures 109-111, and exposes negative trends in absolute numbers and extremely negative trends in relative terms. Figure 111 shows a 6.2 percentage unit or 38.4% decrease in the relative share of applicants to tertiary engineering education among the total number tertiary education applicants in Sweden from 2001 to 2009.

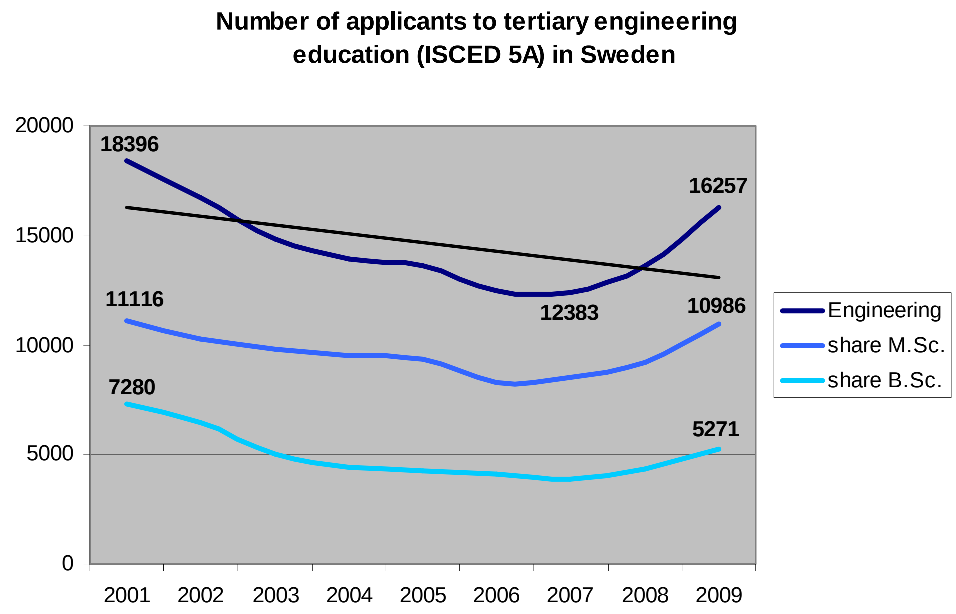

Figure 109 (Data source: Högskoleverket, 2009b)

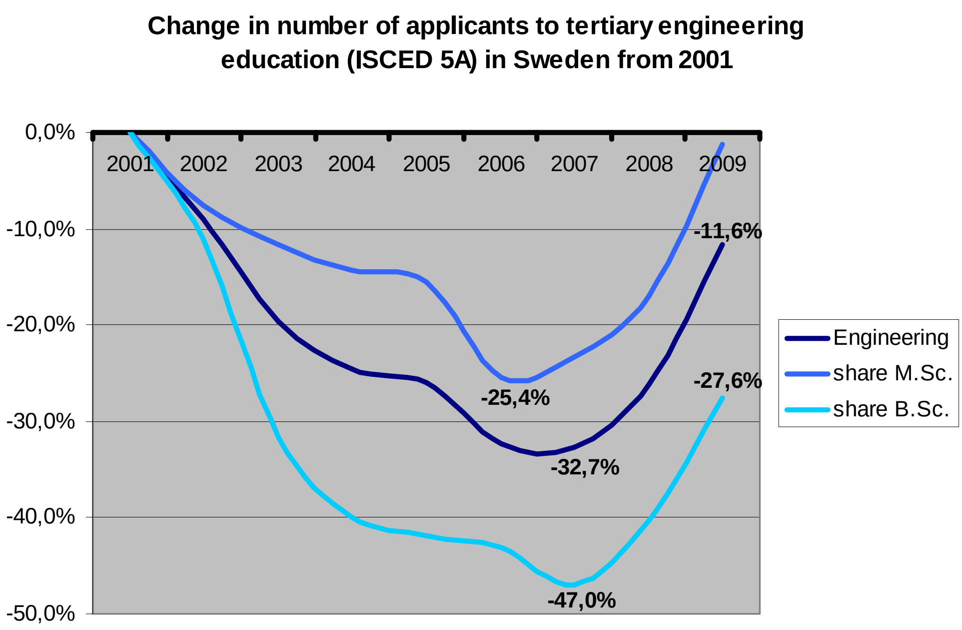

Figure 110 (Data source: Högskoleverket, 2009b)

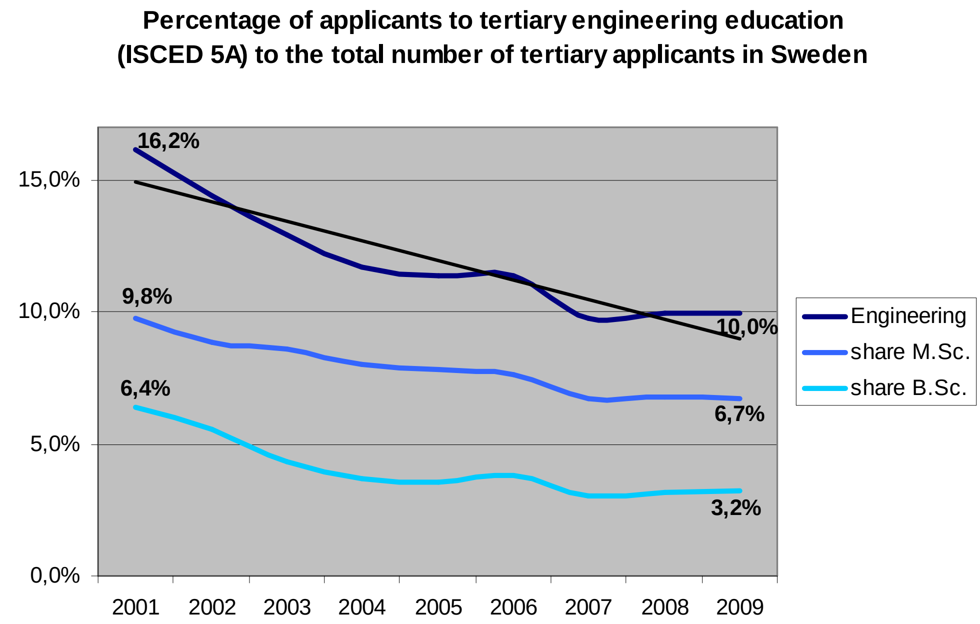

Figure 111 (Data source: Högskoleverket, 2009b)

The primary trend for the development indicator on choice of MST education (M-I) is the combined average of the changes in the percentage of graduates from mathematics, science and technology tertiary education and the percentage of students enrolled in mathematics, science, computing, engineering manufacturing and construction tertiary education, which generates the preliminary indicator value -1 for Sweden. The additional data provided by Sweden on applications to science- and technology-related education at the upper secondary and tertiary levels have been analysed as secondary trends (M-II). These affect the analysis by -2 and set the final development indicator on choice of MST education for Sweden to -3.

Supply development indicator

The assigned development indicators for Sweden are illustrated in figure 112 together with the combined indicator for Sweden constructed according to section 2.2.4. Sweden is facing a very negative trend in the supply of human resources in MST. The main contributing factor is an extremely negative trend in choice of MST education, although a very negative trend in demography is not far behind.

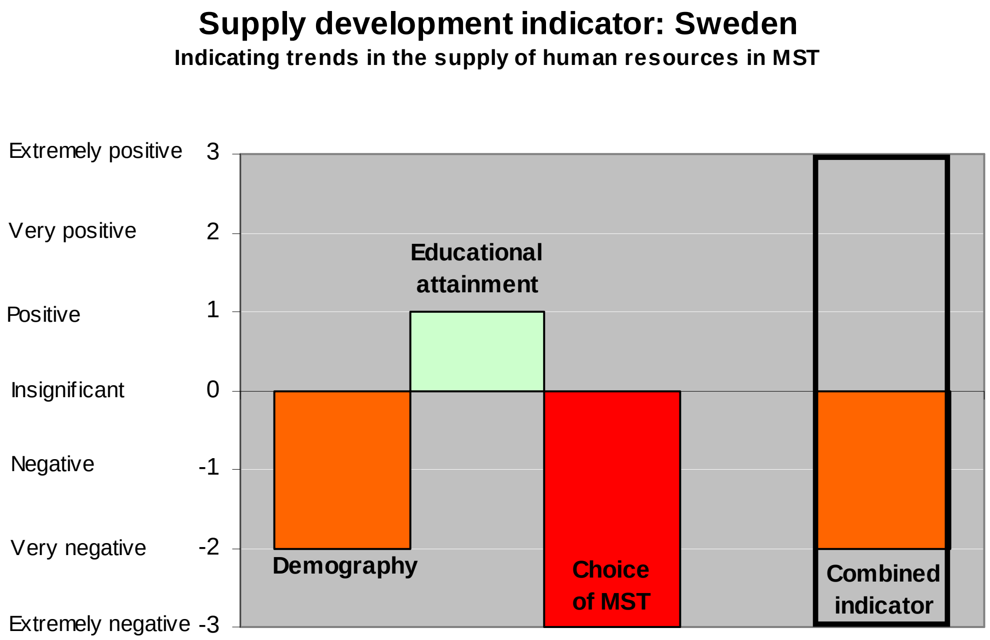

Figure 112

8.9.2. Demand

Age pyramid (See 2.4 for a general analysis)

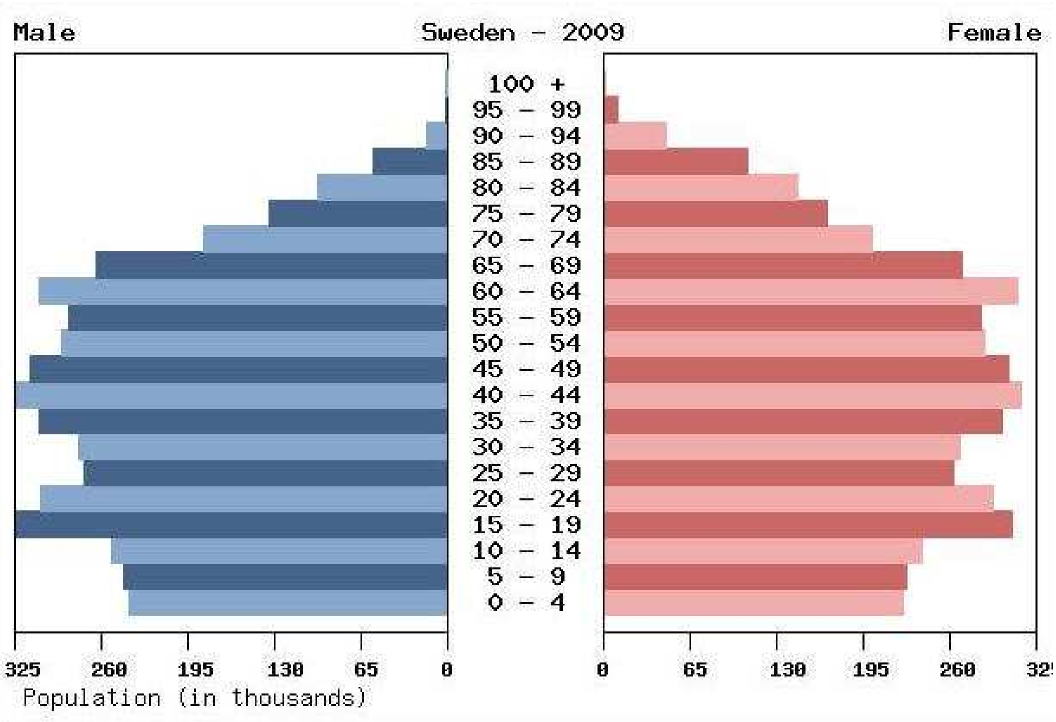

Figure 113 (Source: U.S. Census Bureau, 2009)

8.10. *United Kingdom*

8.10.1. Supply

Demography

The United Kingdom can expect a 19% decrease in the total population of 18-year-olds from 1990 to 2020, as illustrated by figure 114. The actual change from 1990 to 2008 was a 5% decrease, and the projected change from 2008 to 2020 is a 15% decrease. The linear trend over the period 1990-2025 is insignificant (<3%).

