Upper secondary curriculum reform in Sweden: a case study

Erik Mellander

This report forms part of a collection of six case studies commissioned by the Royal Society in 2017 examining upper-secondary education reform in different jurisdictions. The case studies are designed to give the reader an understanding of the trends in upper secondary curriculum reform and, in particular, the recent moves that certain jurisdictions have made towards a broader and more balanced curriculum.

These case studies were officially launched at the Royal Society's symposium *Broad and Balanced: What is the future for our post-16 curriculum?* on 17 October, 2017.

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Abstract

To gather information about how to increase the recruitment to, and skills in, Science, Technology, Engineering and Mathematics (STEM), two reforms of the Swedish upper secondary school are analysed. The first, in 1995, made the curriculum broader by, i.a., extending the vocational tracks, increasing their academic content and making them provide eligibility to university studies. The second reform, in 2011, reinstated the distinctions between vocational and academic programs; courses yielding university eligibility were made compulsory for academic programs only. A descriptive empirical analysis, employing register data, considers before-after reform changes, by gender, in three outcomes: choices of STEM vs non-STEM upper secondary education, upper secondary completion rates, and transitions from upper secondary school to university STEM education. Furthermore, the Swedish results in TIMSS Advanced 1995, 2008, and 2015 are related to the reforms. With respect to both analyses, it is found that, from a STEM perspective, the changes following the second, curriculum narrowing, reform were more favourable than the changes after the first, curriculum broadening, reform. A 1-year 'add-on' education enabling persons with non-STEM upper secondary background to enrol in STEM university studies is found to be an attractive alternative to general curriculum changes and especially beneficial to female students.

Keywords: Curriculum reforms, STEM education, recruitment, achievements, empirical analysis, register data, TIMSS Advanced, gender differences

Acknowledgements

This research constitutes a country case study in the 'Broad Curriculum Research' project initiated and funded by the Royal Society in the UK. Excellent research assistance provided by Patrik Lind is gratefully acknowledged. Helpful discussions at the 2017 Summer seminar arranged by Linköping University's Centre for School Technology Education (CETIS) at Rockelstad Castle and at a seminar at the Institute for Evaluation of Labour Market and Education Policy (IFAU) in Uppsala are much appreciated. Special thanks to Mary James, Charlotta Nordlöf, Johan Svenningsson, Markus Stoor, and Adam Wright for specific comments, and, in particular, to Ulla Riis for detailed and thoughtful suggestions.

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1 Introduction

In many countries, the recruitment to education in Science, Technology, Engineering and Mathematics, STEM, is viewed as insufficient relative to the needs arising in the wake of rapid technological innovations and increased global competition. In Sweden, Lövheim (2016) describes the efforts made between 1950 and 2000 to increase the recruitment to upper secondary and tertiary STEM education. He shows that an important objective of these efforts was to increase the participation of female students in STEM studies.

During the last 30 years, 1986–2016, the curriculum in the Swedish upper secondary school has undergone an interesting development, involving two curriculum reforms. The first one, implemented in 1995, contained several elements which broadened the curriculum. For instance, the academic content of (formerly) strongly vocationally focused upper secondary tracks was increased and all upper secondary education was designed such that it provided basic eligibility to university studies. The second reform, implemented in 2011, reversed many of changes enacted by the first reform. Clear distinctions between vocationally and academically oriented educational programs were reinstated; upper secondary school entry requirements were made to differ across the two categories, separate exams were introduced and courses yielding basic university eligibility became compulsory only for the academically oriented programs. Finally, the present government has very recently conducted a public investigation (SOU 2016:77) resulting in proposals advocating, again, changes that would yield a broader curriculum.

In an empirical analysis, the changes in four outcome variables after the two curriculum reforms are considered. The analysis is descriptive and makes no claim to allow causal inferences – it simply amounts to the computation of before-and-after reform differences.[1] The outcomes are recruitment to upper secondary STEM and non-STEM education, upper secondary school completion rates for these categories, transition rates to university studies and results in Mathematics and Physics for advanced upper secondary STEM students. To capture the gender dimension, the results are reported separately for females and males.

With respect to the first three of the outcome variables, the analysis is based on Swedish register data collected by Statistics Sweden. These are population data, making it possible to follow individual students over their educational career.

[1] However, the results of two causal effect evaluations of a pilot scheme preceding the first curriculum reform (Ekström 2003, and Hall, 2012) will be discussed.

Altogether, the data comprise over 2.9 million individuals for the 1986–2016 period. The analysis of the fourth outcome variable employs published results from the international Trends in Mathematics and Science Study, TIMSS, which has been conducted among third-year upper secondary STEM students on three occasions, in 1995, 2008, and 2015.[2]

Even though the analysis is descriptive, the fact that the Swedish experiences comprise two very different curriculum regimes, whose consequences can be illustrated along several dimensions, should provide useful information about the pros and cons of broad upper secondary school curricula.

The analysis is structured as follows. Section 2 contains a description of the three curriculum regimes that have been in place during 1986–2016. In addition, the discussion conducted in 2015 and 2016 about yet another curriculum reform is briefly reiterated. Next, in Section 3, three alternative definitions of upper secondary STEM education are suggested as well as a definition of upper secondary non-STEM education. Information about the data employed in the empirical analysis is provided in Section 4. The empirical approach is described in Section 5. Sections 6–9 contain the empirical results. Conclusions are provided in Section 10.

2 Three upper secondary curricula

In Sweden, all individuals with completed compulsory schooling are entitled to upper secondary education. The compulsory school extends over nine years, normally starting during the student's seventh year and ending during the year (s)he turns 15. Upper secondary school is voluntary but attended by almost all students. Since the late 1980s, the cohorts of students leaving compulsory school have roughly comprised 95 000 – 125 000 individuals.[3] Of these, at least 90 percent have generally proceeded to some form of further education; most of them, but not all, to upper secondary education.[4]

The essential features of the youth education curricula are decided upon by the Swedish parliament, i.e. goals, guidelines, timetables for the different subjects, and the grading system. Subject syllabi are decided by the government and the teacher

[2] TIMSS is conducted by the International Association for the Evaluation of Educational Achievement, IEA. The IEA was founded in 1958 and has since then carried out some 30 international comparative studies on pupils' knowledge in different school subjects, among the Science (Biology, Chemistry, Geology, and Physics) and Mathematics.

[3] For comparison, the Swedish population was 8.4 million in the late 1980s and reached 10 million in 2016. Accordingly, the cohorts leaving compulsory school roughly make up just above one percent of the population.

[4] In Section 3.2 below there is a discussion about studies *preparing* for upper secondary education vs (regular) upper secondary education.

education is also a state responsibility. The implementation used to be in the hands of the state, too, but that changed in the early 1990s; see Section 2.2.

During the period 1986–2016, three different upper secondary curricula have been in place. The first of these, the Lgy70 curriculum, which was in use 1971–1995, i.e. for almost a quarter of a century, will serve as a reference point. The considerations preceding its implementation will be taken as given and will not be discussed in this paper, although an overview of the curriculum itself will, of course, be provided.[5]

The next two curricula, the Lpf94 and Gy11, spanning the periods 1995–2011 and 2011 and onwards, respectively, will be considered in chronological order. The political discussions and the policy contexts behind the reforms will be reiterated, as well as the resulting curriculum changes.

In spite of the fact that, at the time of writing, the present curriculum has only been in place for six years, curriculum reforms are very high on agenda of the present government, a social democrat and green coalition, that took over power from a liberal, right-wing government in the fall of 2014. Drawing on an extensive government report, SOU 2016:77, the final sub-section provides some information about likely future developments.

To support the verbal presentation, a visual overview of the development over the 30-year period is provided by Figure 1, below. In the figure, the three curriculum periods have been marked along a time axis together with (other) reforms which are of interest from a STEM perspective. References to indicators describing the changes over time are also made in the figure. The references are provided in Roman numerals and 'signed' such that '+' and '–' denote changes corresponding to a broadening and a narrowing of the curriculum, respectively, and '++' denotes more broadening than '+', etc.

[5] For an account of the policy discussions leading up to the Lgy70 reform, see SOU 2002:120

Figure 1: The development of the Swedish upper secondary school 1986 – 2016; Roman numerals with attached + or – signs indicate changes broadening or narrowing the curriculum, respectively, detailed below the figure

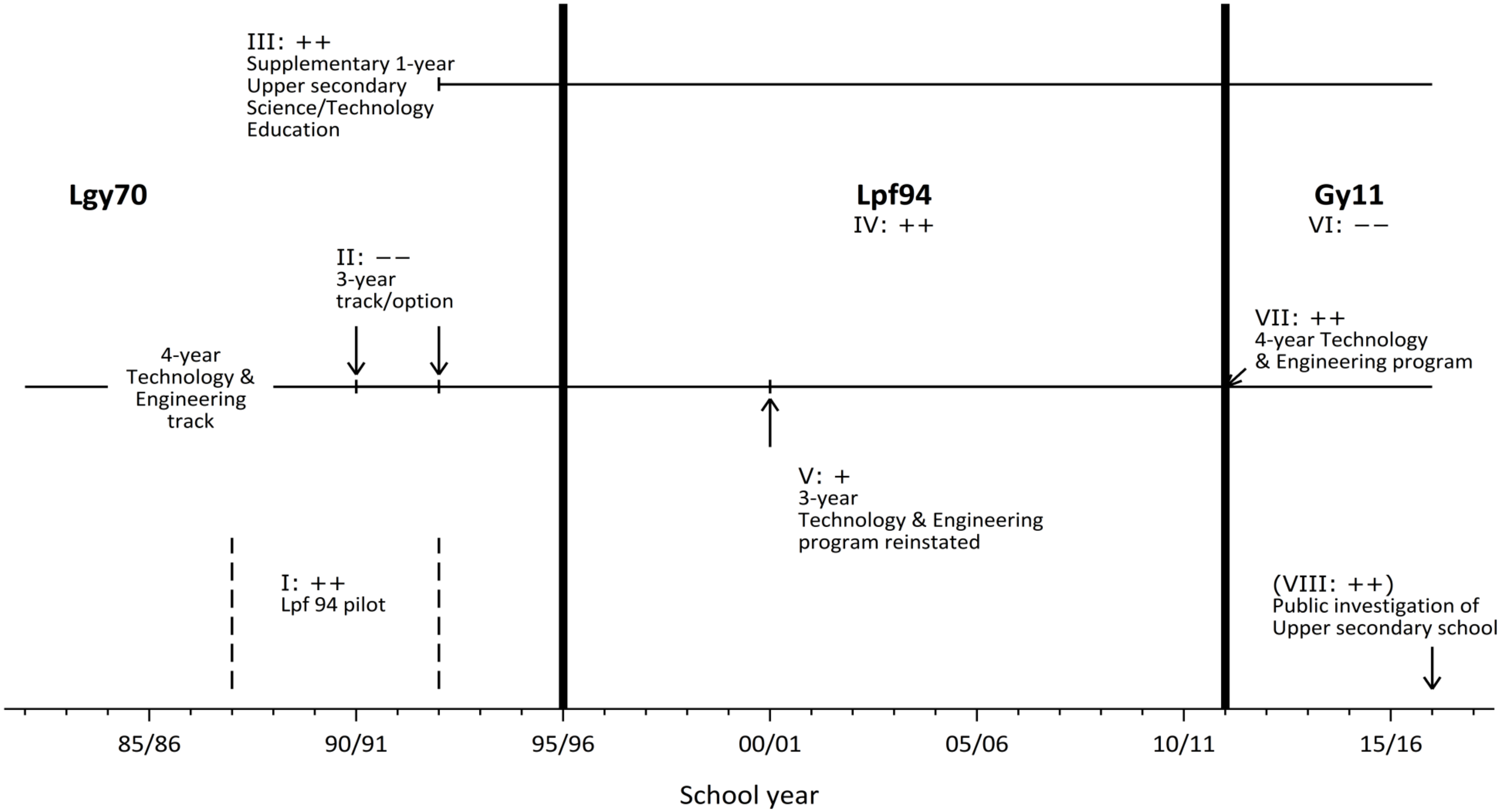


Figure 1 indicators

	Indicators							
	I: + +	II: – –	III: + +	IV: + +	V: +	VI: – –	VII: + +	(VIII: + +)
i	Vocational tracks extended from 2 to 3 years.	1990/1991 the track lost its 4th, vocational training year.	For upper sec. Social scientists & Business admin.: 1 year of upper sec. STEM → eligibility to university STEM studies.	22 tracks replaced by 16 programs, all of which extend over 3 years. Some programs with different options, 'branches',	Technology & Engineering back as separate program; more flexibility in program content	More stringent upper secondary entry requirements for all programs, in particular, for the theoretical programs.	Technology & Engineering regains status as 4-year, theoretical and vocational program.	More restrictive entry require-ments for vocational programs.
ii	Increased academic content: English, social studies and elective course.	1992/1993 ceases to be separate track, becomes option in Science track		8 core subjects: Swedish, English, Math, Science, Social sciences, Religion, Health, Aesthetics.		Math in Science and Technology & Engineering educations increased by 1/7.		Basic university eligibility from vocational pro- grams reinstated.
iii	Workplace training increased from 6% in years 1-2 to 10% in years 1-2 and 40% in year 3.			Compulsory Math and Physics reduced in Science and Technology & Engineering educations.		Upper secondary exams introduced: one for vocational and one for theoretical programs		Option for vocational programs to add courses to obtain full university eligibility.

iv	The 3-year vocational educations provided basic eligibility to university studies.			Grades changed from 1-5 & relative scale to Fail, Pass, Pass with Distinction, Pass with Special Distinction & absolute scale		New grades: A – F; F, E, C, A corresponding to Fail, Pass, Pass with Distinction, Pass with Special Distinction, respectively.		
v				The teaching organized in courses instead of in subjects.		Requirements for basic university eligibility more stringent.		
vi				All programs yield basic eligibility to university studies.		Courses required for basic university eligibility become com-pulsory only for theoretical programs.		