The primary trend for the development indicator on demography (D-I) is the linear trend over the period 1990/1993-2025/2030, which generates the preliminary indicator value 0 for the United Kingdom. The secondary trend (D-II) is the projected change from 2005/2008 to 2020. The large decrease affects the analysis by -1, and sets the final development indicator on demography for the United Kingdom to -1.

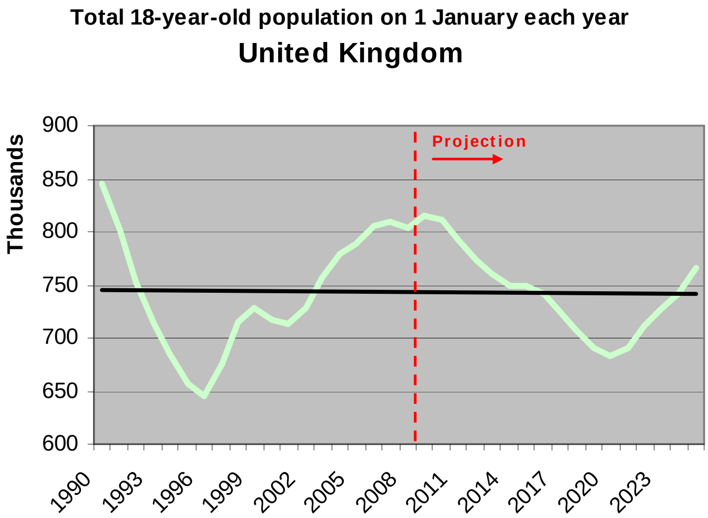

Figure 114 (Data source: Eurostat, 2009a; Eurostat, 2009b)

Educational attainment

The final development indicator on educational attainment for the United Kingdom is set to 1. (See 2.3.2 Educational attainment for a general analysis)

Choice of MST education

Upper secondary school

No additional data has been found. (See sections 2.2.2 Data sources and 2.3.3. Choice of MST education)

Tertiary education

The United Kingdom experienced a 13.8% increase in the number of graduates from mathematics, science and technology tertiary education from 1998 to 2006, as illustrated by figure 115.

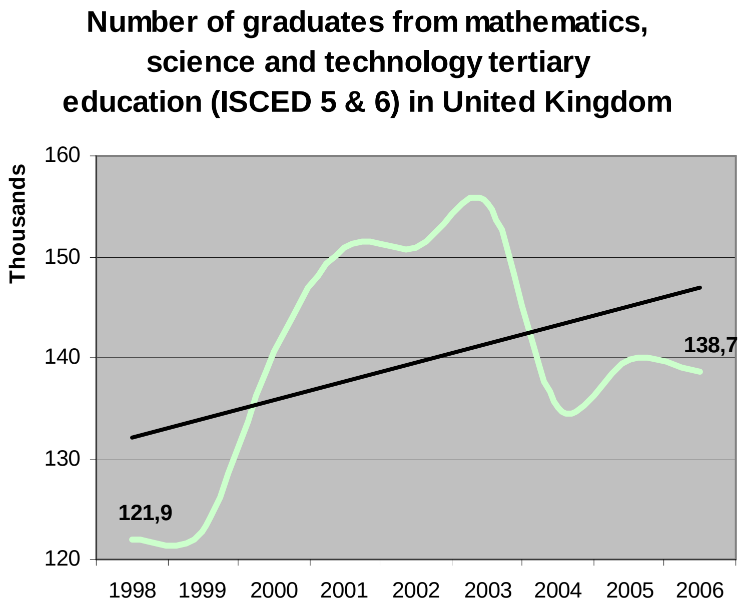

Figure 115 (Data source: Eurostat, 2009f)

As demography and educational attainment have already been accounted for, it is more interesting to look at choice of MST education in relation to the total student population. Figure 116 shows a 4.2 percentage unit or 16.0% decrease in the relative share of graduates from mathematics, science and technology tertiary education (ISCED 5 & 6) among the total population of tertiary graduates in the United Kingdom from 1998 to 2006.

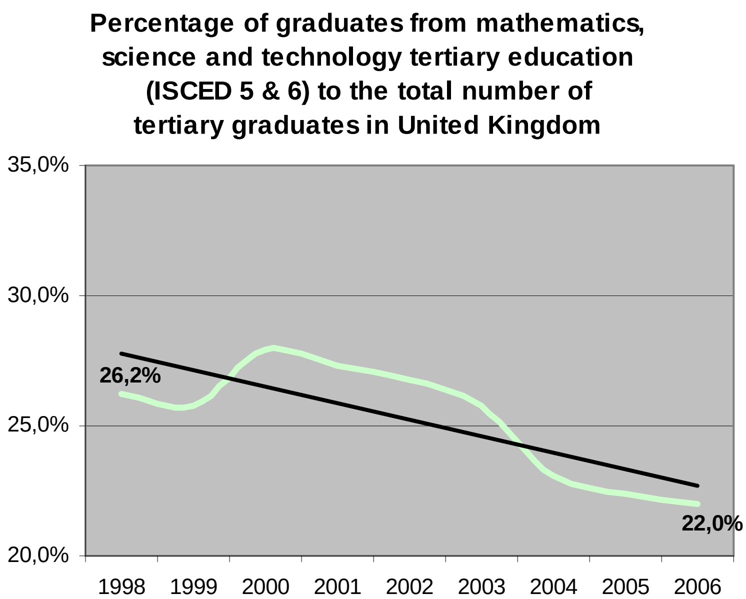

Figure 116 (Data source: Eurostat, 2009f)

Figure 117 shows a 4.9 percentage unit or 17.6% decrease in the relative share of students enrolled in mathematics, science, computing, engineering, manufacturing and construction tertiary education (ISCED 5 & 6) among the total population of tertiary students in the United Kingdom from 1998 to 2006.

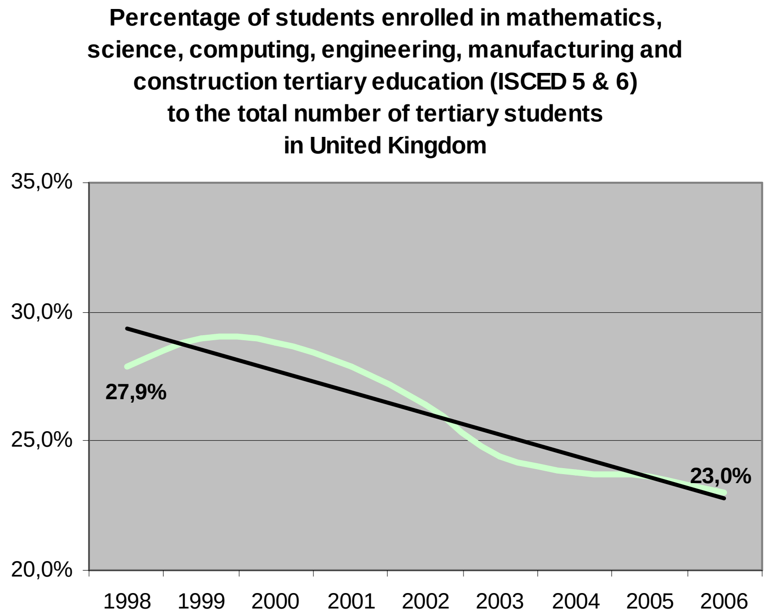

Figure 117 (Data source: Eurostat, 2009f)

The primary trend for the development indicator on choice of MST education (M-I) is the combined average of the changes in the percentage of graduates from mathematics, science and technology tertiary education and the percentage of students enrolled in mathematics, science, computing, engineering manufacturing and construction tertiary education, which generates the preliminary indicator value -3 for the United Kingdom. The secondary trend (M-II) is not applicable, which sets the final development indicator on choice of MST education for the United Kingdom to -3.

Supply development indicator

The assigned development indicators for the United Kingdom are illustrated in figure 118 together with the combined indicator for the United Kingdom, constructed according to section 2.2.4. The United Kingdom is facing a negative trend in the supply of human resources in MST. The main contributing factor is an extremely negative trend in choice of MST education.

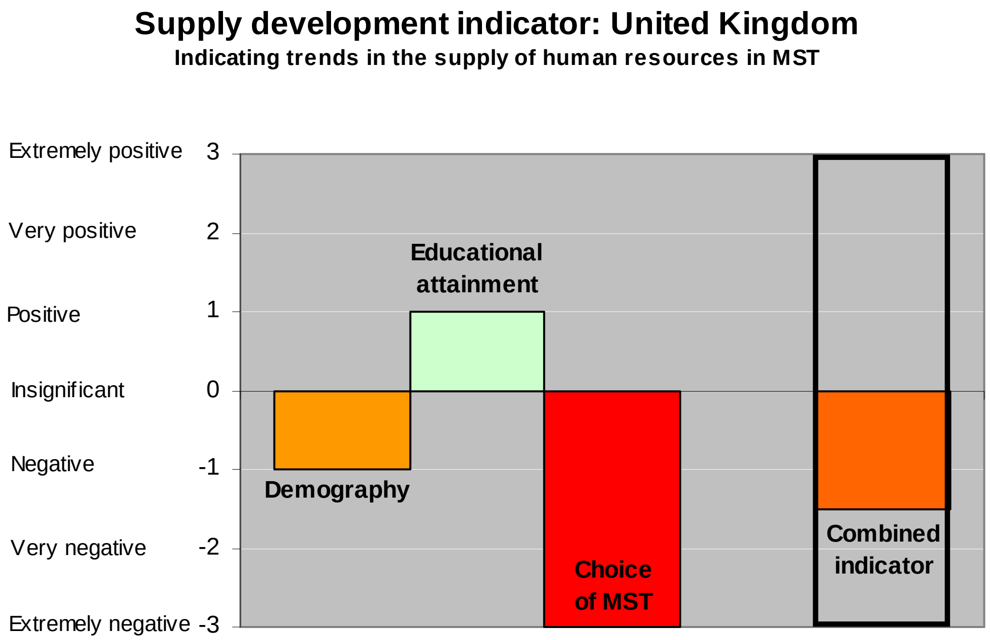

Figure 118

8.10.2. Demand

Age pyramid (See 2.4 for a general analysis)

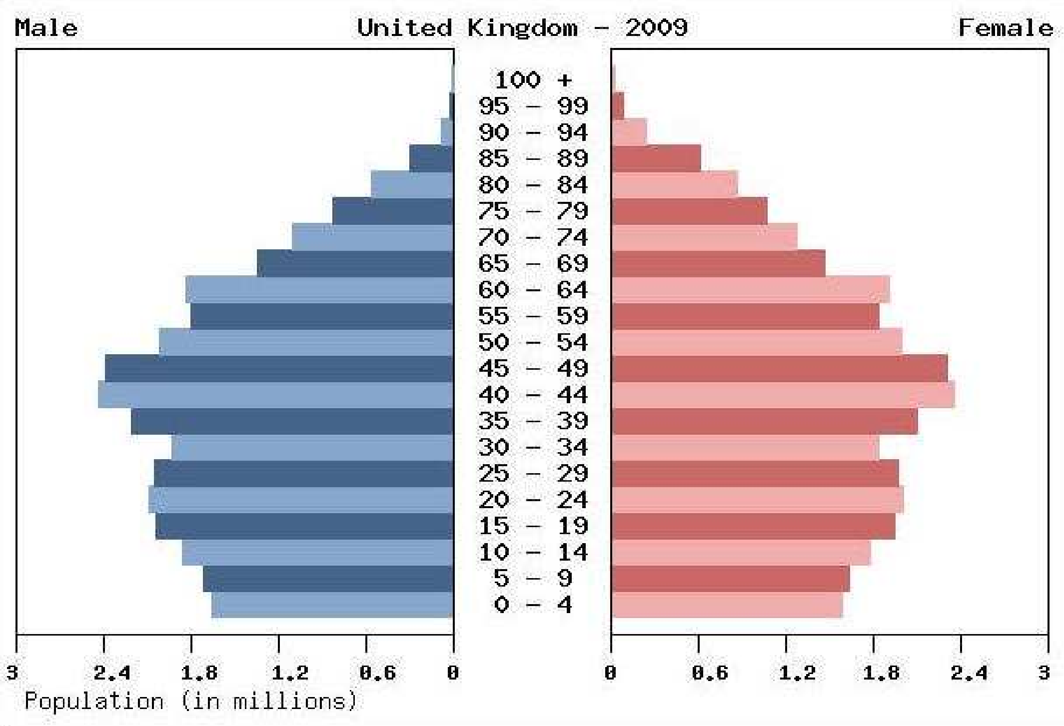

Figure 119 (Source: U.S. Census Bureau, 2009)

8.11. China

8.11.1. Supply

Demography

China can expect a 29% decrease in the total population of 15- to 19-year-olds from 1990 to 2020, as illustrated by figure 120. The actual change from 1990 to 2005 was a 2% increase, and the projected change from 2005 to 2020 is a 30% decrease. The linear trend over the period 1990-2030 is very negative (~25%).

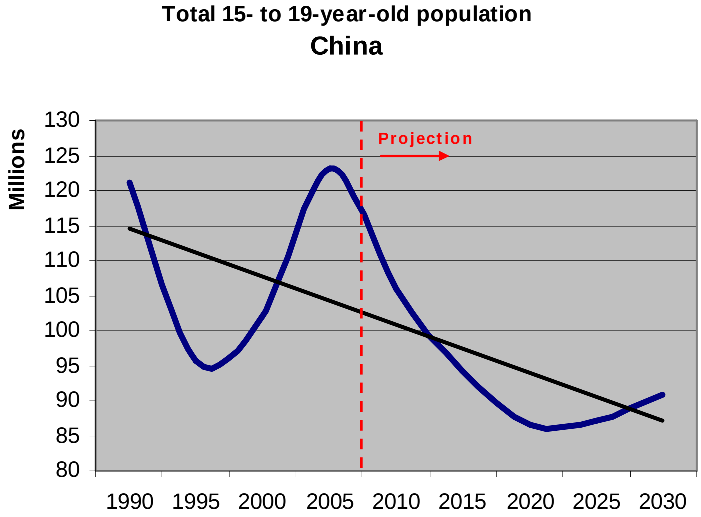

Figure 120 (Data source: United Nations Population Division, 2009)

Supply development indicator

There is not enough information available to construct a supply development indicator.

8.11.2. Demand

Age pyramid (See 2.4 for a general analysis)

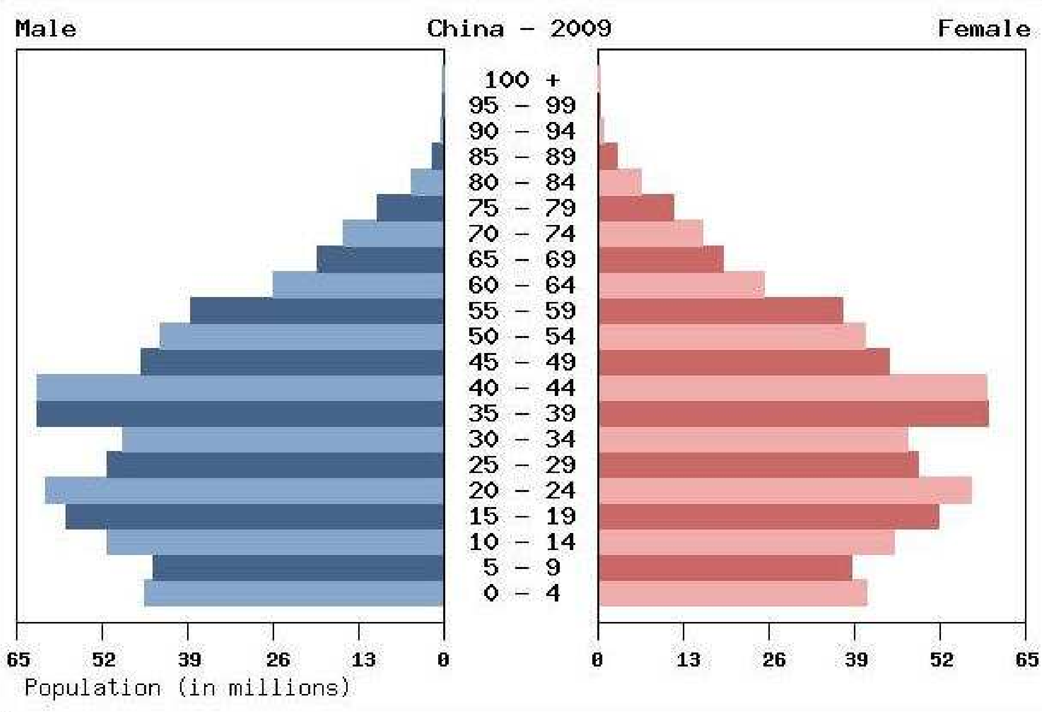

Figure 121 (Source: U.S. Census Bureau, 2009)

8.12. *Japan*

8.12.1. Supply

Demography

Japan can expect a 44% decrease in the total population of 15- to 19-year-olds from 1990 to 2020, as illustrated by figure 122. The actual change from 1990 to 2005 was a 35% decrease, and the projected change from 2005 to 2020 is a 14% decrease. The linear trend over the period 1990-2030 is extremely negative (~55%).

The primary trend for the development indicator on demography (D-I) is the linear trend over the period 1990/1993-2025/2030, which generates the preliminary indicator value -3 for Japan. The secondary trend (D-II) is the projected change from 2005/2008 to 2020. This does not affect the analysis, and sets the final development indicator on demography for Japan to -3.

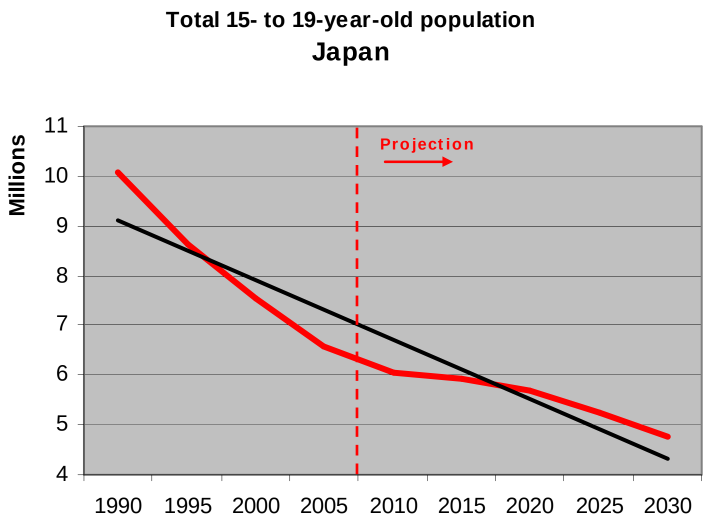

Figure 122 (Data source: United Nations Population Division, 2009)

Educational attainment

The final development indicator on educational attainment for Japan is set to 2. (See 2.3.2 Educational attainment for a general analysis)

Choice of MST education

Upper secondary school

No additional data has been found. (See sections 2.2.2 Data sources and 2.3.3. Choice of MST education)

Tertiary education

Japan experienced a 3.8% decrease in the number of graduates from mathematics, science and technology tertiary education (ISCED 5 & 6) from 1998 to 2006, as illustrated by figure 123.

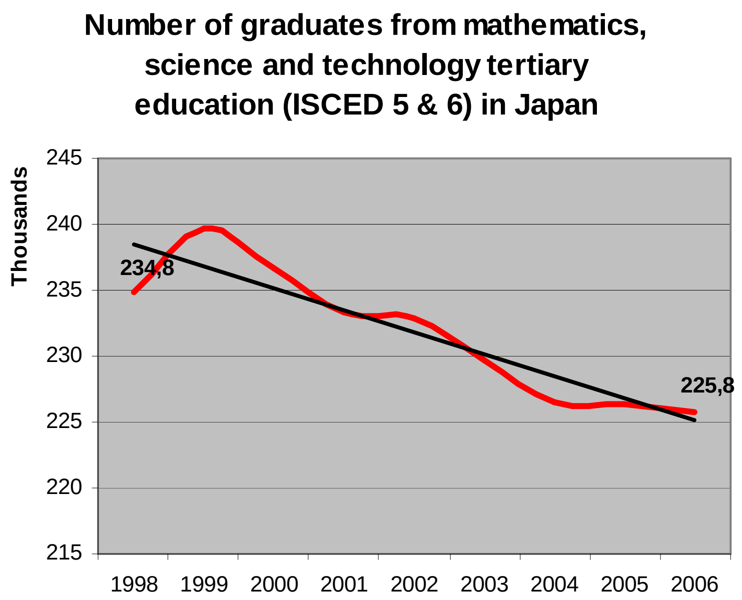

Figure 123 (Data source: Eurostat, 2009f)

As demography and educational attainment have already been accounted for, it is more interesting to look at choice of MST education in relation to the total student population. Figure 124 shows a 2.7 percentage unit or 10.8% decrease in the relative share of graduates from mathematics, science and technology tertiary education (ISCED 5 & 6) among the total population of tertiary graduates in Japan from 1998 to 2006.