2.1 The Lgy70 curriculum: 1971–1995

In 1969, differentiation was abandoned in the Swedish *compulsory* school. From then on completion of compulsory school provided eligibility to all, or at least some, tracks in upper secondary school.[6] A pupil was regarded as having completed compulsory school if (s)he had obtained grades in all subjects. In principle, the only way not to get a grade was to never show up in class. Thus, essentially all students completed compulsory school. According to Marklund (1985), Sweden was one of the first countries to introduce a long *and* non-differentiated compulsory school system.

The Lgy70 upper secondary curriculum was organized in terms of study tracks. During the first 15 years of the 1971–1995 period there were 22 tracks altogether, which encompassed three different forms of upper secondary schooling:

- Five *theoretically oriented three- or four-year tracks, preparing for university studies*. Four of these were three-year tracks, namely Business administration, Humanities, Sciences, and Social sciences. The fifth, Technology & Engineering also contained three years of theoretically oriented education but, on top of these, there was a fourth vocationally oriented year which resulted in a professional engineering qualification. The fourth year was optional; students could proceed to university studies already after the third year.
- Four *theoretically oriented two-year tracks*: Business administration, Music, Social sciences, Technology & Engineering. Apart from the Music track these were *condensed and simplified version of the corresponding three- and four-year tracks*. These tracks *provided basic eligibility to a limited number of university educations but, in general, not to university STEM education*.
- 13 *two-year vocationally oriented tracks*. These included STEM-oriented tracks, like applied technology tracks, e.g. car mechanics and operation of industrial processes; health care tracks; and applied natural sciences tracks, like forestry and farming. About a third of the first year was devoted to general, theoretical, subjects. Even though the major part of these educations consisted of training for specific occupations, the vocational tracks did not yield vocational qualifications. The student’s final training was supposed to take place as part of the student’s first employment, and to be regulated by agreements between the employer organizations and the unions (SOU 2008:27). However, in many industries it proved difficult to enforce such agreements.

[6] Pupils that had substituted the subjects Technology or Business administration for a second foreign language (beside English) were not eligible to theoretically oriented tracks in upper secondary school.

In addition to the aforementioned tracks there was a large number (almost 500) of specialized, vocationally oriented courses, with durations between one semester and two years, i.e. four semesters.

Only one subject was compulsory in all tracks – Swedish. Thus, in many tracks, Mathematics and English were elective subjects.

There were no upper secondary examinations.[7] Instead, national, standardized tests in Swedish, Mathematics and English were used to ascertain consistent grading across the schools in different parts of the country. The grades were provided by subject.

2.2 The Lpf94 curriculum: 1995–2011

In the 1980s, a policy discussion was initiated about the need to reform the vocational upper secondary education. It was proposed that the length of the vocational tracks be extended from two to three years. During the two first years, 90 percent of the curricula would be school-based and 10 percent devoted to practical training, in a workplace. For the final year the corresponding proportions would be 60 and 40 percent, respectively. This amounted to very substantial increase in the share of workplace training which, at the time, corresponded to around 6 percent of the two years that the vocational tracks made up. The intention was to increase the extent to which the vocational tracks provided vocational qualifications. Another ambition was to reduce the differences between the academic and the vocational tracks; both should prepare for tertiary studies. This was to be achieved by a broadening of the curriculum in two respects: an increase in the number of theoretical subjects and extended studies in the theoretical subjects already included (SOU 1986:2 and 1986:3). These changes would enlarge the recruitment pool for the universities, not least with respect to STEM studies, it was argued. The proposal resulted in a pilot scheme, extending over the period 1987–1993, in which new three-year vocational tracks were tried out in parallel with the already existing two-year tracks (Figure 1, indicator I.i–iv).

The three- and four-year theoretical tracks were left unchanged during the pilot scheme, with one exception: in 1990, the four-year technology track was stripped of its fourth, optional, year, thus narrowing its curriculum and turning it (solely) into a theoretical track preparing for tertiary studies. Accordingly, the four-year technology track lost its special feature of offering students not prepared to (immediately) continue to university the possibility to obtain a professional qualification, a feature which appears to have been quite highly regarded in the labour market. Two years later, this track further lost its status as an independent upper secondary track and was turned

[7] Upper secondary examinations had been abandoned in 1968.

into a variant of the science track, a change which, presumably, did not make it more attractive (Figure 1, indicator II.i–ii).

Beginning in the early 1990s, substantial changes also occurred with respect to the organization of youth education. Having been a central government responsibility, it was decentralized to the local governments, just below 300 in numbers. As a consequence, the local governments became responsible for providing free upper secondary education to all 16-19 year olds; see Holmlund et al. (2014).

In 1991, i.e. before the pilot scheme had come to an end, the government decided to extend all two-year vocational tracks to three-year ones. The resulting curriculum, denoted Lpf94, was not fully implemented until 1995, however: the local governments had been allowed to choose when switch to the new regime during the 1992–1995 period.

In the meantime, in 1992, another noteworthy change occurred, which targeted students that had completed non-STEM upper secondary education in Business administration or Social sciences. By means of one year of supplementary studies, encompassing the courses in Mathematics, Sciences, and Technology & Engineering that were specific to the upper secondary three-year science or technology tracks, this so called 'Base-year education' provides eligibility to university-level STEM studies (Figure 1, Indicator III). Moreover, students admitted to the Base year education are guaranteed admittance to subsequent university studies.

The introduction of the Base-year education was a direct response to an urgent need – perceived by politicians and employer organizations alike (Lövheim 2016, pp. 164–170) – to rapidly increase the number of university STEM students (Figure 1, indicator III). Addressing students already acquainted with theoretical studies provided a faster solution to the recruitment problem than the targeting of students about to start their upper secondary education. The Base-year education came to be administered by the universities, despite it being an upper secondary level program, and this organizational anomaly still prevails. Later, Base-year education also to some extent has been provided within the framework of the Swedish adult education system.

When the Lpf94 was fully in place, several additional changes, beside the prolongation of the vocational educations had been implemented.

First, while the upper secondary education had been structured in tracks during the Lgy70 curriculum it now became organized in terms of programs, the name change presumably chosen to indicate that the programs differed from the former tracks not only with respect to study content but also with respect to structure, as described below. There were 16 programs altogether, all of which extended over three years.[8] The three- and four-year theoretical tracks under the Lgy70 curriculum were aggregated into two programs with different ‘branches’: the Science program, branched into Sciences and Technology & Engineering, and the Social sciences program, branched into Business administration, Humanities, and Social sciences. The two-year theoretical educations under the Lgy70 were abandoned in the Lpf94. Concerning the vocational education, in addition to the extension from two to three years of study, two new programs were added: a Media program and a Hotel and restaurant program. (Figure 1, Indicator IV.i)

Second, a set of eight so called core subjects was included in all of the programs: Swedish, English, Mathematics, Science, Social sciences, Religion, Health and sports, and Aesthetic activities (Figure 1, Indicator IV.ii). The designation of a subject as a core subject implied a common minimum amount of teaching in this subject across all programs.[9] An important aspect of the introduction of core subjects was that it provided substance to the strategy to broaden the curriculum of the vocational programs.

Third, for some of the programs, the program-specific minimum study requirements were reduced, compared to the Lgy70 curriculum. In particular, this was true for the Science program and the Technology & Engineering program. While these programs still devoted much more teaching to Mathematics and Sciences than implied by the core subject requirements, compulsory Mathematics and Physics decreased significantly. Regarding Mathematics, the study of differential calculus and complex numbers was made optional in both programs and in the Technology & Engineering program integral calculus and trigonometry also ceased to be compulsory. In Physics, the minimum study requirements were about halved in both programs. (Figure 1, Indicator IV.iii)

Fourth, a new grading system was introduced. The former relative system, where the distribution of grades across the student population had been taken to be approximately normal over five grades ranging from 1 (lowest) to 5 (highest), was replaced by an ‘absolute’ system where four grades – Fail, Pass, Pass with Distinction, and Pass with Special Distinction – were defined in terms of knowledge and skill criteria. (Figure 1, Indicator IV.iv)

[8] Some would add the so called Individual Program (IP) making the total number of programs equal to 17. However, the IP is in this paper not considered to be a (regular) upper secondary education, but an education preparing for upper secondary level studies; see further Section 3.2.

[9] However, in some programs much more time was devoted to some of these subjects than the required minimum amount, an example being the teaching of Mathematics and Sciences in the Sciences program.

Fifth, in contrast to Lgy70, the teaching was organized in terms of courses instead of subjects – accordingly, the grades were assigned to courses, rather than subjects. The re-organization was motivated by increased flexibility. At the school level, courses could be changed in response to changes in society in general and to changes in the labour market in particular. For the students, the possibilities to adapt the programs according to interests, skills, and needs were increased. (Figure 1, Indicator IV.v)

Sixth, completion of any of the programs yielded basic eligibility to university studies. Basic eligibility meant eligibility for many university programs but far from all. In particular, eligibility for university STEM studies in general required additional qualifications. (Figure 1, Indicator IV.vi)

Finally, during the Lpf94 period, a change also occurred with respect to the three-year theoretical Technology & Engineering branch of the Sciences program. In 2000, Technology & Engineering regained its status as an independent program. This allowed its curriculum to be broadened, which led to significant local variations in the program's content (SOU 2008:27, p. 219; Figure 1, indicator V).

2.3 The Gy11 curriculum

During the first decade of the 2000s, several proposals were put forward for a new curriculum for upper secondary school to replace Lpf94 (SOU 2016:77, p. 143-145). Among the issues discussed were the appropriate number and types of core subjects, course grades vs subject grades, and if an upper secondary exam should be introduced.

In 2006 a liberal and right-wing coalition gained power after ten years with a social democrat government. The new government put a stop to the implementation of a rather mild reform of upper secondary education that had just been initiated, in 2006, and launched a new public investigation of upper secondary education, in February of 2007. This investigation resulted in a proposal in 2008 (SOU 2008:27) which was later, in 2011, implemented as the new curriculum, Gy11. This curriculum represented a view on upper secondary education which was distinctly at odds with the one underlying the Lpf94 curriculum.

The change was partly ideologically motivated; the new government was less enthusiastic than the old one about the idea that all upper secondary programs should provide eligibility to university studies. And there were some indicators supporting these doubts. For instance, it appeared that the extension of the upper secondary vocational programs had increased drop-out rates while the possibilities to proceed to university studies were not very much exploited.[10]

Whereas the Lpf94 had reduced the differences between vocational and theoretical education, the Gy11 reversed those changes. To begin with, the explicit distinction between theoretical and vocational education that had existed under the Lgy70 but had been abolished in the Lpf94 was reintroduced, although the programs offered under the Lpf94 were basically kept unchanged. With respect to the programs, the most important change was that, after 22 years, the Technology & Engineering program regained the special status of a four-year program that, in addition to preparing for university studies, offered the option of yielding a vocational qualification (Figure 1, indicator VII). This change was followed by substantial increase in the inflow of students; between 2010 and 2011 the number of students choosing the technology program increased from 5 734 to 8 949, i.e., by 56 percent.[11] It is likely, however, that there were also other reasons for this increase than the reintroduction of the fourth year. This is indicated by the fact that the inflow to the Science program also increased strongly, by 42 percent. And the inflow to the Social sciences + Business administration + Humanities programs was even more spectacular – it almost doubled, from 16 605 to 32 023. Accordingly, the changes implemented under the Gy11 curriculum, described below, spurred a large increase in the demand for upper secondary academic studies in general.

The Gy11 marked the difference between vocational and theoretical education by imposing separate entry requirements on upper secondary vocational and theoretical programs. Under the Lpf94, grade Pass or higher in Swedish, English and Mathematics granted eligibility to all of the programs in upper secondary school. Under the Gy11, enrolment in a vocational program was contingent on at least grade Pass in eight of the 16 subjects in compulsory school, while the corresponding condition for the theoretical programs was at least Pass in 12 subjects (Figure 1, Indicator VI.i). Thus, the entry requirements were not only differentiated across the vocational and theoretical programs, they were also made stricter for both of them, thereby, in addition, increasing the difference between the students who proceeded from compulsory to upper secondary school and those who did not (SOU 2016:77, pp. 144-146).

[10] These indications were later confirmed by research evidence, cf. below.

[11] Among the theoretically oriented programs, Business administration and Humanities, which had formerly been ‘branches’ in the Social sciences program, became programs of their own. With respect to the vocational education, the Media program was discarded while a program for plumbing and real estate maintenance was added.

The Gy11 incorporated several features which implied a narrower curriculum, compared to the Lpf94. The most significant one was that no longer did all upper secondary programs yield basic eligibility for university studies. Taking the courses required for basic eligibility became compulsory only with respect to the theoretical programs preparing for further studies. For the students in the vocational programs, there was merely an option to extend the studies to include the courses necessary for basic eligibility or, alternatively, to take up these subjects later within the framework of adult education.[12] Moreover, the requirements that had to be satisfied to obtain basic eligibility were increased, thus adding to the divide between the programs preparing for university studies and the vocationally oriented programs. Specifically, the necessary studies in Swedish and English were extended (Figure 1, Indicator VI.v–vi).

That the vocational programs no longer provided university eligibility was partly counteracted by an expansion of vocational tertiary studies, eligibility to which was granted for all with completed upper secondary education, irrespective of program attended.[13] The Swedish National Agency for Higher Vocational Education, established in 2009, makes assessments of the labour market's needs for qualified workers and decides on permissions to educational suppliers. The suppliers, dominated by private enterprises and municipalities, receive state grants to finance the education, which is provided at zero or nominal costs for the students. Typically, the programs extend over two years and many involve STEM subjects. In 2014, the number of study places available was almost 19 000, making it the second largest category of tertiary education, after the traditional university education (Lind & Westerberg, 2015).[14]

The difference between the theoretical and vocational programs was further emphasized by the introduction of two upper secondary exams, one vocational exam and one university preparatory exam (Figure 1, Indicator VI.iii). Furthermore, for the Sciences program and the Technology & Engineering program the compulsory studies in Mathematics were extended under the Gy11 curriculum, relative to the Lpf94 curriculum (Figure 1, Indicator VI.ii).