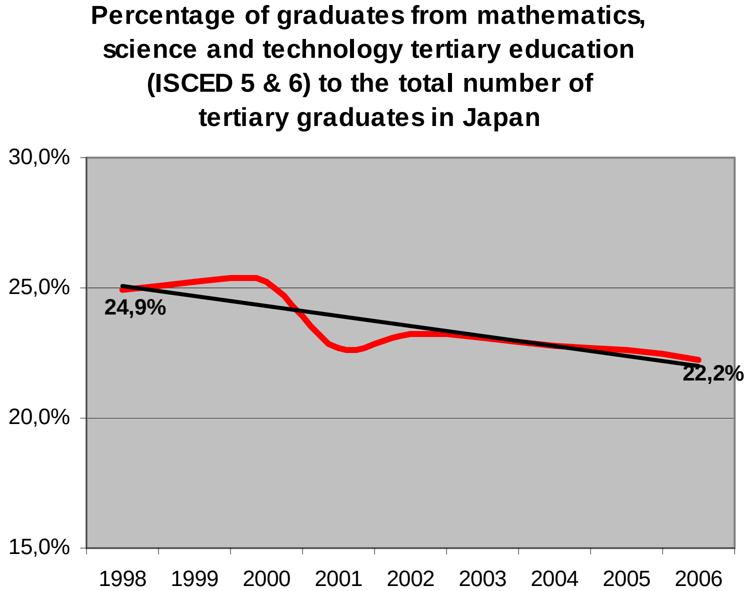

Figure 124 (Data source: Eurostat, 2009f)

Figure 125 shows a 2.7 percentage unit or 11.5% decrease in the relative share of students enrolled in mathematics, science, computing, engineering, manufacturing and construction tertiary education (ISCED 5 & 6) among the total population of tertiary students in Japan from 1998 to 2006.

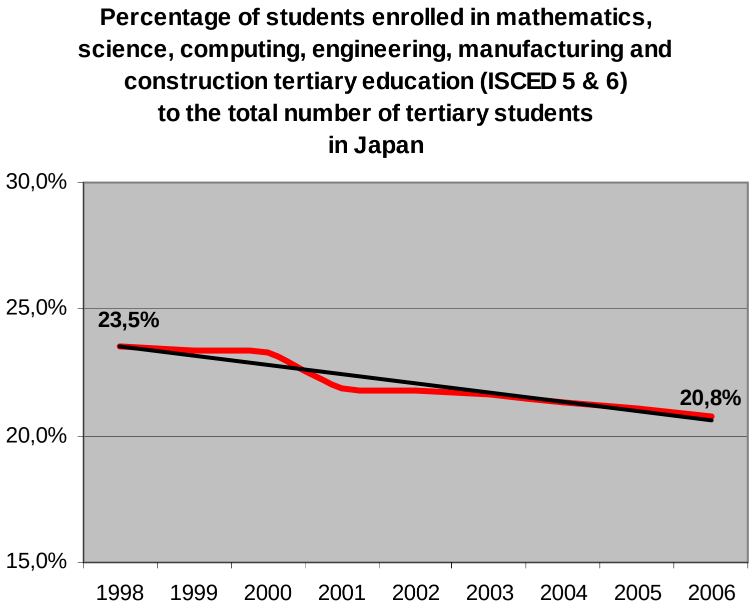

Figure 125 (Data source: Eurostat, 2009f)

The primary trend for the development indicator on choice of MST education (M-I) is the combined average of the changes in the percentage of graduates from mathematics, science and technology tertiary education and the percentage of students enrolled in mathematics, science, computing, engineering manufacturing and construction tertiary education, which generates the preliminary indicator value -2 for Japan. The secondary trend (M-II) is not applicable, which sets the final development indicator on choice of MST education for Japan to -2.

Supply development indicator

The assigned development indicators for Japan are illustrated in figure 126 together with the combined indicator for Japan constructed according to section 2.2.4. Japan is facing a very negative trend in the supply of human resources in MST. The most important contributing factor is an extremely negative trend in demography, although a very negative trend in choice of MST education is not far behind.

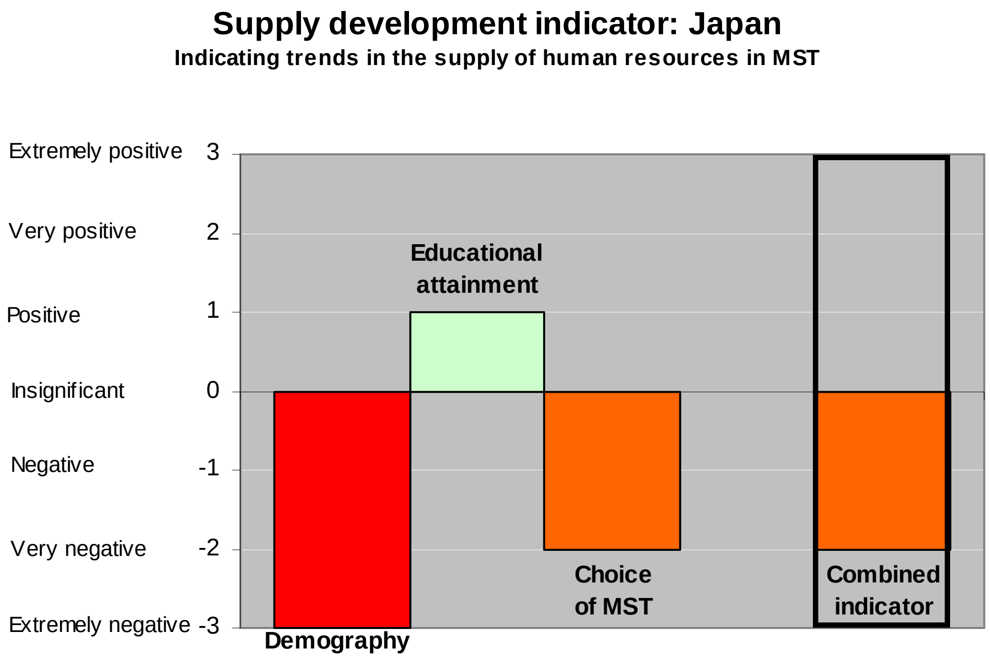

Figure 126

8.12.2. Demand

Age pyramid (See 2.4 for a general analysis)

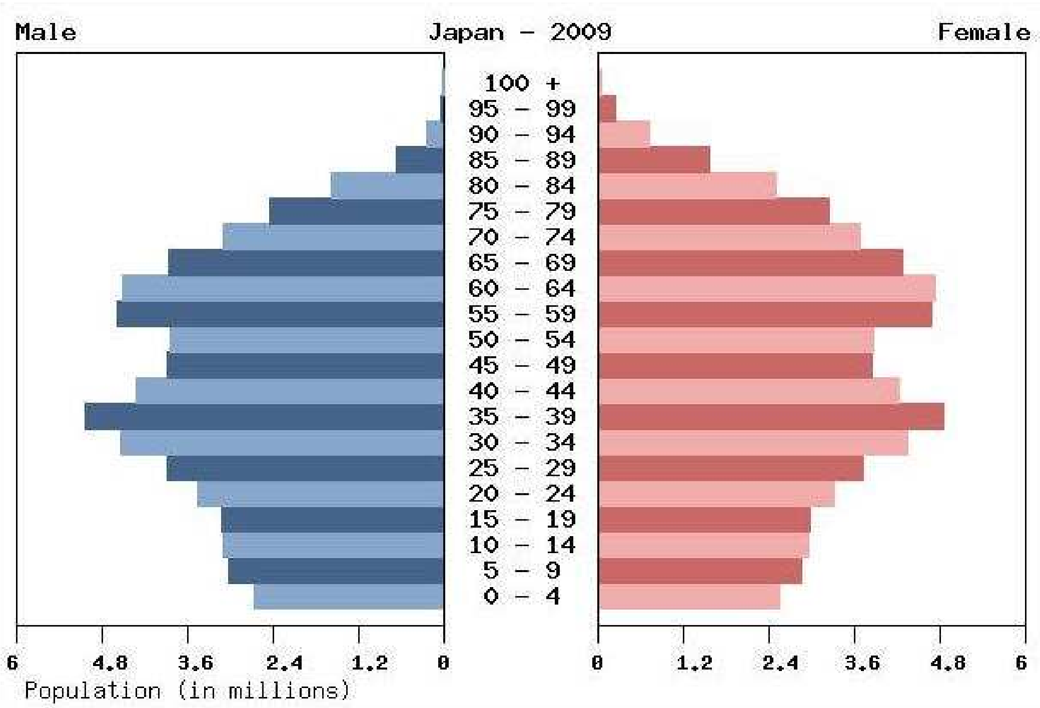

Figure 127 (Source: U.S. Census Bureau, 2009)

8.13. *United States of America*

8.13.1. Supply

Demography

The United States of America can expect a 25% increase in the total population of 15- to 19-year-olds from 1990 to 2020, as illustrated by figure 128. The actual change from 1990 to 2005 was a 21% increase, and the projected change from 2005 to 2020 is a 3% increase. The linear trend over the period 1990-2030 is very positive (~30%).

The primary trend for the development indicator on demography (D-I) is the linear trend over the period 1990/1993-2025/2030, which generates the preliminary indicator value 3 for the United States of America. The secondary trend (D-II) is the projected change from 2005/2008 to 2020. This does not affect the analysis, and sets the final development indicator on demography for the United States of America to 3.

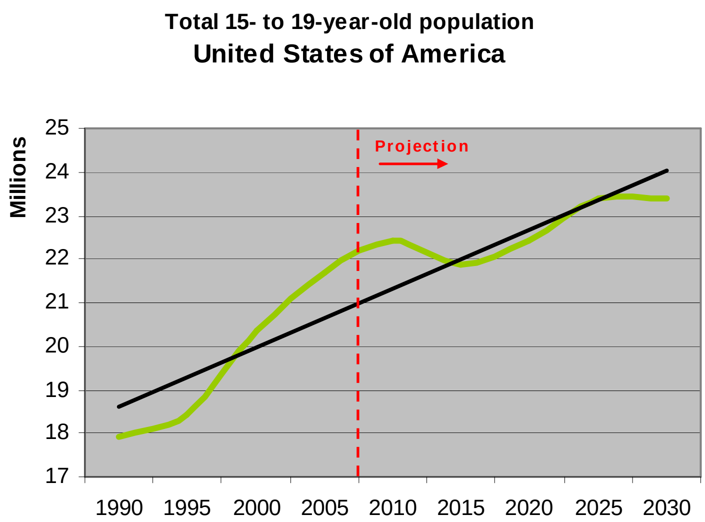

Figure 128 (Data source: United Nations Population Division, 2009)

Educational attainment

The final development indicator on educational attainment for the United States of America is set to 1. (See 2.3.2 Educational attainment for a general analysis)

Choice of MST education

Upper secondary school

No additional data has been found. (See sections 2.2.2 Data sources and 2.3.3. Choice of MST education)

Tertiary education

The United States of America experienced a 21.9% increase in the number of graduates from mathematics, science and technology tertiary education from 1998 to 2006 (see figure 129).

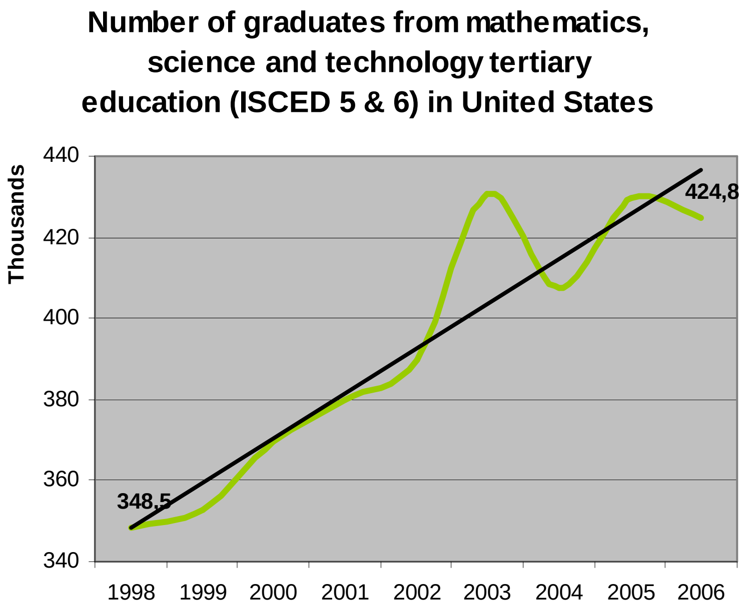

Figure 129 (Data source: Eurostat, 2009f)

As demography and educational attainment have already been accounted for, it is more interesting to look at choice of MST education in relation to the total student population. Figure 130 shows a 0.9 percentage unit or 5.3% decrease in the relative share of graduates from mathematics, science and technology tertiary education (ISCED 5 & 6) among the total population of tertiary graduates in the United States from 1998 to 2006.

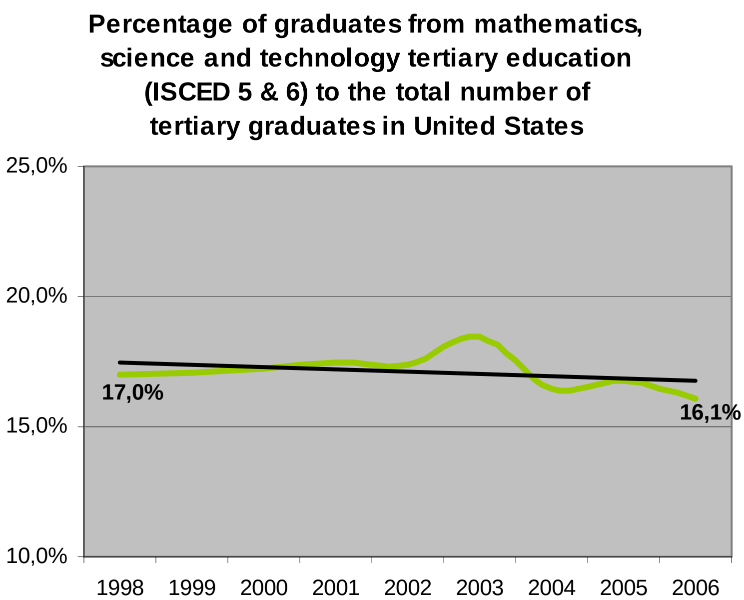

Figure 130 (Data source: Eurostat, 2009f)

The primary trend for the development indicator on choice of MST education (M-I) is the combined average of the changes in the percentage of graduates from mathematics, science and technology tertiary education and the percentage of students enrolled in mathematics, science, computing, engineering manufacturing and construction tertiary education, which generates the preliminary indicator value -1 for the United States of America. The secondary trend (M-II) is not applicable, which sets the final development indicator on choice of MST education for the United States of America to -1.

Supply development indicator

The assigned development indicators for the United States of America are illustrated in figure 131 together with the combined indicator for the United States of America constructed according to section 2.2.4. The United States of America is facing a positive trend in the supply of human resources in MST. The main contributing factor is an extremely positive trend in demography.

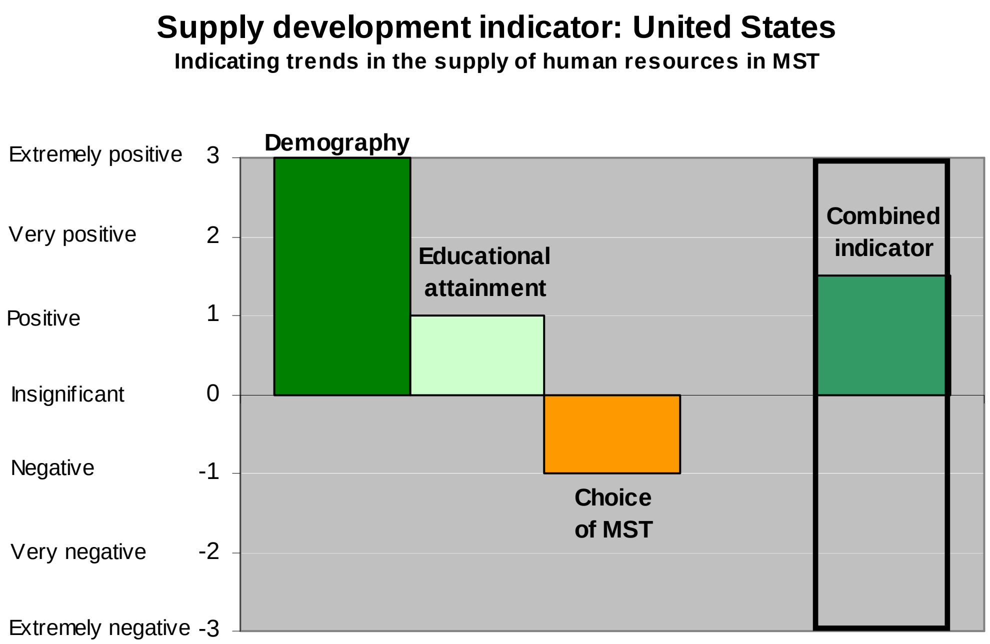

Figure 131

8.13.2. Demand

Age pyramid (See 2.4 for a general analysis)

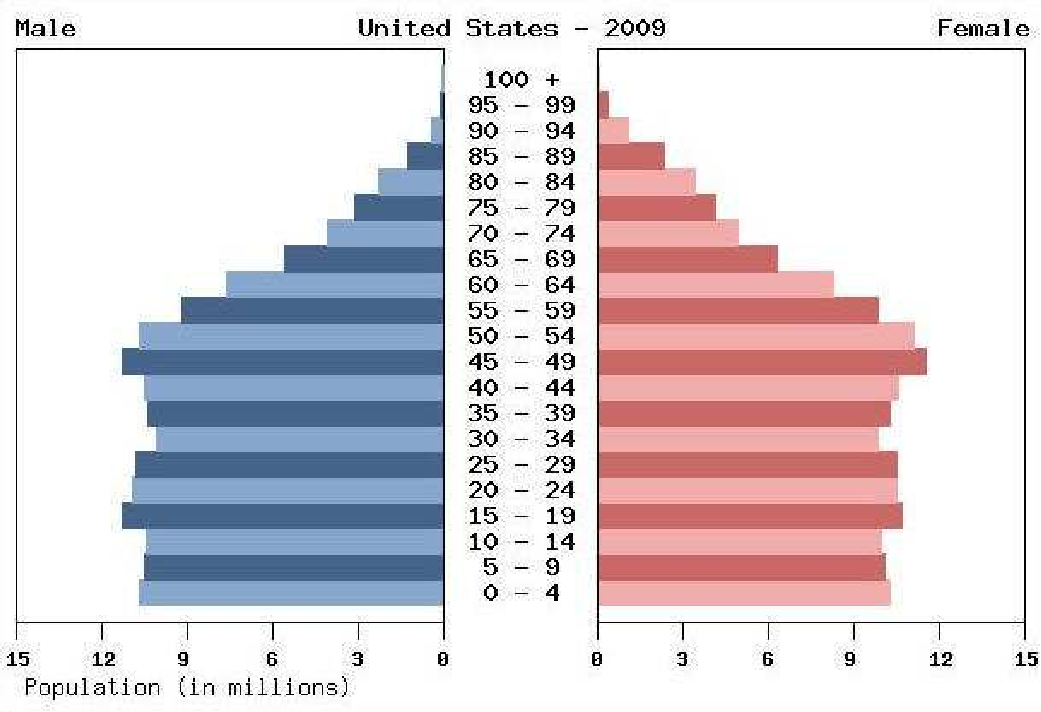

Figure 132 (Source: U.S. Census Bureau, 2009)