Regarding assessment, the system with course grades that had been introduced in conjunction with Lpf94 was kept. However, a new grading scale was implemented, running from A to F with F, E, C, and A corresponding to Fail, Pass, Pass with

[12] Only individuals that are at least 20 years old are entitled to participate in the Swedish adult education system. For brevity, the Swedish adult education system will not be considered in this paper.
[13] With the implementation of the Gy11, upper secondary exams were introduced, cf. below. These exams acted as proofs of completed upper secondary education. Before that, when the Lpf94 curriculum was in place, an upper secondary education amounted to a least grade Pass in 90 percent of the program's subjects.
[14] In 2014, approximately 61 000 new students were admitted to university studies (SCB, 2015).

Distinction and Pass with Special Distinction under the preceding system, respectively (Figure 1, Indicator VI.iv).

Before the Gy11 was implemented, two evaluations of the effects of the Lpf94 pilot scheme were published. Follow-up analyses of the pilot scheme had, of course, been conducted before the decision was taken in 1991 to extend all two-year vocational tracks to three years. However, the first attempt to establish *causal* impacts of the prolonged studies, by comparing similar students that in parallel attended the corresponding two- and three-year educations was not published until 2003, as part of a PhD dissertation. In that dissertation Ekström (2003, p. 121) concluded that ‘A three-year upper secondary vocational education increases the probability of university enrolment by a third … .’. Apparently, the people working with the 2008 government proposal were not aware of this result – at least the dissertation was not included among the references cited in the government proposal. Had they been aware, it stands to reason that they would have discussed the finding and motivated the change in the Gy11 in the opposite direction, compared to Lpf94.

As it happened, the second evaluation, which had access to more and better data than the first one and, furthermore, employed a more credible strategy to identify the causal effects, came to entirely different conclusions. Specifically, Hall (2009, 2012) inferred that the extra school year did not have any effect on the transition to university studies. Instead, it had a detrimental impact in that it increased the rate of upper secondary school dropouts by 3.8 percentage points (from an initial level of 11 percent). Accordingly, while Hall’s (op. cit.) results were published too late to be accounted for in the formulation of the Gy11, they provided an *ex post* justification of the changes it entailed.

Later evaluations of the Lpf94 reform have established positive effects outside the educational system, however. Grönqvist et al. (2015) concluded that the extension of the vocational programs by one year lead to a reduction in property crime and Lindgren et al. (2017) found that it increased electoral participation among low socio-economic status families.

2.4 Future curriculum developments

In the 2014 elections, the liberal and conservative coalition government was succeeded by social democrat and green (minority) coalition. In 2015 the new government initiated yet another public investigation of the Swedish upper secondary school. Although the main task of the investigation was said to be to consider measures to decrease the escalating upper secondary dropout rate, proposals for curriculum changes were also envisaged. The result of the investigation and the proposals formulated were published in the fall of 2016 (SOU 2016:77). One way to describe the proposals is to say that they support the idea of the Lpf94 curriculum to provide eligibility to university studies from all upper secondary programs but try to create circumstances that increase the likelihood that this objective is actually realized and exploited. Since, as of yet, the suggested changes are merely proposals the indicator in Figure 1 has been put in parenthesis.

One proposal intended to decrease the dropout rate and, at the same time, reduce the differences between vocational and theoretical programs is to sharpen the entry requirements for the upper secondary vocational programs so as to bring them on par with the requirements for the theoretical programs. This implies at least grade Pass in twelve of the compulsory school subjects (Figure 1, Indicator VIII.i). However, to counteract the likely side effect that fewer students proceed from compulsory school to upper secondary education in the first place it is also proposed that it should be possible to make exceptions from the entry requirements, for students that are close to fulfilling the requirements and are 'judged to be likely to be able to cope with the studies'. Special support, adapted to individual needs should also be provided for students that do not satisfy the entry requirements.

Regarding university studies, it is not only proposed that the basic eligibility that was provided by vocational programs under the Lpf94 curriculum be reinstated (Figure 1, Indicator VIII.ii). A proposition is launched which goes even further in this direction: students attending vocational programs should be offered opportunities to take additional courses providing (full) eligibility to specific university programs such as, e.g., engineering programs, and teacher and nursing educations (Figure 1, Indicator VIII.iii).

3 Categories of upper secondary education

In this section, three increasingly wider definitions of STEM education are first considered. Besides covering successively more educational programs and larger numbers of students, the definitions have also been chosen so as to capture gender differences with respect to the choices of STEM studies.

With the widest of the STEM definitions as starting point, non-STEM education is discussed. In addition to the definition of STEM education, the definition of non-STEM education is also contingent upon the definition of upper secondary education in general. It will be seen that the latter definition involves non-trivial considerations.

3.1 Three alternative definitions of STEM education

Starting with the upper secondary tracks/programs with the highest STEM content and adding tracks/programs with lower STEM content, the following three definitions will be employed:

STEM1: Three- and four-year theoretically oriented educations preparing for tertiary studies; the tracks/programs denoted Science, Technology & Engineering and International Baccalaureate (IB). [15]

STEM2: STEM1 + Two- and three-year vocationally oriented education in Applied Biology (Farming, Forestry, Gardening and Animal Care) and Health Care.

STEM3: STEM2 + Two- or three-year vocationally oriented education in Applied Technology and Engineering (Applied Engineering, Electricity and Energy Operation, Car and Transport Technology, Operations and Maintenance Technology and Industrial Processing Technology).

Regarding the STEM1 category it should be noted that while the Science and Technology & Engineering tracks/programs are focused on STEM subjects, they are still, from a STEM perspective, quite general in that they do not involve specialization in a specific STEM subject.

The STEM2 and STEM3 categories should exhibit clear-cut differences with respect to gender. Specifically, for females, but not for males, the number of STEM2 students should be substantially larger than the number of STEM1 students. Conversely, for males, but not for females, the number of students in the STEM3 category should be much larger than the number of students in the STEM2 category.

A general caveat is that, since there are no generally accepted definitions of STEM education the three categories above are necessarily arbitrary to some extent. For example, it could be argued that Building and Construction ought to be included in the STEM3 category. It seems unlikely, however, that the empirical results below should be strongly dependent upon marginal changes in the definitions of the STEM aggregates.

3.2 Non-STEM education

Given the set of all upper secondary education tracks/programs, it would seem that non-STEM education tracks/programs can simply be residually determined, by subtracting the appropriate category of STEM tracks/programs. However, there are two qualifications to be made.

[15] The International Baccalaureate education, which encompasses a limited number of students – less 1 200 enroll per year, is not explicitly STEM-oriented but includes science subjects to such an extent to its students become eligible to some university level STEM studies.

First, the set of non-STEM tracks/programs residually determined will depend on the STEM category considered. For simplicity, the non-STEM tracks/programs will in the following be defined relative to the largest category of STEM tracks/programs, i.e. the STEM3 category.

Second, and more importantly, it is not obvious how the set of all upper secondary education tracks/programs should be defined. In this study, two types of education are regarded as *not* belonging to upper secondary school.

The first type consists of (very) short tracks/program, which were quite common before the Lpf94 reform, cf. Section 2.1. For simplicity, all programs with a normal study times less than two years have in this study been considered to be too short to qualify as (regular) upper secondary tracks/programs.

The second type of education that is here considered not to be part of upper secondary school was introduced in connection with the Lpf94 reform. As noted in Section 2.2, the Lpf94 reform resulted in 16 educational programs; cf. Figure 1, Indicator IV.i. However, a 17th program was also introduced, called the 'Individual program' (IP). The IP was intended for students who either had incomplete grades from compulsory school or grade point averages too low to qualify them for any the 16 (regular) upper secondary programs. The objective of the IP is to provide the students with the skills and qualifications required to enable them to be transfer to a regular upper secondary school program. With the implementation of the Gy11 curriculum reform, the Individual program was replaced by to the 'Introductory program'. For simplicity, both will be denoted IP in the following.

The primary reason for leaving out the IP is that, as just noted, the IP is not an upper secondary education, but a preparation for such an education. An additional reason is that a non-negligible share of the IP students are immigrants that have arrived after 7 years of age, implying that they often have a weaker educational background than the Swedish students and/or insufficient knowledge of Swedish to fully benefit from their education in Sweden. This aspect has become increasingly important after 2005, following rising immigration to Sweden, increasingly made up of refugees rather than foreign workers.[16]

Of course, the fact that a student one year is admitted to the IP does not exclude that (s)he is admitted to upper secondary school at some later point in time. Indeed, as

[16] While it is generally agreed that the recent immigration has mattered negatively for scholastic achievements in Sweden, the views differ on the extent of this problem; see, e.g., Sahlgren (2015) and Skolverket (2016).

just noted, that is the objective of the IP. Students transferring from the IP to a (regular) upper secondary program are included in the analysis below.

Figure 2 shows how the total number of upper secondary students is affected by the exclusion of students attending tracks/programs shorter than two years, the Individual program, and the Introductory program.[17]

Figure 2: The total number of (regular) upper secondary students included in the analysis (white bars) and the number of students excluded from the analysis (black bars), because they attended short education (< 2 years) or preparatory education

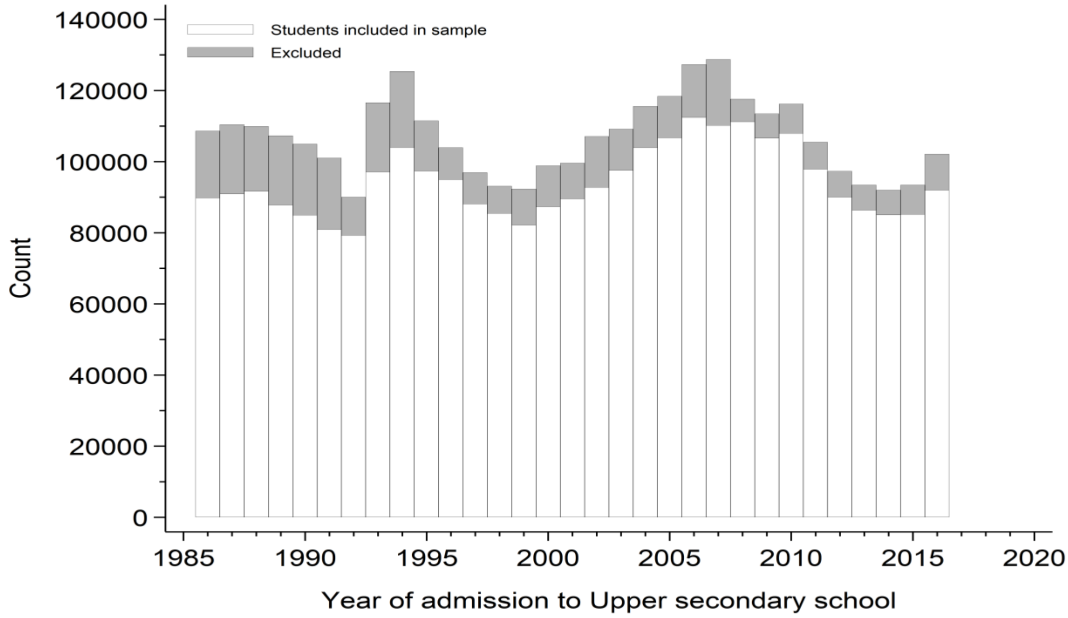


Figure 2 shows that the numbers of excluded students are largest 1986–1994, approximately between 18 000 and 21 000 (except for 1992). For this period – before the implementation of the Lpf94 reform – the reason for exclusion is that the students attended tracks/programs that were less than two years in length. From 1995 and onwards, the reason for the exclusion is that the students attended the Individual program or the Introductory program. The number of excluded students is then generally smaller than in the 1986–1994 period. It should be noted, however, that the number of excluded students 1995–2016 is *not* equal to the number of students that have been admitted to the Individual program or the Introductory program; as noted above, students that transfer from either of these programs to a (regular) upper

[17] In addition, a small number of students are excluded because there is no code for the study track/program they attended.

secondary program will be included in the analysis, from the point in time when the transfer occurred.

Finally, it will in some cases be desirable to separate the Social sciences and Business administration tracks/programs from the aggregate of non-STEM tracks/programs. The reason is the introduction in 1992 of the Supplementary 1-year upper secondary Science/Technology ‘Base year’ education; cf. the discussion in Section 2.2. This change can be expected to have influenced the numbers of students choosing the Social sciences and Business administration tracks/programs in upper secondary school, as well the proportion of (former) upper secondary students studying STEM subjects at the university. Moreover, since the Base year education created an alternative route to university STEM studies it is likely to have affected the ‘traditional’ route, too, i.e. via the Science or Technology & Engineering tracks/programs. To account for these developments, Appendix 2 contains a comparison between the STEM1 category, on the hand, and the (non-STEM) Social sciences and Business administration tracks/programs, on the other hand, with respect to the proportions of upper secondary school students, upper secondary completion rates and transitions to university STEM studies.

4 The data

This study mainly employs register data, which are made up of administrative records maintained by Statistics Sweden. Register data are individual level, population data. Thus, when, e.g., Swedish upper secondary school students in year *t* are considered, all the Swedish upper secondary students in that year are included.

Another distinguishing feature of register data is that they are panel data, which means that, for each individual, they contain multiple observations over time.[18] This property will be used to avoid the double-counting over time that occurs in official statistics. The cross-sectional approach taken in official statistics implies, e.g., that individuals who have enrolled in upper secondary school several times will be included among the upper secondary school beginners at equally many points in time. In this study, where the students’ educational careers are tracked over time, they will be counted as upper secondary school beginners only once.

Specifically, the primary population considered in the empirical analyses based on register data is defined by all individuals that started upper secondary school sometime during the thirty-year period 1986–2016, altogether almost 3 million individuals

[18] For a discussion of register data and how they can be put to use in analyses of education, cf. Mellander (2017).

(2 916 958).[19] If they have started several times, only the latest time will be considered. The implied assumption is that if a student has started *n* times, the first *n* – 1 attempts were unsuccessful in some sense – otherwise (s)he would not have started all over again.[20] The students will be followed over time, to see if they completed upper secondary school and, if so, if they continued to university.

The following individual-level register data will be employed:

- *The grade 9 register (end of compulsory school):* year of completion of compulsory school.
- *The upper secondary school application register:* when and on what track/program an individual started upper secondary school (for the last time).
- *The completion of upper secondary school register:* when and on what track/program an individual completed upper secondary school; definitions of 'completed education' are provided in Section 7.
- *The registers of completed university level course s and programs*: successful transitions from upper secondary school to university. Here, a successful transition is defined as having taken place if the individual has earned a minimum amount of university level credit points; details are provided in Section 8.

In addition, results from the international survey TIMSS Advanced will be considered. TIMSS Advanced has tested the skills in Mathematics and Physics among third-year upper secondary STEM students in 1995, 2008 and 2015. Sweden participated on all of these occasions (Skolverket, 2016). The Swedish results will be compared to the results of other countries and they will also be related to the Lpf94 and Gy11 curriculum reforms.

5 The empirical approach

To determine the causal effects of the curriculum developments described in Section 2 on the recruitment to STEM vs non-STEM education and the resulting student

[19] 2 916 958 is the sum obtained when the numbers corresponding to the white bars in Figure 2 are added together.

[20] Of course, the last attempt may also be unsuccessful, in the sense of, e.g., not resulting in a completed upper secondary education. But, if so, the last attempt marks the end of the individual's educational career, in contrast to the earlier attempts. Conversely, a completed education may also be regarded as an unsuccessful outcome. In the registers, around 4 percent of the students that finished Upper secondary school during the period under study have completed two or more upper secondary tracks/programs. Nine out of ten of these observations concern individuals that have completed two upper secondary tracks/programs in two consecutive years and a for majority of them the grade point average of the last education is higher than the grade point averages of the first education completed. That is to say, they have devoted an additional year to make their grades more competitive.

achievements is a complex and very extensive task. Such an effect evaluation requires information about comparable groups of students faced, in parallel, with a new, reformed curriculum and an old, unreformed curriculum. In principle, it would be possible to construct such a data set, at least with respect to the Lpf94 reform, as that reform was successively implemented by the Swedish local governments over the period 1992–1995; cf. Section 2.1. However, the analysis would entail detailed investigations of each of the close to 300 Swedish municipalities, with respect to when they changed from the old to the new curriculum.[21] That kind of study is far beyond the scope of this paper.

It is possible, however, to conduct descriptive analyses comparing outcomes before and after the Lpf94 and Gy11 reforms. Here, outcomes will be educational choices and educational achievements.

With respect to the analyses employing register data there are two issues to consider. The first concerns demographic variations in the (total) number of students over time, i.e. changes in cohort sizes; these should not be allowed to influence the results. The second issue is the choice of appropriate pre-reform and post-reform dates.

Regarding the first issue, the simplest way to control for cohort size is to define the outcome variables in terms of shares of the total number of students admitted to upper secondary school. With respect to the choices of tracks/programs in upper secondary school this is perfectly straightforward – the only thing to remember is that the total number of students does not include students attending the individual/introductory programs; cf. Section 3.2. When proceeding to consider completion rates, it should be noted that the completion rate for a given STEM or non-STEM category is not defined in terms of the students admitted to that particular category but relative to the sum total of admitted students. The university transition rates will be computed analogously.

Turning to the issue of choosing appropriate pre- and post-reform dates, consider, first the pre-reform dates. These should be chosen according to three criteria.

First, they should be characterized by the relevant actors (the students) not knowing about the reform – if they do, they make act upon this knowledge, thus invalidating the interpretation of the before information as reflecting choices in the absence of the reform.

[21] This kind of approach was employed by Hall (2012) when she used the Lpf94 pilot scheme – implemented at different points in time in different Swedish municipalities, and to different extents – to evaluate the causal effects of increasing the length of the vocational educations from two to three years.

Secondly, the before data should be unaffected by the reform. This condition need not coincide with the first criterion. Specifically, for the Lpf94 reform, consider 1987 as a potential before date. In 1987 there was no information about the reform, simply because it had not yet been decided upon. Accordingly, the first criterion is satisfied. However, the pilot scheme supposed to provide the politicians with the input necessary to make the reform decision had already been set in motion; cf. Figure 1. This means that the second criterion is not satisfied – some students had already in 1987 had the opportunity to choose (vocational) tracks with a broader curriculum.

The third criterion is that the before date should be as close as possible to the reform date, so as to minimize the risk that other events than reform affect the difference between the before and after measurements.

Taken together, the three criteria suggest that 1986 is the appropriate before date for the Lpf94 reform. With respect to Gy11 reform, the appropriate before date is the year 2006. The reason is that the instructions governing the public investigation that laid the foundation for the reform were made public in February of 2007; cf. Section 2.3. When students made their choices to upper secondary school in the spring of 2007 the investigation was well underway and well known.

Regarding the post-reform data, there are two aspects to take into account. The first is that the date should be as close as possible to the date when the decision is taken to avoid the data being 'contaminated' by other events. The second consideration is that the after date should be chosen such that the reform has not only has been decided upon but also is fully implemented. In Figure 1 the vertical bars marking the beginnings of the Lpf94 and Gy11 curriculum regimes correspond to the years when the respective reforms were fully implemented. Thus, 1995 and 2011 are valid after dates for the Lpf94 and Gy11 reforms, respectively.

6 Choice of STEM vs non-STEM education in upper secondary school

This section shows how the students proceeding to upper secondary school have chosen between STEM and non-STEM tracks/programs. It does not consider the students' choices in terms of their preferences, as expressed by the rankings of tracks/programs in their upper secondary school applications, but their *realized choices*, manifested by the tracks/programs in which they actually pursued their upper secondary educations.

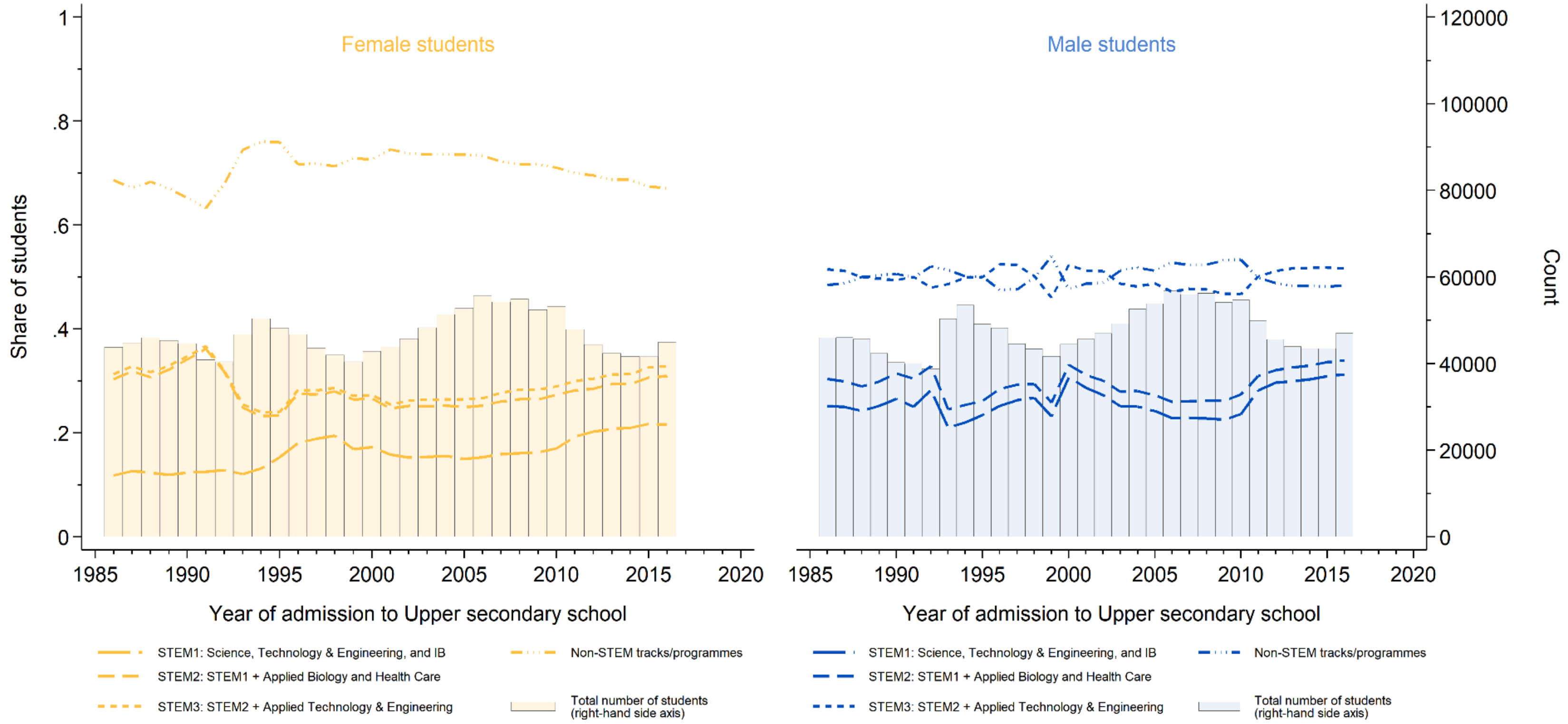
As noted in Section 4, students observed to have started upper secondary school at several points in time are represented by their last observation. In addition to eliminating double-counting of students, this convention should imply that the choices recorded are more in accordance with the students' capabilities, than if earlier observations were employed. For example, the Science program, in the STEM1 category, is by many Swedes considered to be the education *par préférence*, cf. Börjesson et al. (2016). This means that the Science program partly will attract students that do not really have the cognitive resources to master the studies and, hence, will sooner or later transfer to another program. By counting only the last observed program choices, the initial choices of these students are not allowed to overestimate the number of students admitted to STEM1 educations.[22]

Figure 3 shows, by gender, the numbers the total numbers of students that have been admitted to upper secondary school 1986–2016 (vertical bars, right scale) and the shares admitted to STEM and non-STEM tracks/programs (lines, left scale). Since the shares for the STEM tracks/programs are cumulative, the shares for the STEM3 and non-STEM tracks/programs sum to unity, by construction.

With respect the numbers of admitted students, Figure 3 shows that these are very similar for females and males, with respect to both levels and time profiles, although the numbers of males generally are slightly above the number of females. There has been considerable variation over time from around 40 000 female and male students, respectively, in the early 1990s to over 55 000 students per gender in 2006. Accordingly, eliminating the influence of changes in cohort size by considering the shares, rather than the numbers, of students admitted to different tracks/programs is important.

[22] However, the practice of only considering the last observation will also imply that the time spent in upper secondary education will be underestimated for the students that started upper secondary school at several points in time. Conceivably, the underestimation could have two reasons for a student that started upper secondary school *n* times. First, the time spent in upper secondary school the *n*-1 first times is disregarded. Second, to the extent that the student benefited from those n-1 spells they may have reduced the length of her/his *n*th spell. Both of these sources of underestimation are likely to be of minor importance, however, because students leaving a track/program generally do so after a very short period of time, oftentimes during the course of the first or second semester.

Figure 3: Total number of students admitted to (regular) upper secondary education and shares of students admitted to STEM and non-STEM tracks/programs, by gender



Notes:

1. The STEM and non-STEM categories as well as the total number of students are defined in Section 3.

2. The sum of the vertical bars for females and the vertical bars for males equals the white bars in Figure 2.

Figure 3 makes it very clear that the choices of tracks/programs in upper secondary school differ markedly by gender. To begin with, the female students choose non-STEM tracks/programs to a much larger extent – roughly 65–75 percent – than the males – around 50 percent. Moreover, there are also large differences across gender with respect to the choices of different STEM tracks/programs. The share of male students admitted to STEM1 tracks/programs is consistently higher than the corresponding share for females. In contrast, the gender differences are small regarding the shares admitted to STEM2 education. This is due to the fact that while many female students choose studies in Applied Biology and Health Care, i.e. the tracks/programs making up the difference between the STEM1 and STEM2 categories, few male students do so. On the other hand, very few female students select Applied Technology & Engineering tracks/programs while among male students this choice is almost as common as the choice of STEM1 education. As a result of this difference, the share of male students choosing STEM3 education (around 50 percent) is considerably larger than the corresponding share for female students (25–35 percent).

With one exception, the shares of the chosen tracks programs in Figure 3 are quite stable over time. The exception is the share of females choosing STEM1 education. This share exhibits a positive time trend and increases by 10 percentage points over the period studied, from around 12 percent in 1986 to almost 22 percent in 2016.

The shares in Figure 3 are roughly constant over time, with one exception: the STEM1 one share exhibits a weakly positive trend, increasing from just below 19 percent in 1986 to just below 27 percent in 2016

The data underlying Figure 3 can be used to relate changes in the shares of students choosing STEM and non-STEM tracks and programs to the curriculum reforms Lpf94 and Gy11. In particular, does it appear to be the case that the broadening of the curriculum induced by the implementation of the Lpf94 reform increased the number of students choosing STEM tracks/programs? Conversely, has the narrowing of the curriculum brought about by the Gy11 reform been followed by a decrease in the proportion of students admitted to STEM programs? And do the answers to these questions differ between female and male students?

Table 1: Shares of female and students admitted to STEM and non-STEM tracks/programs before and after the Lpf94 and Gy11 curriculum reforms

	The Lpf94 reform			The Gy11 reform		
Tracks/programs	Shares, %, of students admitted		Difference, in %-age	Shares, %, of students admitted		Difference, in %-age
	1995	1986	points	2011	2006	points
Females						
STEM1	15.29	11.82	3.47	19.30	15.35	3.95
STEM2	23.40	30.36	–6.96	28.20	25.27	2.93
STEM3	24.06	31.33	–7.27	29.99	26.71	3.28
Non-STEM	75.94	68.67	7.26	70.01	73.29	–3.28
All female students	100.00	100.00	0.00	100.00	100.00	0.00
Males						
STEM1	23.47	25.20	–1.73	28.21	22.98	5.23
STEM2	26.17	30.37	–4.20	30.95	25.99	4.96
STEM3	49.97	51.53	–1.56	50.12	47.17	2.95
Non-STEM	50.03	48.47	1.56	49.88	52.83	–2.95
All male students	100.00	100.00	0.00	100.00	100.00	0.00

Notes:
1. The STEM and non-STEM categories are defined in Section 3.
2. The choices of pre- and post-reform years are motivated in Section 5.