9. APPENDIX 2: Calculations

9.1. HEVA

	2002	2003	2004	2005	2006	2007	2008
Operating income	2 837 000 000 kr	2 504 000 000 kr	14 679 000 000 kr	18 153 000 000 kr	18 713 000 000 kr	20 583 000 000 kr	14 454 000 000 kr
Tax (30%)	-851 100 000 kr	-751 200 000 kr	-4 403 700 000 kr	-5 445 900 000 kr	-5 613 900 000 kr	-6 174 900 000 kr	-4 336 200 000 kr
Net operating income after tax	1 985 900 000 kr	1 752 800 000 kr	10 275 300 000 kr	12 707 100 000 kr	13 099 100 000 kr	14 408 100 000 kr	10 117 800 000 kr
Interest-bearing receivables	-8 495 000 000 kr	-9 413 000 000 kr	-12 127 000 000 kr	-7 691 000 000 kr	-13 214 000 000 kr	-13 701 000 000 kr	-6 056 000 000 kr
Liquid funds	-24 154 000 000 kr	-28 102 000 000 kr	-34 628 000 000 kr	-36 047 000 000 kr	-29 907 000 000 kr	-30 026 000 000 kr	-22 575 000 000 kr
Shareholders' equity	78 525 000 000 kr	72 636 000 000 kr	70 155 000 000 kr	78 760 000 000 kr	87 188 000 000 kr	75 129 000 000 kr	75 046 000 000 kr
Provision for post employment benefits	16 218 000 000 kr	15 264 000 000 kr	14 677 000 000 kr	11 966 000 000 kr	8 661 000 000 kr	9 746 000 000 kr	11 677 000 000 kr
Interest-bearing liabilities	22 494 000 000 kr	24 677 000 000 kr	13 968 000 000 kr	13 097 000 000 kr	9 779 000 000 kr	38 286 000 000 kr	46 749 000 000 kr
Cost of capital (9%)	7 612 920 000 kr	6 755 580 000 kr	4 684 050 000 kr	5 407 650 000 kr	5 625 630 000 kr	7 149 060 000 kr	9 435 690 000 kr
Full time equivalents (incl. temps.: +10% on average)	78276	83314	89188	90046	91509	111870	111518
HEVA (NPV)	-71 887 kr	-60 047 kr	62 691 kr	81 064 kr	81 669 kr	64 888 kr	6 117 kr

HEVA 7-year average	**23 499 kr**
Weight	1,343995942
Weighted HEVA 7-year average	**31 583 kr**

9.2. Extended model

SWEDEN	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Annual production deficit	4143	4295	4691	4597	4496	4202	3859	3622	3437	3350	3307	3389	3382	3327	3532	3395	3733	3856
Accumulated gross deficit	4143	8438	13129	17726	22222	26424	30283	33905	37342	40692	43999	47388	50770	54097	57629	61024	64757	68613
share Volvo Group	0	0	0	331	415	493	565	0	0	760	821	885	948	0	0	1139	1209	1281
Gross total cost NPV	1 551 613 976 kr	2 986 200 731 kr	4 390 579 562 kr	5 601 594 601 kr	6 635 823 100 kr	7 456 258 294 kr	8 074 804 321 kr	8 542 944 514 kr	8 891 031 283 kr	9 155 336 818 kr	9 354 462 176 kr	9 520 398 424 kr	9 638 393 083 kr	9 704 683 564 kr	9 769 222 654 kr	9 775 305 128 kr	9 802 279 885 kr	9 814 258 962 kr
share Volvo Group	0 kr	0 kr	0 kr	104 559 770 kr	123 864 754 kr	139 179 057 kr	150 724 881 kr	0 kr	0 kr	170 894 179 kr	174 611 068 kr	177 708 446 kr	179 910 942 kr	0 kr	0 kr	182 466 553 kr	182 970 065 kr	183 193 668 kr
Investment, 10 year delay NPV	0 kr	0 kr	539 038 266 kr	403 944 014 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr
no of people recruited	0	0	5813	4610	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Investment, 7 year delay NPV	0 kr	0 kr	539 038 266 kr	509 366 434 kr	481 327 915 kr	454 832 801 kr	429 796 133 kr	205 659 944 kr	186 801 141 kr	194 092 369 kr	189 451 577 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr
no of people recruited	0	0	6975	6975	6975	6975	6975	3532	3395	3733	3856	0	0	0	0	0	0	0
Investment, 4 year delay NPV	0 kr	0 kr	127 514 428 kr	120 495 286 kr	113 862 518 kr	107 594 856 kr	101 672 203 kr	96 075 568 kr	90 787 005 kr	85 789 555 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr
no of people recruited	0	0	1100	1100	1100	1100	1100	1100	1100	1100	0	0	0	0	0	0	0	0
Total investment NPV	0 kr	0 kr	1 205 590 960 kr	1 033 805 734 kr	595 190 433 kr	562 427 657 kr	531 468 336 kr	301 735 512 kr	277 588 146 kr	279 881 924 kr	189 451 577 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr
share Volvo Group, 100% take responsibility	0 kr	0 kr	22 503 648 kr	19 297 093 kr	11 109 868 kr	10 498 315 kr	9 920 426 kr	5 632 217 kr	5 181 480 kr	5 224 296 kr	3 536 317 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr
share Volvo Group, 50% take responsibility	0 kr	0 kr	45 007 296 kr	38 594 185 kr	22 219 735 kr	20 996 631 kr	19 840 853 kr	11 264 434 kr	10 362 961 kr	10 448 592 kr	7 072 634 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr
share Volvo Group, 25% take responsibility	0 kr	0 kr	90 014 592 kr	77 188 370 kr	44 439 471 kr	41 993 261 kr	39 681 706 kr	22 528 868 kr	20 725 922 kr	20 897 185 kr	14 145 267 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr
share Volvo Group, 10% take responsibility	0 kr	0 kr	225 036 480 kr	192 970 926 kr	111 098 677 kr	104 983 153 kr	99 204 264 kr	56 322 169 kr	51 814 804 kr	52 242 962 kr	35 363 168 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr
Accumulated net deficit	4143	8438	13129	17726	22222	26424	29183	31705	34042	29317	24549	19863	9358	0	0	0	0	0
share Volvo Group	0	0	0	331	415	493	545	0	0	547	458	371	175	0	0	0	0	0
Net cost due to deficit NPV	1 551 613 976 kr	2 986 200 731 kr	4 390 579 562 kr	5 601 594 601 kr	6 635 823 100 kr	7 456 258 294 kr	7 781 495 046 kr	7 988 616 895 kr	8 105 310 025 kr	6 596 063 342 kr	5 219 270 710 kr	3 990 539 248 kr	1 776 467 663 kr	0 kr	0 kr	0 kr	0 kr	0 kr
share Volvo Group	0 kr	0 kr	0 kr	104 559 770 kr	123 864 754 kr	139 179 057 kr	145 249 949 kr	0 kr	0 kr	123 122 595 kr	97 423 285 kr	74 487 694 kr	33 159 674 kr	0 kr	0 kr	0 kr	0 kr	0 kr
Net total cost NPV	1 551 613 976 kr	2 986 200 731 kr	5 596 170 522 kr	6 635 400 335 kr	7 231 013 532 kr	8 018 685 951 kr	8 312 963 382 kr	8 290 352 407 kr	8 382 898 170 kr	6 875 945 266 kr	5 408 722 286 kr	3 990 539 248 kr	1 776 467 663 kr	0 kr	0 kr	0 kr	0 kr	0 kr
share Volvo Group, 100% take responsibility	0 kr	0 kr	22 503 648 kr	123 856 863 kr	134 974 622 kr	149 677 372 kr	155 170 376 kr	5 632 217 kr	5 181 480 kr	128 346 892 kr	100 959 601 kr	74 487 694 kr	33 159 674 kr	0 kr	0 kr	0 kr	0 kr	0 kr
share Volvo Group, 50% take responsibility	0 kr	0 kr	45 007 296 kr	143 153 955 kr	146 084 489 kr	160 175 687 kr	165 090 802 kr	11 264 434 kr	10 362 961 kr	133 571 188 kr	104 495 918 kr	74 487 694 kr	33 159 674 kr	0 kr	0 kr	0 kr	0 kr	0 kr
share Volvo Group, 25% take responsibility	0 kr	0 kr	90 014 592 kr	181 748 140 kr	168 304 225 kr	181 172 318 kr	184 931 655 kr	22 528 868 kr	20 725 922 kr	144 019 780 kr	111 568 552 kr	74 487 694 kr	33 159 674 kr	0 kr	0 kr	0 kr	0 kr	0 kr
share Volvo Group, 10% take responsibility	0 kr	0 kr	225 036 480 kr	297 530 696 kr	234 963 431 kr	244 162 210 kr	244 454 213 kr	56 322 169 kr	51 814 804 kr	175 365 558 kr	132 786 453 kr	74 487 694 kr	33 159 674 kr	0 kr	0 kr	0 kr	0 kr	0 kr
Cash flow difference (Gross total cost - Net total cost) NP	0 kr	0 kr	-1 205 590 960 kr	-1 033 805 734 kr	-595 190 433 kr	-562 427 657 kr	-238 159 062 kr	252 592 107 kr	508 133 113 kr	2 279 391 552 kr	3 945 739 890 kr	5 529 859 176 kr	7 861 925 419 kr	9 704 683 564 kr	9 769 222 654 kr	9 775 305 128 kr	9 802 279 885 kr	9 814 258 962 kr
share Volvo Group, 100% take responsibility	0 kr	0 kr	-22 503 648 kr	-19 297 093 kr	-11 109 868 kr	-10 498 315 kr	-4 445 494 kr	-5 632 217 kr	-5 181 480 kr	42 547 288 kr	73 651 466 kr	103 220 751 kr	146 751 268 kr	0 kr	0 kr	182 466 553 kr	182 970 065 kr	183 193 668 kr
share Volvo Group, 50% take responsibility	0 kr	0 kr	-45 007 296 kr	-38 594 185 kr	-22 219 735 kr	-20 996 631 kr	-14 365 921 kr	-11 264 434 kr	-10 362 961 kr	37 322 991 kr	70 115 149 kr	103 220 751 kr	146 751 268 kr	0 kr	0 kr	182 466 553 kr	182 970 065 kr	183 193 668 kr
share Volvo Group, 25% take responsibility	0 kr	0 kr	-90 014 592 kr	-77 188 370 kr	-44 439 471 kr	-41 993 261 kr	-34 206 773 kr	-22 528 868 kr	-20 725 922 kr	26 874 399 kr	63 042 516 kr	103 220 751 kr	146 751 268 kr	0 kr	0 kr	182 466 553 kr	182 970 065 kr	183 193 668 kr
share Volvo Group, 10% take responsibility	0 kr	0 kr	-225 036 480 kr	-192 970 926 kr	-111 098 677 kr	-104 983 153 kr	-93 729 332 kr	-56 322 169 kr	-51 814 804 kr	-4 471 379 kr	41 824 615 kr	103 220 751 kr	146 751 268 kr	0 kr	0 kr	182 466 553 kr	182 970 065 kr	183 193 668 kr
Interest per annum	9%																	
Inflation per annum	3%																	
Economic value of an engineer	343 591 kr	353 899 kr	364 516 kr	375 452 kr	386 715 kr	398 317 kr	410 266 kr	422 574 kr	435 251 kr	448 309 kr	461 758 kr	475 611 kr	489 879 kr	504 576 kr	519 713 kr	535 304 kr	551 363 kr	567 904 kr
Engineers (2008 estimate)	305099																	
-- share Volvo Group (2008)	5695																	
-- share Volvo Group (2008) (%)	2%																	
Nominal investment per potential	11 910 kr	12 267 kr	12 636 kr	13 015 kr	13 405 kr	13 807 kr	14 221 kr	14 648 kr	15 087 kr	15 540 kr	16 006 kr	16 486 kr	16 981 kr	17 491 kr	18 015 kr	18 556 kr	19 112 kr	19 686 kr