Table 1 shows that, in general, the Lpf94 reform was followed by decreases in the shares of students admitted to STEM tracks/programs; for both female and male students, the share of students admitted to STEM3 tracks programs was smaller in 1995 than in 1986. The only exception, but an important one, was that the share of female students admitted to STEM1 tracks/programs increased quite substantially, by 3.5 percentage points, from 11.8 to 15.3 percent. This may have been a response to government worries about a decline in the number of students admitted to Technology & Engineering and Science programs in the beginning of the 1990s.[23] Presumably, the

[23] In a proposition from 1993 the Swedish Ministry of Education declared that an increase in the number of students choosing Science and Technology & Engineering in upper secondary school was of 'the utmost importance'; Proposition 1992/1993:169, p 39.

stronger response among female students than among male students, was due to the potential increase being larger among the females.

With respect to Gy11 reform, the findings in Table 1 are unambiguous. For female and male students alike the shares of students admitted to STEM tracks/programs increased, for all of three of the alternative definitions STEM1, STEM2 and STEM3.

In summary: While this descriptive analysis does not allow any causal interpretations, it can be observed that the broadening of the curriculum induced by the Lpf94 reform was followed by a decrease in the total number of students choosing STEM tracks/programs, with one important exception: the share of female students admitted to STEM1 programs increased substantially, from 11.8 to 15.3 percent. Simultaneously, the shares admitted to non-STEM upper secondary programs increased, with respect to both female and male students. The narrowing of the curriculum through the Gy11 reform was unambiguously associated with increased proportions of STEM students, of all categories, while the shares admitted to non-STEM programs decreased, for female as well as male students.

7 Upper secondary school completion rates: STEM vs non-STEM educations

Figure 4 reports the shares of students that have completed their upper secondary education within normal study time + 2 years, separately for female and male students. For the majority of tracks/programs, which have a normal study time of three years, this means that the curves measure the proportions of students that have completed their education within five years after admittance.

To define what constitutes a completed upper secondary education is a non-trivial task. In the *Completion of upper secondary school register* a very ‘permissive’ definition is applied; essentially it requires only that the student has grade Pass in at least one of subjects/courses included in the track/program. Obviously, this definition is meaningless for most purposes. At the other extreme are definitions corresponding to the requirements implying basic eligibility to university studies. Those are too stringent in the present context because the upper secondary completion rates should reflect the facts that while the Lpf94 reform implied that all completed upper secondary programs provided basic university eligibility, the Gy11 reform did not. To account for this difference, the following definitions of completed upper secondary education have been applied:

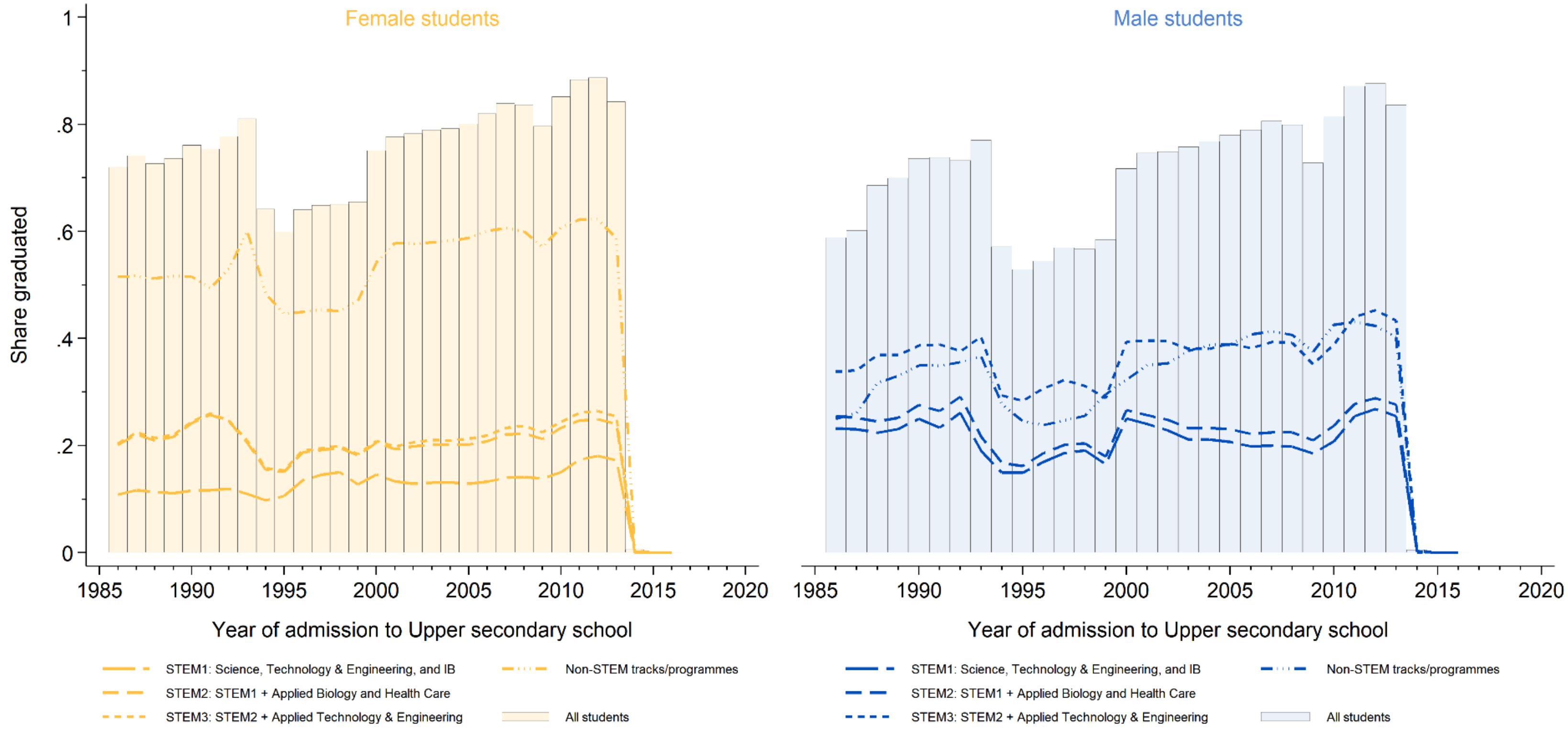
a) For students leaving upper secondary school before 1997, i.e. students admitted while Lgy70 was still in place: The student should have grades in Swedish and English for two years, but the grades need not necessarily be Pass or higher.
b) For students leaving upper secondary school 1997–2013, i.e. students admitted to upper secondary school while Lpf94 was in place: At least grade Pass with respect to at least 90 percent of course points corresponding to program. [24]
c) For students leaving upper secondary school 2014 or later, i.e. students that were admitted to upper secondary school after Gy11 had been implemented: Upper secondary exam, *either* from theoretical program *or* from a vocational program.

With these definitions, equivalence between completion of upper secondary education and basic eligibility to university studies holds for students admitted to upper secondary school in the Lpf94 regime but not for students admitted after the implementation of the Gy11 curriculum. Specifically, for students admitted after the implementation of the Gy11 equivalence holds only if they have an exam from a theoretical program.

It should be noticed that the shares in Figure 4 will at most equal to the shares in Figure 3. Equality can only hold if all of the students within a given category of students completed their upper secondary studies within five years after admittance. Otherwise the shares in Figure 4 will be smaller than the corresponding shares in Figure 3. Specifically, consider the shares for females and STEM1 in the year 1998, in Figure 4. That share is equal to 0.151. As the corresponding share in Figure 3 is 0.195 it can be inferred that 77.8 percent [(0.151 / 0.195) × 100] of the female students admitted to STEM1 programs in 1998 completed their education within five years after admittance.

[24] Until 2002, the number of course points corresponding to a full upper secondary education was 2 150 for theoretically oriented education and 2 370 for vocationally oriented educations. From 2003, the number became 2 500 points for all upper secondary educations.

Figure 4: Shares of students with completed upper secondary education within normal study time + 2 years, by track/program categories, by gender



Notes:

1. The STEM and non-STEM categories are defined in Section 3.

The vertical bars in Figure 4 show the overall yearly completion rates, equal to the sum of the completion rates for the STEM3 and non-STEM categories. The sharp drop in the overall completion rate in the mid-1990s follows the introduction of a new grading system in connection with the Lpf94 reform, cf. Figure 1, Indicator IV.iv.[25] The new grading system included the grade Fail; a corresponding grade had not been included in the previous grading system. It should also be noticed that the magnitude of the drop is influenced by the fact that the overall completion rate exhibits a clear positive trend 1986–1993. This trend may be due to the proportion of students studying Swedish and English for two years increased over time – cf. criterion a) above – as a consequence of the pilot scheme introduced in 1987 (Figure 1, Indicator I). The severe economic recession in Sweden during the 1990s may also have contributed to the downturn in completion rates. Presumable, the limited supply of jobs made some students complete their studies at a slower pace than would have been the case given better labour market conditions. Most likely, the recession also made some individuals choose upper secondary school for want of job options and these persons may have needed more time to complete their studies than the average student.

Since our data extend up to the year 2016, the last cohort of students for which we can fully observe whether they have completed their studies within five years after admittance is the cohort admitted in 2011.

Most of the gender differences noted in Figure 3 are reflected in Figure 4, too. For instance, the differences in completion rates for STEM1 and STEM2 are substantial for females but small for males, while the corresponding differences between STEM2 and STEM3 are very small for females but very substantial for males.

But there are also some developments to be noted in Figure 4 that act to decrease the gender differences. First, the positive trend in Figure 3 in the number of female students admitted to STEM1 studies is mirrored in Figure 4 by an increase over time in the share of female students completing STEM1 studies, from about 11 percent in 1986 to over 17 percent in 2011. The male students, in contrast, exhibit a strongly positive trend in the completion rate for *non-STEM* studies, from 25 percent in 1986 to 43 percent in 2011. To some extent, however, this trend is counteracted by a similar, but weaker positive trend in the share of male students completing STEM3 studies; this share rose from 34 percent in 1986 to 44 percent in 2011.

[25] The drop is somewhat larger for the males than for the females, in line with the stylized fact that the female students in general do better in school than the males.

Table 2 considers the differences between STEM and non-STEM tracks/programs with respect to the changes in completion before and after the Lpf94 and Gy11 reforms. The table shows that for females and males alike, the Lpf94 was followed by decreased completion rates in all of the upper secondary tracks/programs. For the Gy11 reform the completion rates instead increased for all upper secondary programs. Moreover, for the STEM programs the increase was approximately twice as fast as for the non-STEM programs.

Table 2: Shares of female and male students with completed upper secondary education within normal study time + 2 years, before and after the Lpf94 and Gy11 reforms

	The Lpf94 reform			**The Gy11 reform**		
Tracks/programs	**Shares, %, of students completed**		**Difference, in %-age points**	**Shares, %, of students completed**		**Difference, in %-age Points**
	1995	**1986**		**2011**	**2006**	
Females						
STEM1	10.60	10.85	–0.25	17.38	13.27	4.11
STEM2	15.11	20.12	–5.01	24.71	20.82	3.89
STEM3	15.35	20.46	–5.11	26.09	21.90	4.19
Non-STEM	44.59	51.55	–6.96	62.23	60.13	2.10
All female students	59.94	72.01	–12.07	88.32	82.03	6.29
Males						
STEM1	14.91	23.22	–8.31	25.50	19.87	5.63
STEM2	16.22	25.49	–9.27	27.81	22.18	5.63
STEM3	28.37	33.81	–5.44	44.03	38.19	5.84
Non-STEM	24.54	25.03	–0.49	43.09	40.78	2.31
All male students	52.91	58.84	–5.93	87.12	78.97	8.15

Notes:
1. The STEM and non-STEM categories are defined in Section 3.
2. The choices of pre- and post-reform years are motivated in Section 5.

With respect to gender differences in Table 2, the following can be noted. For females, the reduction in the completion rate with respect to STEM1 programs after the

Lpf94 reform is much smaller than the corresponding reduction for males. With respect to changes in the shares completing non-STEM studies after the same reform, the picture is reversed; the reduction is much smaller among male than among female students. Regarding the Gy11 reform a general observation is while increases in completion rates are noted throughout, for both female and male students, the percentage point increases are somewhat larger among the male students.

To sum up: The broader curriculum implemented by the Lpf94 reform was followed by a general decrease in the completion rates for all upper secondary programs, for two reasons. First, the principal feature of the reform was that the vocationally oriented programs were extended from two to three years and their academic content broadened and deepened (Figure 1, Indicator IV.i). As shown by Hall (2012), this caused the drop-out rates to increase. Secondly, the reform involved the introduction a new grading system which included the grade Fail, which, effectively, had not existed earlier (Figure 1, Indicator IV.iv). Interestingly, the decrease in STEM tracks/programs was larger than the corresponding decrease for non-STEM tracks/programs. This was unexpected a priori, because the compulsory mathematics and science studies in the STEM1 programs were reduced as part of the reform (Figure 1, Indicator IV).

The transition to a more narrow curriculum implied by the curriculum reform Gy11 was followed by a general increase in the completion rates. This change was in line with the fact that the upper secondary entry requirements were made more stringent as part of the reform (Figure 1, Indicator VI.i). However, for the STEM programs the increases in the completion rates were approximately twice as large, in percentage points, as the increase in the completion rate for non-STEM programs, in spite of extended studies in mathematics in STEM1 programs (Figure 1, Indicator IV.ii).

Qualitatively, there were no gender differences in the responses to the two reforms. However, following the Lpf94 reform the completion rate with respect to STEM1 programs decreased less for females than for males whereas the opposite was true for non-STEM programs. The changes after the Gy11 were larger in magnitude for males than for females.

8 Transitions from upper secondary school to university

This section concerns the transition from upper secondary school to university, getting successively more detailed. The first sub-section considers the shares transiting to STEM and non-STEM university studies. The second sub-section provides information about the upper secondary background of the transiting students. The final subsection discusses university STEM students with non-STEM upper secondary background.

8.1 Transitions to university studies in general and to STEM studies

The fact that a transition has occurred is operationalized by means of records on credits received; an individual is defined as having successfully enrolled at the university if (s)he has gained credits corresponding to at least a quarter of one full year of studies, during one semester.[26] Due to data constraints, the time horizon for this criterion is equal to the time horizon used in the previous section with respect to the completion of upper secondary education, i.e. within normal upper secondary school study time + 2 years, in general corresponding to five years after the admittance to upper secondary school. This means, of course, that the actual university enrolment will be under-estimated – it is quite common that persons work and/or travel an extended period of time after upper secondary school, before they apply to university.

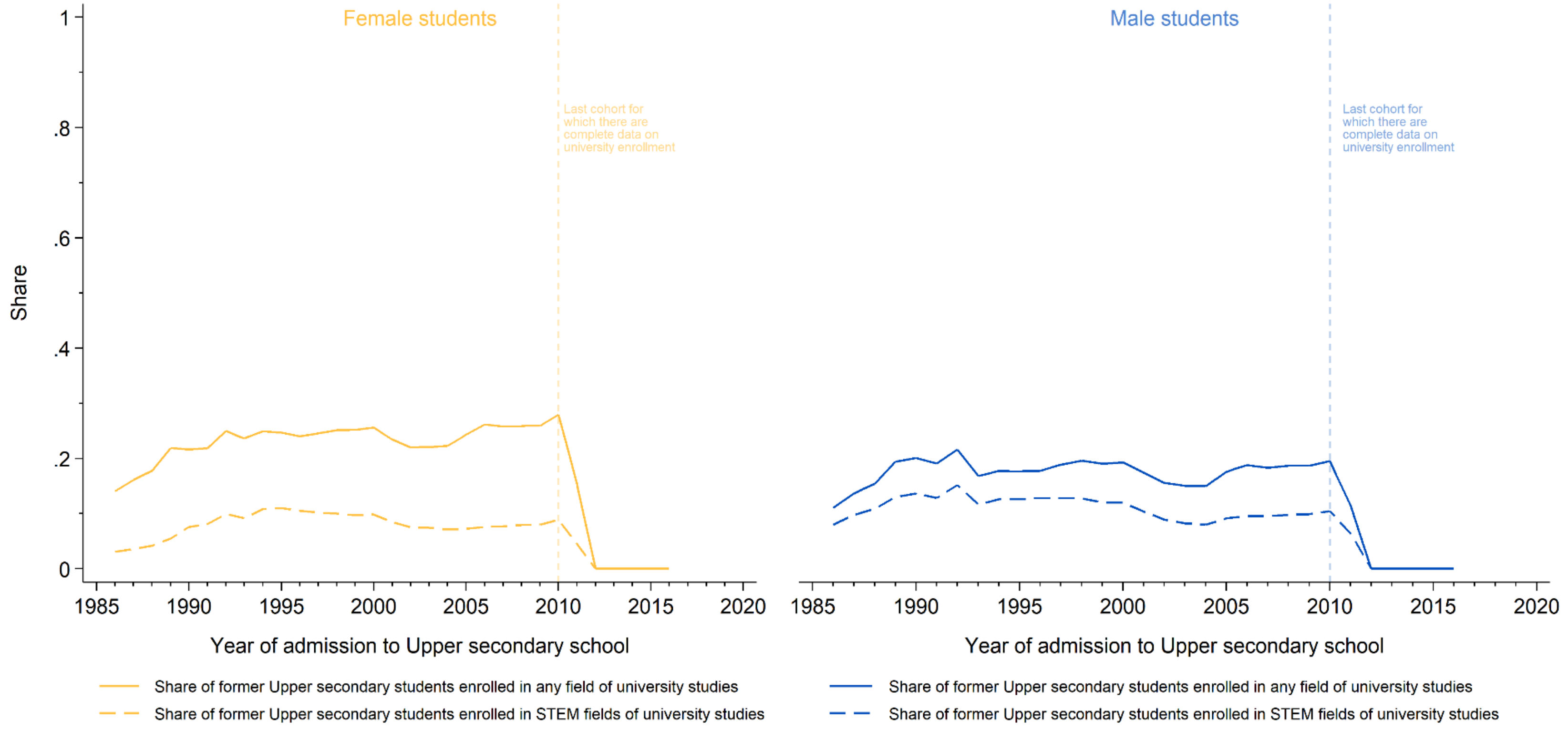
A first look at the former upper secondary students that have successfully enrolled at the university, according to the criterion just described, is provided by Figure 5. In the figure, the solid lines show the shares of female and male students admitted to upper secondary education that subsequently have successfully enrolled in *any* type of university studies, while the dashed lines show the shares that have successfully enrolled in university STEM studies, in particular.

It can be seen in Figure 5 that the highest overall share of successfully enrolled university students, almost 28 percent, is recorded for female students admitted to upper secondary education in 2010. For the same cohort of male students, the share that has successfully enrolled in university studies is close to 22 percent. For females and males taken together approximately every fourth student in that cohort successfully transited to university studies within five years after having begun upper secondary education.

The dashed lines in Figure 5 show that the shares of male students successfully transiting to university STEM studies, 8–15 percent, is higher than the corresponding female shares, 3–11 percent. Both the female and male shares exhibit weakly negative trends after the mid-1990s.

[26] Sweden applies a two-semester system; the school year begins with the fall semester and ends with the spring semester. The criterion of successful university enrollment is applied such that the student is characterized as having enrolled successfully at the point in time when the criterion is satisfied for the first time.

Figure 5: Shares of former upper secondary students that have successfully enrolled at university within 2 years after normal upper secondary school study time, by gender



Notes:
1. Successful university enrolment is defined as having attained credits corresponding to at least a quarter of a full year of study.
2. The most recent available register data on university attainments concern the spring of 2015. This implies that the proportion having proceeded to university must be zero for individuals admitted to upper secondary school in (the fall of) 2012 or later and that the cohort admitted to upper secondary school in 2010 is the last one for which successful university enrolment can be checked over the entire horizon, made up of normal upper secondary school study time + 2 years.

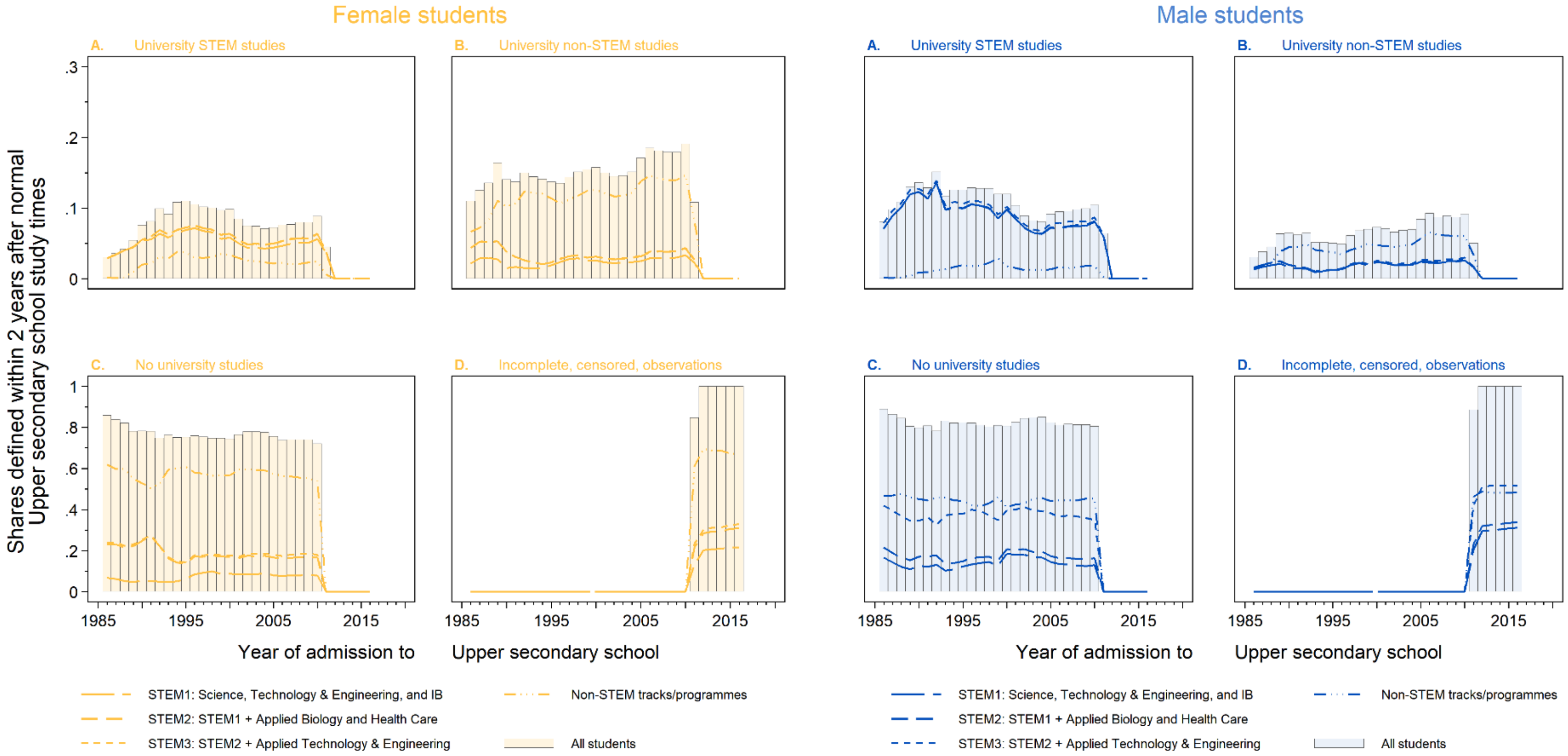
The vertical dotted lines in Figure 5 indicate that the cohort admitted to upper secondary school in 2010 is the last one for which there is complete data on university enrolment, as defined above. That means that an analysis concerning changes in university enrolment following the implementation of the Gy11 curriculum cannot be conducted, because the data on university enrolment are incomplete for the cohort of students admitted to upper secondary school in 2011.

For the period for which there is complete data, i.e. 1986–2010, it can be inferred from Figure 5 that the composition of university studies looks quite different for females and males, and has developed differently over time, too. For females, the proportion with STEM studies has varied between 22 percent in 1986 and 45 percent in 1995 of all university studies. At the end of the period, in 2010, the proportion was 32 percent. For males, the proportion with successful transition to university STEM studies has been above ½ over the entire 1986–2010 period, varying between 51 percent in 2006 and 72 percent in 1986 and 1996. However, since the share of male students successfully enrolled in STEM university studies has decreased more over time than the corresponding female share the gender difference in this respect is considerably smaller at the end of the 1986–2010 period, than at its beginning.

8.2 Where did they come from and where did they go?

In Figure 6, the information in Figure 5 is detailed in two respects. First, the university enrolment shares are broken down according to the tracks/programs that the students attended in upper secondary school – a brake-down by origin, as it were. Second, in contrast to Figure 5, Figure 6 is exhaustive with respect to where the former upper secondary students went after upper secondary school – Figure 6 also provides a complete brake-down by 'destination'. Whereas Figure 5 only accounts for the students that continued with tertiary studies, Figure 6 also accounts for the students that did not proceed to university within the time horizon considered and, finally, the students for which there is not complete information, i.e. the censored observations. Thus, all of the former upper secondary students are included in Figure 6 and each individual is included in one, and only one, of the panels A, B, C, and D, for females and males, respectively.

Figure 6: Former upper secondary students observed within 2 years after normal upper secondary school study time, categorized with respect to earlier upper secondary track/program and subsequent university studies, lack of university studies, or censoring, by gender



Notes:
1. Successful university enrolment is defined as having attained credits corresponding to at least a quarter of a full year of study.
2. The most recent available register data on university attainments concern the spring of 2015. This implies that the proportion having proceeded to university must be zero for individuals admitted to upper secondary school in (the fall of) 2012 or later and that the cohort admitted to upper secondary school in 2010 is the last one for which successful university enrolment can be checked over the entire horizon, made up of normal upper secondary school study time + 2 years.

We first consider panels A in Figure 6, for females and males. They show that among those studying STEM subjects at the university, the majority have upper secondary STEM backgrounds, as expected. However, that majority is much larger for males than for females. This can be verified by observing that the vertical distance between the non-STEM line and STEM3 line is much smaller in the female panel A than in the male panel A. It can thus be concluded that the ‘recruitment base’ for female STEM university students is broader than the recruitment base for the corresponding male students.

Another interesting observation is that the shares corresponding to the STEM1, STEM2 and STEM3 categories in panel A of Figure 6 are all very similar, for both females and males. Since the STEM categories are cumulatively defined this means that almost all students attending university STEM studies have a STEM1 upper secondary background. Put differently, the vocationally oriented upper secondary programs that make up the difference between the STEM1 category, on the one hand, and the STEM2 and STEM3 categories, on the other hand, contribute very little to the recruitment of university STEM students. Indeed, for the females, the difference between the STEM3 and STEM1 shares is smaller than the difference between the STEM3 and the non-STEM shares, for the entire 1986–2010 period, implying that non-STEM upper secondary background is more common among female STEM university studies than vocationally oriented upper secondary STEM programs. For the males, the pattern is the same except for the years 1986–1989. These results are definitely noteworthy. It appears that, to a considerable extent, they are due to the introduction of the Supplementary 1-year Upper secondary Science/Technology education in 1992 (Figure 1, Indicator III). Section 8.1 below contains a further discussion of the relation between the supplementary education and the number of students with non-STEM upper secondary background that successfully conduct STEM university studies. For now, suffice it to say that the supplementary education has mattered more for female than for male students, thus broadening the recruitment to university STEM studies with respect to gender. This statement is consistent with a comparison of the A panels in Figure 6 for females and also in line with the observations made in the preceding paragraph.

In panels B of Figure 6 students conducting non-STEM studies at the university are reported, by tracks/programs that they attended in upper secondary school. The differences between females and males are quite substantial, both with respect to the overall shares of students enrolled in non-STEM university studies and with respect to the shares with non-STEM upper secondary background, as opposed STEM upper secondary background. Both are much larger for females than for males.[27]

Panels C in Figure 6 constitute the mirror images of (the sum of the) panels A and B. A comparison of Figure 3 and panels C in Figure 6 reveals an interesting gender difference. For females, students with a non-STEM upper secondary background do *not* proceed to university studies to a much larger extent than students with a STEM upper secondary background. For males, the corresponding difference is very small.