Investment in Secondary School, 10 year delay																			
Full potential			46500	46500	46500	46500	46500	46500	46500	46500	46500	46500	46500	46500	46500	46500	46500	46500
realistic maximum potential			12,5%	12,5%	12,5%	12,5%	12,5%	12,5%	12,5%	12,5%	12,5%	12,5%	12,5%	12,5%	12,5%	12,5%	12,5%	12,5%
Investment per potential			12 636 kr	10 321 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr
Success rate as percentage of full potential			12,5%	9,9%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Success rate as percentage of maximum potential	*Nominal 2008*		100,0%	79,3%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Investment per recruit	*95 282 kr*		101 084 kr	104 117 kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr
Investment per recruit (future value at effect)	*225 566 kr*		239 303 kr	246 482 kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr

Investment in Secondary School, 7 year delay																		
Full potential			46500	46500	46500	46500	46500	46500	46500	46500	46500	46500	46500	46500	46500	46500	46500	46500
realistic maximum potential			15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%	15,0%
Investment per potential			12 636 kr	13 015 kr	13 405 kr	13 807 kr	14 221 kr	7 417 kr	7 344 kr	8 317 kr	8 849 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr
Success rate as percentage of full potential			15,0%	15,0%	15,0%	15,0%	15,0%	7,6%	7,3%	8,0%	8,3%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Success rate as percentage of maximum potential	*Nominal 2008*		100,0%	100,0%	100,0%	100,0%	100,0%	50,6%	48,7%	53,5%	55,3%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Investment per recruit	*79 401 kr*		84 237 kr	86 764 kr	89 367 kr	92 048 kr	94 809 kr	97 654 kr	100 583 kr	103 601 kr	106 709 kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr
Investment per recruit (future value at effect)	*145 149 kr*		153 988 kr	158 608 kr	163 366 kr	168 267 kr	173 315 kr	178 514 kr	183 870 kr	189 386 kr	195 068 kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr

Investment in Upper Secondary School, 4 year delay																		
Full potential			11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000	11000
realistic maximum potential			10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%
Investment per potential			12 636 kr	13 015 kr	13 405 kr	13 807 kr	14 221 kr	14 648 kr	15 087 kr	15 540 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr
Success rate as percentage of full potential			10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Success rate as percentage of maximum potential	*Nominal 2008*		100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Investment per recruit	*119 102 kr*		126 355 kr	130 146 kr	134 050 kr	138 072 kr	142 214 kr	146 480 kr	150 875 kr	155 401 kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr
Investment per recruit (future value at effect)	*168 122 kr*		178 361 kr	183 712 kr	189 223 kr	194 900 kr	200 747 kr	206 769 kr	212 972 kr	219 361 kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr	- kr

References

AB Volvo (2009) *Annual Report 2008* AB Volvo [Online]. Available at: http://www3.volvo.com/investors/finrep/ar08/annual_report_2008_eng.pdf [Accessed: 29 April 2009]

Augustsson, H., Irding, M., Persson, M. and Westerling, A.[1] (2009) *Company investments into university education.* Göteborg: Chalmers University of Technology.

Barrow, B. and Cavazza M. (2006) Rolls Royce boss despairs at lack of British engineering talent. *Dailymail.co.uk,* 27 July 2006 [Online]. Available at: http://www.dailymail.co.uk/news/article 397957/Rolls-Royce-boss-despairs-lack-British-engineering-talent.html [Accessed: 29 April 2009].

Becker, F.S. (2009) *Why not opt for a career in Science and Technology? An analysis of potentially valid reasons.* [Online] http://www-ice.upc.edu/butlleti2/juliol2009/sefi/papers/Becker.pdf [Accessed: 19 August 2009]

Bunn, M., Savage, G. and Holloway, B.(2002) Stakeholder analysis for multi-sector innovations. *The Journal of Business & Industrial Marketing,* 17 (2/3), p.181-203.

C.Génial (2009) *C.Génial*. [Online]. Available at: http://www.cgenial.org/ [Accessed: 11 June 2009].

Côte, J. (1996) Sociological perspectives on identity formation: the culture-identity link and identity capital. *Journal of Adolescence,* 19, p. 417-428.

Czech Presidency of the European Union (2009) *Conference on partnership – Opening address by Minister Ondřej Liška*. [Online]. Available at: http://www.eu2009.cz/event/1/434/ [Accessed: 29 June 2009].

Dansk Naturvidenskabsformidling (2009) *Science Team K*. [Online]. Available at: http://www.formidling.dk/sw460.asp [Accessed: 11 June 2009].

Deloitte Research (2004) *It's 2008: Do You Know Where Your Talent Is?* Deloitte Development LLC [Online] Available at: http://www.deloitte.com [Accessed: 28 April 2009]

Earl, G. and Clift, R. (1999) Stakeholder Value Analysis: A Methodology for Integrating Stakeholder Values into Corporate Environmental Investment Decisions. *Business Strategy and the Environment,* 8 (3), p.149-162.

Economic Policy Committee (2009) *The economic consequences of ageing populations: projections for the EU27*. [Online]. Available at: http://europa.eu/epc/pdf/technical_press_briefing_ageing_report.pdf [Accessed: 30 July 2009]

Engineering Council (2004) *Digest of Engineering Statistics 2003/2004.* London: Engineering Council.

EurActive.com (2007) The EU's labour-shortage 'time bomb'. *EurActive.com,* 5 June 2007 [Online]. Available at: http://www.euractiv.com/en/socialeurope/eu-labour-shortage-time-bomb/article-164261 [Accessed: 29 April 2009]

[1] The authors Augustsson, H., Irding, M., Persson, M. and Westerling, A. submitted the report to Chalmers University of Technology as a part of a university course.

European Round Table of Industrialists (2008) *Executive Summary – "Inspiring the Next Generation"* European Round Table of Industrialists [Online]. Available at: http://www.ert.eu [Accessed: 29 April 2009]

European Commission (2007) *Technopolis – Identification and dissemination of best practice in science mentoring and science ambassador schemes across Europe*. [Online]. Available at: http://ec.europa.eu/research/science-society/document_library/pdf_06/technopolis-mainreport_en.pdf [Accessed: 11 June 2009]

European Commission (2008) *Progress towards the Lisbon objectives in education and training*. [Online]. Available at: http://ec.europa.eu/education/policies/2010/doc/progress08/report_en.pdf [Accessed: 11 June 2009]

European Commission (2009) *A new partnership for the modernisation of universities: the EU Forum for University Business Dialogue*. [Online] Available at: http://ec.europa.eu/education/higher-education/doc/business/com158_en.pdf [Accessed: 11 June 2009]

Eurostat (2009a*) Population by sex and age on 1. January of each year (demo_pjan)*. [Online] Available at: http://epp.eurostat.ec.europa.eu/portal/page/portal/population/data/database [Accessed: 11 May 2009].

Eurostat (2009b*) Convergence year 2150 - 1 January population by sex and single year of age (proj_08c2150p)*. [Online] Available at: http://epp.eurostat.ec.europa.eu/portal/page/portal/population/data/database [Accessed: 11 May 2009].

Eurostat (2009c*) Educational attainment by sex (educ_iatt)*. [Online] Available at: http://epp.eurostat.ec.europa.eu/portal/page/portal/education/data/database [Accessed: 13 May 2009].

Eurostat (2009d*) Graduates in ISCED 3 and 4 by age and sex (educ_grad2).* [Online] Available at: http://epp.eurostat.ec.europa.eu/portal/page/portal/education/data/database [Accessed: 13 May 2009].

Eurostat (2009e*) Graduates in ISCED 5 and 6 by age and sex (educ_grad4).* [Online] Available at: http://epp.eurostat.ec.europa.eu/portal/page/portal/education/data/database [Accessed: 13 May 2009].

Eurostat (2009f) *Mathematics, science and technology enrolments and graduates (educ_thflds).* [Online] Available at: http://epp.eurostat.ec.europa.eu/portal/page/portal/education/data/database [Accessed: 19 May 2009].

Eurostat (2009g) *Introduction - Science, Technology and Innovation*. [Online] Available at: http://epp.eurostat.ec.europa.eu/portal/page/portal/science_technology_innovation/introduction [Accessed: 31 July 2009].

Fassin, Y. (2009) The Stakeholder Model Refined. *Journal of Business Ethics,* 84, p.113-135.

Financial Times Deutschland (2007) Lack of engineers costs Germany billions. *Financial Times Deutschland,* 8 May 2007.

Fitz-ens, J. (2000) *The ROI of human capital: measuring the economic value of employee performance.* New York: AMACOM.

Freeman, R.E. (1984) *Strategic Management: A Stakeholder Approach.* Pittman, Boston.

Frøsnes, I. (1998) *De likeverdige. Om socialisering og de jevnaldrendes betydning.* Oslo: Universitetsforlaget.

Gago, J., Ziman, J., Caro, P., Constantinou, C., Davies, G., Parchmann, I., Rannikmäe, M. and Sjøberg, S. for the European Commission (2004) *Increasing Human Resources for Science and Technology in Europe*. Luxembourg: Office for Official Publications of the European Communities.

Giddens, A. (1991) *Modernity and Self-Identity.* Self and Society in the Late Modern Age. Cambridge: Polity Press.

Goffman, E. (1959) *The Presentation of Self in Everyday Life*. New York: Anchor Book.

Gustavsson, S. (2007) Ingenjörsbrist hotar exportföretagen. *DN.se,* 14 May 2007 [Online]. Available at: http://www.dn.se/ekonomi/ingenjorsbrist-hotar-exportforetagen-1.553050 [Accessed: 29 April 2009].

Högskoleverket (2009a) *Högskoleutbildningarna och arbetsmarknaden. Ett planeringsunderlag inför läsåret 2009/2010.* Huskvarna: NRS Tryckeri.

Högskoleverket (2009b*) Sökandetryck.* [Online] Available at: http://www.hsv.se/statistik/statistikomhogskolan/sokandetryck/ [Accessed: May 18 2009].

Illeris, K.; Katznelson, N.; Simonsen, B. and Ulriksen, L. (2002) *Ungdom, identitet og uddannelse.* Fredriksberg: Roskilde universitetsforlag.

Intize (2009) *Intize*. [Online]. Available at: http://www.intize.org/ [Accessed: 11 June 2009].

Jet-Net (2009) *Jet-Net*. [Online]. Available at: http://www.jet-net.nl/ [Accessed: 11 June 2009].

Johansson, B. and Mouwitz, L. (2007) *For the teaching and learning of mathematics in Europe.* Göteborg: National Centre for Mathematics Education.

Kaler, J. (2002) Morality and Strategy in Stakeholder Identification. *Journal of Business Ethics,* 39, p.91-99.