Table 3 shows the proportions of the students admitted to upper secondary school that had gained university credits corresponding to at least a quarter of full year of university STEM studies within 2 years after normal upper secondary school study time, before and after the Lpf94 reform. As noted above, it is not possible to conduct such an analysis with respect to the Gy11 reform, since there are complete data on university transitions only up to 2010; this is also evident from panel C in Figure 6.

Actually, there is a potential problem with the analysis for the Lpf94 reform, too. The problem STEMs from the Supplementary 1-year Upper secondary Science/Technology education. That initiative was independent of the Lpf94 reform.

Unfortunately, we lack data to control for the Supplementary education. However, while not formally included in Lpf94 reform, the introduction of the Supplementary Science/Technology education was in the spirit of the reform, in the sense that its aim was to broaden the possibilities to conduct university studies. The only difference was that it exploited a different margin; instead of targeting persons which previously had not been eligible to university studies (at all), its objective was to extend the range of possible university studies among individuals which already were eligible to some university education. When viewed in this way, the Supplementary education does not need to be controlled for.

According to Table 3, the combination of Lpf94 reform and the introduction of the Supplementary 1-year Upper secondary Science/Technology education increased the shares of students from all upper secondary tracks/programs that successfully conducted STEM studies at the university, in line with the general expansion of university education at the time. The increase, in percentage points, was larger for students with an upper secondary STEM background than for students with a non-STEM upper secondary background. This was the case for both females and males.

[27] Incidentally, while the non-negligible share of students with non-STEM background in panel A must (partly) be due to the availability of the Supplementary 1-year Upper secondary Science/Technology education, there is no need for a similar explanation of the share of students with upper secondary STEM background in panel B; students attending upper secondary STEM tracks/programs are in general eligible to non-STEM university studies.

There was a gender difference with respect to magnitude, however: the increases observed for females were invariably larger than the corresponding increases for males, irrespective of the students' upper secondary background.

Table 3: Shares of students admitted to upper secondary school that successfully have conducted university STEM studies, within 2 years after normal upper secondary school study time, before and after the Lpf94 curriculum reform, by gender

From upper sec. tracks/programs:	Share with successful university STEM studies, %		Difference, in %-age points
	1995	1986	
Females			
STEM1	6.91	2.89	4.02
STEM2	7.25	2.90	4.35
STEM3	7.27	2.92	4.35
Non-STEM	3.76	0.16	3.60
All female students	11.03	3.08	7.95
Males			
STEM1	9.95	7.09	2.86
STEM2	10.01	7.11	2.90
STEM3	10.62	7.88	2.74
Non-STEM	1.97	0.16	1.81
All male students	12.59	8.04	4.55

Notes:
1. Successful university STEM studies are defined by credits corresponding to at least a quarter of a full year of study.
2. The entries in the table are based on the data underlying panel A in Figure 6.

In summary: For both females and males the Lpf94 reform, together with the introduction of a Supplementary 1-year Upper secondary Science/Technology education, was followed by increases in successful transitions to university STEM studies for students with upper secondary STEM and non-STEM backgrounds alike, but more so for the former category. Regardless of the students' upper secondary backgrounds, the increases were larger for females than for males, however.

8.3 STEM university studies in spite of non-STEM upper secondary education

The introduction in 1992 of a 1-year Supplementary Science/Technology education has been discussed in Section 2.2 and shown in Figure, by Indicator III. The aim of this section is to provide the reader with a rough idea of the importance of this education for enabling individuals that attended non-STEM programs in upper secondary school to successfully conduct STEM studies at the university.

Unfortunately, this study has not had access to individual-level register information about the Supplementary Science/Technology education.[28] Instead, aggregate data on the number of students admitted to the Supplementary education, from Bryntesson et al. (2015), will be compared to aggregate data on the number of students with non-STEM upper secondary background that successfully have conducted university STEM studies.

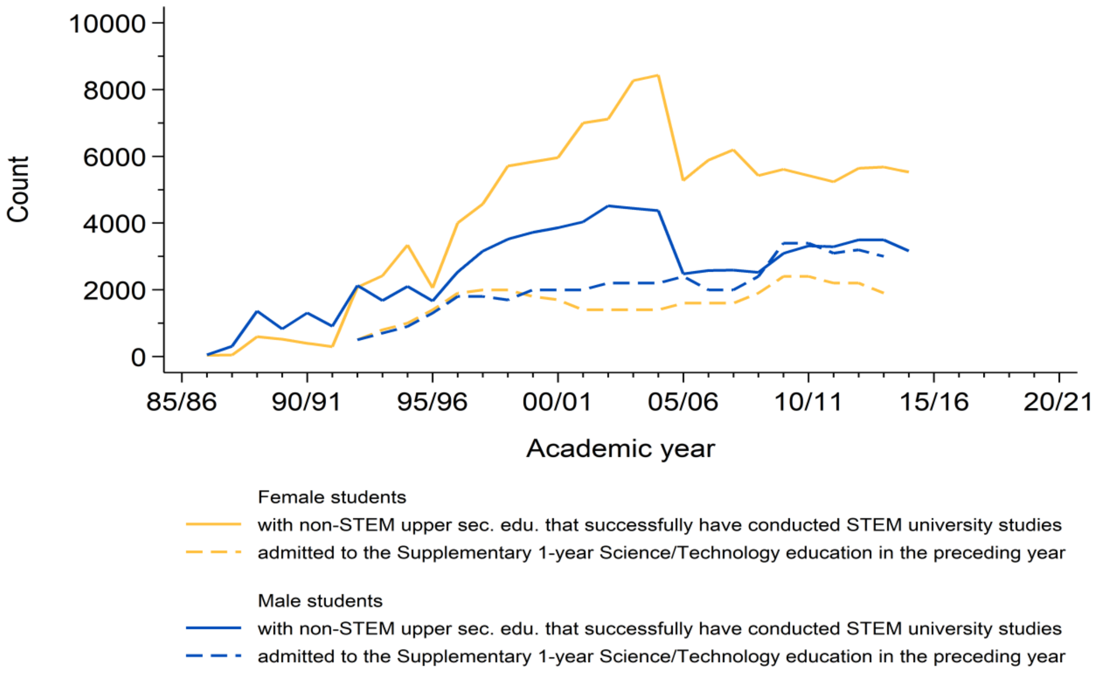
The Bryntesson et al. (op. cit.) data used below concern the Supplementary education that is administered by the universities. As noted in Section 2.2, the Supplementary education is also provided within the Swedish Adult Education system. Very little is known about the number students in the latter category of the Supplementary education. However, for a single (school-)year, namely 1996/1997, Högskoleverket (1997) has estimated that the number of students attending the Supplementary education within the adult education framework was of about the same magnitude as the number attending the Supplementary education administered by the universities. Accordingly, the numbers of Supplementary education students considered here constitute potentially large under-estimates of the true numbers, although a single observation, of course, does not admit any conjecture about the degree of underestimation in general.

The data on the number of students with non-STEM upper secondary background that have conducted university STEM studies have been compiled from register data, as follows. Applying the definition of successful university studies provided in the beginning of Section 8, all individuals which attended a non-STEM upper secondary program and later successfully enrolled in STEM university studies have been extracted. These students are taken to be observed in the first year during which they satisfy the criterion of successful STEM university studies. That is to say, unlike in the previous figures, the students are not 'dated' by means of the year that they were admitted to upper secondary education. Instead they are dated according to their STEM university achievements, irrespective of when they started their upper secondary education.

[28] To some extent, such individual-level register information does exist. It is incomplete, however, in both the cross-sectional dimension – for a given point in time there is not records of all individual that have participated – and in the time dimension – the data do not extend all the way back to 1992.

In Figure 7 the numbers of students with non-STEM upper secondary background that successfully have conducted STEM university studies are provided, separately for female and male students. In addition, the number of students admitted to the Supplementary 1-year Science/Technology Education administered by the universities *in the previous year* is also displayed. This is because admittance to the Supplementary education comes with a guarantee: students completing the Supplementary education within the stipulated year have places reserved in the appropriate university STEM education the subsequent year. Accordingly, it is natural to assume that most of those completing the Supplementary education in (school-)year *t* start their university studies in year *t*+1, although it is possible to start later, too.[29]

Figure 7: Numbers of individuals with non-STEM upper secondary background that successfully have conducted STEM university studies and numbers of students admitted to university-administered Supplementary 1-year Science/Technology education one year earlier, by gender



Notes:
1. An individual is counted as having successfully conducted STEM university studies the year in which (s)he for the first time during one semester gained STEM credits corresponding to a quarter of one full year of studies. This information is available up to, and including, the school-year 2014/2015.
2. The data in Bryntesson et al. (2015) on the numbers of students admitted to the Supplementary education do not extend beyond the school-year 2013/2014. Moreover, for the years 2004/2005, 2007/2008, and 2010/2011 only the total numbers of students are provided. Interpolation using the gender shares in year *t*–1 and *t*+1 has been employed to partition the total numbers into estimates of the numbers of females and males.
3. As information about individuals attending the Supplementary education provided within the framework of the Adult Education system is lacking, the true numbers of Supplementary education participants are underestimated.

[29] However, the placement guarantee expires after one year.

According to Figure 7, the increases in the numbers of students admitted to the Supplementary education that took place up until around the year 2000 was followed by concomitant increases in the numbers of females and males with non-STEM upper secondary background that successfully conducted STEM university studies, although the increase was stronger for females than for males. That the numbers of university STEM students are considerably larger than the numbers of individuals admitted to the (university-administered) Supplementary education one year earlier must, at least in part, be attributable to the Supplementary education administered within the Adult education system, for which we lack information.

After the year 2000, the developments in Figure 7 differ substantially across gender.

For males, the numbers admitted to the Supplementary education continue to increase while the numbers that successfully enrol in university STEM studies comes to a halt and then decreases somewhat. During the period 2005/2006–2013/2014 the number of university STEM students is very close to the numbers admitted to the Supplementary education one year earlier.

For females, the number of successful university STEM students continue to increase between 2000 and 2005, reaching almost 8 500 in the school year 2004/2005, in spite of decreasing numbers admitted to the Supplementary education. Presumably, this can be explained by an increased intake to the Supplementary education within the Adult education. During the period 2005/2006–2013/2014, the numbers admitted to the Supplementary education increase somewhat, from around 1 500 to about 2 000, while the number of STEM university students decreases and then fluctuates around 5 500. Still, in contrast to the males, there is still a large positive difference, approximately 3 500 individuals, between the numbers conducting university STEM studies and the numbers admitted to the (university-administered) Supplementary education.

Taken together, the observations made yield two conclusions.

The first is that the introduction of the Supplementary program has been beneficial for the recruitment to university STEM studies, by broadening the recruitment base to include individuals that have attended non-STEM programs in upper secondary school. The numbers of students with non-STEM upper secondary background that successfully conduct STEM university studies are larger than the number of students admitted to the university-administered Supplementary education in the previous year, suggesting that most of those taking the Supplementary education do also proceed to STEM university studies, although we do not know the magnitude of the intake to the Supplementary education administered within the adult education system.

The second conclusion is that females have benefited more from the Supplementary education than males. At the very least this conclusion applies from 2005/2006 and onwards, because the number of males with non-STEM upper secondary background that successfully enrol in STEM university studies is then not significantly larger than the number of males admitted to the university-administered Supplementary education. That is to say, the conclusion is not subject to the uncertainty stemming from the lack of information about the Supplementary education administered within the Adult education system.

9 Attainments in TIMSS Advanced 1995, 2008 and 2015

There are three international surveys measuring skills in Sciences and Mathematics: PISA (Programme for International Student Assessment), TIMSS (Trends in International Mathematics and Science Study) and TIMSS Advanced. Of these, only TIMSS Advanced (TIMSS A) concerns the skills of upper secondary school students.[30] Specifically, TIMSS A surveys students attending theoretical upper secondary Science and Technology & Engineering education, when the students are in their third year.

TIMSS Advanced has been conducted in 1995, 2008 and 2015; Sweden participated on all three occasions. In the most recent survey, 7 664 Swedish students participated, almost equally divided between Mathematics and Physics.

As it happens, the 1995 survey was conducted when the Lgy70 curriculum was in place, the 2008 survey under the Lpf94 curriculum and the 2015 survey was carried out when the Gy11 curriculum had been implemented; cf. Figure 1.[31] This means that the changes in the Swedish results over time will partly reflect the effects of the curriculum changes, for a specific group of upper secondary students, namely the most qualified of the STEM students, essentially the STEM1 category.[32].

In the 1995 TIMSS A survey, the country scores were adapted to a normal distribution with an average score across the participating countries equal to 500 and a standard deviation equal to 100. The latter implies that just above two thirds of all students achieve scores between 400 and 600.

[30] The PISA survey concerns 15-year olds and TIMSS targets fourth and eighth grade students.
[31] It might seem as if the 1995 TIMSS Advanced survey was conducted when the Lpf94 curriculum was in place. However, the 1995 survey was conducted in the spring of 1995 and the participating students had started their upper secondary educations in the fall 1992.
[32] In addition to the students on theoretical Science and Technology & Engineering tracks/programs, the STEM 1 category also comprises students attending the International Baccalaureate (IB) education, which do not participate in TIMSS Advanced. However, in the student cohorts relevant for the survey the IB students only make up around 5 % of the STEM1 students, with respect to the 2008 and 2015 surveys. Regarding to 1995 the IB share of the corresponding STEM1 cohort is zero, because the IB education was not introduced in Sweden until 1993.

The results in the 2008 and 2015 surveys have been scaled so as to be compatible with the mean and standard deviation in the 1995 survey. It should be noted that scores are not comparable across subjects, i.e. the Math score cannot be compared with the score in Physics. However, within a country, the scores in a given subject are comparable over time.

Table 4 provides the results the results in Mathematics for the four countries that have participated in all of the three TIMSS A Mathematics surveys conducted hitherto. Three observations can be made which apply to females and males alike. First, all of the four countries in the table had mean scores in the 500 ± 1 standard deviation (100) interval in 1995, 2008, and 2015. Second, of these four, only one 'country', Russia 6h+, consistently has achieved mean scores above the international average of 500; two countries, Italy and Slovenia, consistently achieved scores below the international average. Third, three of the countries achieved their highest score in 1995, namely Italy, Slovenia, and Sweden.