Kunnskapsdepartementet (2009) *Nyheter*. [Online]. Available at: http://www.regjeringen.no/nb/dep/kd/aktuelt/nyheter.html?id=595 [Accessed: 11 June 2009].

Lavonen, J., Byman, R, Juuti, K. Meisalo, V., and Uitto, A. (2005) Pupil Interest in Physics: A Survey in Finland. *Nordina*, 1(2), p 72-85.

Lyng, S. (2004) Være eller lære? Om elevroller, identitet og læring *i ungdomsskolen.* Oslo: Universitetsforlaget.

Maignan, I., Ferrell, O.C. and Hult, G.T.M. (1999) Corporate citizenship: Cultural antecedents and business benefits. *Journal of the Academy of Marketing Science,* 27 (4), p. 455-469.

Ministère Éducation Nationale (2008) *Conclusions of the EU French Presidency Conference: Science Education in the Europe of Knowledge*. [Online]. Available at: http://eduscol.education.fr/D0122/PFUE-sciences_EN.pdf [Accessed: 11 June 2009]

Mitchell, R.K., Agle, B.R. and Wood, D.J. (1997) Toward a Theory of Stakeholder Identification and Salience: Defining the Principle of Who and What Really Counts. *Academy of Management Review*, 22 (4), p. 853-886.

MoMoTech (2009) *MoMoTech*. [Online]. Available at: http://www.motivation-technik-entdecken.de/ [Accessed: 24 August 2009].

Munro, M. and Elsom, D. (2000) *Choosing science at 16,* NICEC project report. Cambridge: NICEC.

Næringslivets hovedorganisasjon (2009) *Næringslivet i skolen*. [Online]. Available at: http://www.nho.no/bedrift_og_samfunn/ [Accessed: 11 June 2009].

OECD (2007) *PISA 2006, Science Competencies for Tomorrow's World, Volume 1: Analysis.* Paris: OECD.

OECD (2008a) *Education at a Glance 2008, OECD Indicators*. Paris: OECD.

OECD (2008b) *OECD Factbook 2008*. Paris: OECD.

OECD (2008c) *Encouraging Student Interest in Science and Technology Studies.* Paris: OECD.

OECD (2009a) *OECD Factbook 2009*. Paris: OECD.

Osborne, J., Simon, S. and Collins, S. (2003) Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education,* 25 (9), p. 1049-1079.

Osborne, J. and Dillon, J. (2008) *Science Education in Europe: Critical Reflections.* London: The Nuffield Foundation.

Pollen (2009) *Pollen*. [Online]. Available at: http://www.pollen-europa.net/ [Accessed: 11 June 2009].

Renate (2009) *Renate – nasjonalt senter for realfagsrekruttering.* [Online]. Available at: http://www.renatesenteret.no/ [Accessed: 11 June 2009].

Rocard, M., Csermely, P., Jorde, D. Lenzen, D. Wallberg-Henriksson, H. and Hemmo, V. for the European Commission (2007) *Science Education NOW: A Renewed Pedagogy for the Future of Europe.* Luxembourg: Office for Official Publications of the European Communities.

Schiebinger, L. (1989) *The Mind has no Sex? Women in the Origins of Modern Science*. London: Harvary University Press.

Schreiner, C. and Sjøberg, S. (2007) *Science education and young people's identity construction – two mutually incompatible projects?.* [Online]. Available at: http://www.ils.uio.no/english/rose/network/countries/norway/eng/nor-schreiner-values2006.pdf [Accessed: 31 May 2009]

Science Learning Centres (2009) *National STEM Centre – Director Announced.* [Online] Available at: http://www.sciencelearningcentres.org.uk/WebPortal.aspx?page=2&module=DB920A53-

01EA-4886-8878-F2CDF5FA8CFD&mode=101&newsIdDB920A53_01EA_4886_8878_F2CDF5FA8CFD=13148 [Accessed: 15 June 2009]

Seymour, E. and Hewitt, N. (1997) *Talking about leaving, why undergraduates leave the sciences.* Boulder: Westview Press.

Simonsen, B. and Ulriksen, L. (1998) *Universitetsstudier i krise. Fag, prosjekter og moderne studenter*. Frederiksberg: Roskilde Universitetsforlag.

Sjøberg, S. (2004) *Naturfag som allmenndannelse – en kritisk fagdidaktikk*. Oslo: Gyldendal Norsk Forlag AS.

Sjøberg, S. (2008) *Science for the children?* Report from the Science and Scientists-project, Acta Didactica 1/2002. Oslo: Department of Teacher Education and School Development, University of Oslo.

Sjøberg, S. and Schreiner, C. (2008) *Young people, science and technology; Attitudes, values, interests and possible recruitment; Selected results from recent research.* [Online]. Available at: http://www.ils.uio.no/english/rose/network/countries/norway/eng/nor-sjoberg-ert2008.pdf. [Accessed: 19 May 2009].

Skolverket (2006a) *Tabell 6.2 A Behöriga sökande till år 1 läsåret 2005/06.* [Online]. Available at: http://www.skolverket.se/sb/d/1718/a/8002 [Accessed: 15 May 2009].

Skolverket (2006b) *Tabell 6.2 A Behöriga sökande till år 1 läsåret 2004/05.* [Online]. Available at: http://www.skolverket.se/sb/d/1718/a/8004 [Accessed: 15 May 2009].

Skolverket (2006c) *Tabell 6.2 A Behöriga sökande till år 1 läsåret 2003/04.* [Online]. Available at: http://www.skolverket.se/sb/d/1718/a/8005 [Accessed: 15 May 2009].

Skolverket (2006d) *Tabell 6.2 Behöriga sökande och intagna till år 1 läsåret 2002/03.* [Online]. Available at: http://www.skolverket.se/sb/d/1718/a/8006 [Accessed: 15 May 2009].

Skolverket (2006e) *Tabell 6.2 Behöriga sökande och intagna till år 1 läsåret 2001/02.* [Online]. Available at: http://www.skolverket.se/sb/d/1718/a/8007 [Accessed: 15 May 2009].

Skolverket (2006f) *Tabell 6.2 Behöriga sökande och intagna till år 1 läsåret 2000/2001.* [Online]. Available at: http://www.skolverket.se/sb/d/1718/a/8008 [Accessed: 15 May 2009].

Skolverket (2006g) *Tabell 6.2 Behöriga sökande och intagna till år 1 läsåret 1999/2000.* [Online]. Available at: http://www.skolverket.se/sb/d/1718/a/8009 [Accessed: 15 May 2009].

Skolverket (2006h) *Tabell 6.2 Behöriga sökande och intagna till årskurs 1 läsåret 1998/99.* [Online]. Available at: http://www.skolverket.se/sb/d/1718/a/8010 [Accessed: 15 May 2009].

Skolverket (2006i) *Tabell 4.2 Behöriga sökande och intagna till årskurs 1 läsåret 1997/98.* [Online]. Available at: http://www.skolverket.se/sb/d/1718/a/8011 [Accessed: 15 May 2009].

Skolverket (2006j) *Tabell 4.2 Behöriga sökande och intagna till årskurs 1 läsåret 1996/97.* [Online]. Available at: http://www.skolverket.se/sb/d/1718/a/8012 [Accessed: 15 May 2009].

Skolverket (2007) *Tabell 3 A Elever som sökt i 1:a hand och intagna läsåret 2006/07.* [Online]. Available at: http://www.skolverket.se/sb/d/1718/a/8918 [Accessed: 15 May 2009].

Skolverket (2008) *Tabell 3 A Elever som sökt i 1:a hand och intagna läsåret 2007/08.* [Online]. Available at: http://www.skolverket.se/sb/d/1718/a/11261 [Accessed: 15 May 2009].

Skolverket (2009) *Tabell 3 A Elever som sökt i 1:a hand och intagna läsåret 2008/09.* [Online]. Available at: http://www.skolverket.se/sb/d/1718/a/14862 [Accessed: 15 May 2009].

SOU (2004) *Att lyfta matematiken –intresse, lärande, kompetens*. SOU 2004:97. Utbildningsdepartementet, Statens Offentliga Utredningar, Stockholm.

Sweden. *Education Act 1985:1100.* Stockholm: Svensk författningssamling (SFS)

Teknikdelegationen (2009a) *Rapport 2009:1 Nyfiken på naturvetenskap och teknik – en kartläggning av initiativ som syftar till att öka barns och ungdomars intresse för ämnena.* [Online] Available at: http://www.teknikdelegationen.se/bazment/teknikdelegationen/download.aspx?id=rapport_2009_1 [Accessed: 11 June 2009].

Teknikdelegationen (2009b) *Delegationen*. [Online] Available at: http://www.teknikdelegationen.se/ [Accessed: 11 June 2009].

The Japan Times (2006) Science crisis in the making. *The Japan Times*, 11 April 2006.

Ulrikssen, L. (2003) Børne- og ungdomskultur og naturfaglige uddannelser *in* Busch, H.; Horst, S.; and Troelsen, R. *Inspiration till fremtidens naturfaglige uddannelser.* Copenhagen: Undervisningsministeriets forlag.

Undervisningsministeriet (2009) *Nyheder om folkeskolen*. [Online]. Available at: http://www.uvm.dk/Uddannelse/Folkeskolen/Om%20folkeskolen/Nyheder.aspx [Accessed: 11 June 2009].

United Kingdom Department of Education and Skills (2006) *The Science, Technology, Engineering and Mathematics (STEM) Programme Report.* [Online] Available at: http://www.stemnet.org.uk/_db/_documents/The_STEM_Programme_Report_-_October_2006_20090323042254.pdf [Accessed: 15 June 2009].

United Nations Population Division (2009) *World Population Prospects: The 2008 Revision*. [Online] Available at: http://esa.un.org/unpp [Accessed: 11 May 2009].

U.S. Census Bureau (2009) *International Data Base*. [Online] Available at: http://www.census.gov/ipc/www/idb/index.php [Accessed: 4 August 2009]

USA Today (2007) America is in trouble in science and education. *USA Today,* 3 August 2007.

Varvasovszky, Z. and Brugha, R. (2000) A Stakeholder Analysis. *Health and Policy Planning*, 15 (3), p.338-345.

Vetenskap och Allmänhet (2007) *Projekt utan effekt? –utvärderingar av N&T-initiativ under luppen.* [Online] Available at: http://www.va.se/dokument/ungdomar/projekt_utan_effekt_utvarderingar_av_n_t-initiativ_under_luppen/download/ [Accessed: 11 June 2009]

Wertheim, M. (1997) *Pythagoras' trousers: God, physics, and the gender wars.* New York: W.W. Norton & Company Inc.

Wertheim, M. (2006) Numbers are male, said Pythagoras, and the idea persists. *New York Times,* 3 October 2006.

Wissensfabrik (2009) *Wissensfabrik*. [Online]. Available at: http://www.wissensfabrik-deutschland.de/ [Accessed: 11 June 2009].