Regarding the Swedish results, the very large and significant decreases by 88 and 90 score points between 1995 and 2008 for females and males, respectively, stands out. The changes are dramatic both compared to the 1995 mean scores – relative changes of almost –18 percent – and compared to the changes observed for the other three countries. The downturn followed the replacement of the Lgy70 curriculum by the Lpf94 curriculum reform and, in particular, the concomitant reduced requirements with respect to compulsory Mathematics and Physics for the Science and Technology & Engineering students, cf. Figure 1, Indicator IV.iii.

Table 4 further shows that between 2008 and 2015 the Swedish results in Mathematics improved somewhat, for both females and males. Although the increases do not appear overly impressive relative to the mean scores in 2008, amounting to 4.9 and 4.3 percent for females and males, respectively, it should be noted that in 2015 the three other countries in the table either experienced decreases in their mean scores (Italy and Russia6h+) or very small and insignificant increases (Slovenia).

Table 4: Results, by gender, in Mathematics in TIMSS Advanced for the countries that have participated in all of the surveys conducted up until 2016

Gender/	**Mean scores (standard errors)**			**Difference between 2008**	**Difference between 2015**
country	***1995***	***2008***	***2015***	**and 1995 [2]**	**and 2008 [2]**
Females					
Italy	477	454	427	–23	–27*
Russia6h+[1]	526	551	530	25*	–21
Slovenia	469	448	449	–21	1
Sweden	*492*	*404*	*424*	*–88**	*20**
Males					
Italy	487	446	419	–41*	–27*
Russia6h+[1]	569	569	549	0	–20
Slovenia	486	472	476	–14	4
Sweden	*507*	*418*	*436*	*–89**	*18**

Notes:
1. Russia 6h+ denotes Russian students which attend extra intensive Mathematics education, corresponding to at least six hours of Mathematics per week.
2. Differences that are statistically significantly different from zero are indicated by '*'.

Source: Skolverket (2016).

The positive change in the Swedish results followed the Gy11 curriculum reform. This reform incorporated (at least) two features speaking in favour improved results in TIMSS A. First, entry requirements to upper secondary school were made more stringent and especially so for the theoretical programs. On average, this should result in student with higher ability attending the Science and Technology & Engineering programs, than before the reform (Figure 1, Indicator VI.i). Secondly, the Math content on the Science and Technology & Engineering programs was extended by 1/7 (Figure 1, Indicator VI.ii).

Table 5 reports the results in the Physics part of TIMSS A, for the countries that have participated in all of the 1995, 2008, and 2015 surveys. Similarly, for the Mathematics results in Table 4 all of the countries in Table 5 have mean scores within 500 ± 1 standard deviation of 100 score points, for both females and males. Another similarity between Table 4 and Table 5 is that for three of the four countries in the table the highest scores are observed in 1995, with respect to females as well as males; Slovenia is the only exception.

In contrast to the Mathematics results in Table 4, the results in Physics differ substantially across gender. In terms of levels, the differences are to the disadvantage of the females, but in terms of changes over they are to the females' advantage. Accordingly, the gender gap is decreasing over time.

Like in Mathematics, Sweden is the country with the largest decrease in mean scores between 1995 and 2008; in relative terms the decreases amounted to 11 percent of the mean score in 1995 for females and 15 percent for the males. The reflection made above about a possible relation between the deterioration in TIMSS A Mathematics achievement from 1995 to 2008 and the change from the Lgy70 to the Lpf94 curriculum is relevant here, too.

Table 5: Results, by gender, in Physics in TIMSS Advanced for the countries that have participated in all of the surveys conducted up until 2016

Gender/	**Mean scores (standard errors)**			**Difference**	**Difference**
Country	*1995*	*2008*	*2015*	**between 2008 and 1995** [1]	**between 2015 and 2008** [2]
Females					
Norway	553	517	489	–36*	–28*
Russia	507	498	498	–9	0
Slovenia	478	535	510	57*	–25*
Sweden	*551*	*491*	*448*	*–60**	*–43**
Males					
Norway	591	541	515	–50*	–26*
Russia	577	540	514	–37*	–26*
Slovenia	550	535	540	–15	5
Sweden	*590*	*500*	*459*	*–90**	*–41**

Notes:
1. Differences that are statistically significantly different from zero are indicated by '*'.

Source: Skolverket (2016).

Unlike the Swedish results in Mathematics, the Swedish results in Physics did not improve between 2008 and 2015, cf. the last column of Table 5. However, the rates of decline were slowed down, for both females and males, compared to the negative changes between 2008 and 1995. Like the, much more impressive, change between 2008 and 2015 in Mathematics achievement the change for the better, albeit modest, may partly be a consequence of the more stringent entry requirements imposed on the upper secondary school theoretical programs, as part of the Gy11 curriculum reform. And the fact that the improvements were much weaker with respect to Physics is consistent with the fact that while the Mathematics education on the Science and Technology & Engineering programs was extended the Physics education was left unchanged.

To sum up: The Lpf94 reform was followed by large and significant negative changes in the TIMSS A results in both mathematics and physics, for females and males alike. These changes can be associated with reduced requirements with respect to compulsory Mathematics and Physics for the Science and Technology & Engineering students (Figure 1, Indicator IV.iii). After the Gy11 reform the Swedish mathematics score increased significantly, for females as well as for males, albeit not enough to compensate for the decrease after the Lpf94 reform. The results in physics decreased, but at a much slower rate than after the Lpf94 reform, again with respect to both females and males. The different developments for mathematics and physics are consistent with the facts that while entry and study requirements became more stringent for both subjects, as part of the Gy11 reform (Figure 1, Indicators VI.i, VI.v, VI.vi) the course content with respect to mathematics was extended, too, while it was left unchanged with respect to physics (Figure 1, Indicator VI.ii). The Swedish gender are to the advantage of the male students but not very large and difference in Physics decreased following the Lpf94 reform.

10 Summary and concluding discussion

This paper has tried to relate the recruitment to Swedish upper secondary Science, Technology, Engineering and Mathematics (STEM) educations and the subsequent academic achievements of the recruited students to the two reforms of the Swedish upper secondary school curriculum that took place during the 1986–2016 period. In very general terms, the reforms can be characterized as follows; detailed descriptions are provided in Section 2 of the paper.

The Lpf94 curriculum reform, implemented in 1995, amounted to a broadening of the curriculum in two respects:

- All upper secondary educations came to include eight core subjects: Swedish, English, Mathematics, Sciences, Social sciences, Religion, Health and Sports, and Aesthetic activities. Previously, only Swedish had been compulsory in many vocationally oriented educations.

- Earlier, the vocationally and academically oriented educations had extended over two and three years, respectively. With the Lpf94, all upper secondary educations became three-year educations and all were structured such that they yielded basic eligibility to university studies.

With respect to STEM educations in particular, the Lpf94 resulted in reductions in compulsory Math and Physics studies.

The Gy11 curriculum reform, implemented in 2011, reintroduced the differences between vocationally and academically oriented educations:

- Upper secondary school entry requirements became more stringent for the academically oriented educations, than for the vocational educations.
- Courses yielding basic university eligibility became compulsory only for the academically oriented educations.
- The requirements for basic university eligibility were enlarged.

For STEM educations Math studies were expanded.

The paper's descriptive empirical analyses results in the following conclusions regarding the developments following the two reforms:

a) *Recruitment to upper secondary school*: For female students, the implementation of the Lpf94 curriculum was followed by a marked increase in the recruitment to the academic STEM tracks/programs (STEM1). Otherwise, the shares admitted to all upper secondary STEM programs decreased for both female and male students. In contrast, the share of students admitted to non-STEM tracks/programs increased, for females and males alike. After the implementation of the Gy11 curriculum, the shares of students admitted to all types of STEM programs increased, whereas the share of students admitted to non-STEM tracks/programs decreased, in both cases with respect to females as well as males.

b) *Completion of upper secondary educations*: Following the Lpf94, the shares of the students admitted to upper secondary education that completed their studies with the frame of normal study time +2 years declined for all upper secondary tracks/programs. This was to be expected, for two reasons. First, the extension of the vocational programs from two to three years was followed by increased drop-out rates. Second, unlike before the reform, the new grading system turned incomplete upper secondary educations into real possibilities. For the STEM tracks/programs the decreases were larger than for the non-STEM categories. This was partly unexpected, as compulsory math and science in the STEM1 program was reduced. In line with its more restrictive upper secondary entry requirements, the Gy11 reform was followed by increases in the shares of students with completed studies, with respect to all study programs. The increases were larger for the STEM programs than for the non-STEM programs. The gender differences in the responses to the reform concerned magnitudes, not directions. After the Lpf94 reform, the completion rates for STEM1 programs decreased less, in relative terms, for females than for males whereas the opposite was true for non-STEM programs. The changes following the Gy11 reform were larger for males than for females, in terms of percentage points.

c) *Successful transitions from upper secondary school to STEM university studies*: A student is defined as having successfully proceeded to university studies if (s)he has gained university credits in a STEM field of study corresponding to at least a quarter of one year of full studies, within two years after normal upper secondary school study time. Due to data constraints, this outcome can only be analysed with respect to the Lpf94 reform. Furthermore, the changes following this reform are somewhat difficult to interpret because another reform took place in parallel, namely the introduction of a supplementary 1-year upper secondary education providing upper secondary graduates in Social sciences and Business Administration with eligibility to university STEM studies. After the Lpf94 reform *and* the introduction of the 1-year supplementary education, the shares of the students admitted to upper secondary education that successfully proceeded to university STEM studies increased for students with upper secondary STEM and non-STEM backgrounds alike. Regardless of upper secondary background, the completion rates increased more, in percentage points, for females than for males. For both females and males, the increase was larger for the students with STEM upper secondary background, in spite of the fact that the supplementary education targeted non-STEM students. Still, the supplementary education is found to have been beneficial, especially for females, by broadening the recruitment base for university STEM studies by means of a short education with a high university transition rate.

d) *Achievements in TIMSS Advanced for the most academically oriented upper secondary, third-year, STEM students:* The TIMSS Advanced survey has tested advanced skills in Mathematics and in Physics in 1995, 2008 and 2015. The changes in results between 1995 and 2008 can be related to the Lpf94 reform and the changes between 2008 and 2015 can be related to Gy11 reform. The Lpf94 reform was followed by very large and statistically significant declines in the TIMSS Advanced achievements in both Mathematics and Physics. With respect to Mathematics, the decrease was approximately 18 percent for both females and males, in both cases from a level roughly corresponding to the TIMSS A average score. In Physics the female and male the relative decreases were smaller, 11 and 15 percent, respectively, and from levels above the TIMSS A average scores. A component of the Lpf94 reform consistent with the decreases was a reduction of compulsory Math and Physics studies in the Science and Technology & Engineering programs. After the Gy11 reform, statistically significant improvements in Mathematics achievements were recorded for females and males alike, in line with expanded studies in Mathematics in the aforementioned programs. These changes for the better were, however, insufficient to compensate for the decreases after the Lpf94 reform. In Physics, the results continued to deteriorate after the Gy11 reform, for both genders, but at a slower pace than after the Lpf94 reform.

The points a) – d) are summarized in Table 6.

The entries in Table 6 are remarkably similar for females and males; the only gender difference observed concerns the outcome a) Recruitment to upper secondary STEM tracks/programs. It should be noted however, that the table considers only the directions of the observed responses to the reform changes. With respect to the magnitudes of the responses, in terms of percentage points, there are differences between females and males, but no systematic pattern in these differences can be observed.

Table 6: Summary of the directions of changes following the Lpf94 and Gy11 curriculum reforms, by gender

Gender/Outcomes	**Lpf94**	**Gy11**
Females		
a) Recruitment to upper secondary STEM tracks/programs	+ / –[1]	+
b) Completion of upper secondary STEM education	–	+
c) Successful transitions to university STEM studies	(+)[2]	n.a.
d) Achievements in TIMSS Advanced	–	+
Males		
a) Recruitment to upper secondary STEM tracks/programs	–	+
b) Completion of upper secondary STEM education	–	+
c) Successful transitions to university STEM studies	(+)[2]	n.a.
d) Achievements in TIMSS Advanced	–	+

Notes:
1. The positive sign refers to the increase in the recruitment to STEM1 programs, while the negative sign refers to the finding that the recruitment to the vocational STEM categories deceased.
2. The parenthesis is used for two reasons. First, in the 1990s, there was a general expansion of Swedish university education, which should matter for the transitions to university studies in general. Second, the introduction of the 1-year supplementary Science and Technology education, which occurred in parallel with the Lpf94, most likely also influenced the transitions to university STEM studies, in particular.

The overall impression of Table 6 is that the implementation of the broader Lpf94 curriculum does not seem to have been a clear change for the better with respect to the outcome variables considered. In contrast, the implementation of the Gy11 reform, which resulted in a narrower curriculum, has been followed by favourable changes.

It should be stressed, however, that the findings presented here are based on a descriptive analysis and, thus, do not allow causal inferences. In contrast, Hall's (2012) study of the pilot scheme preceding the Lpf94 reform is a causal effect evaluation. She infers that extending vocational upper secondary ´programs by one year, increasing their academic content and making them provide eligibility to university studies leads to higher drop-out rates in upper secondary education and has negligible effects on transitions to university education. When Hall's (op.cit.) causal evidence about the effects of a broader curriculum, in general, are added to this paper's descriptive results regarding the consequences of a broader curriculum for STEM educations, in particular, the overall conclusion must be that the Swedish experiences of a broader curriculum are not encouraging, at least not with respect to (strictly) educational outcomes. It should be noted, though, that, in a wider perspective, positive effects have been established. Specifically, the extension of vocational education by one year has been shown to lead to reductions in property crime (Grönqvist et al., 2015) and increased electoral participation among low socio-economic groups (Lindgren et al., 2017).

However, focusing on educational outcomes, there are three lessons to be learned from the Swedish experiences.

First, attempts to broaden the curriculum by increasing the theoretical content of vocational study programs are not likely to be successful. The consequent prolongation of the upper secondary studies appears to have no positive influences on the recruitment to vocationally oriented programs with STEM profiles. Moreover, descriptive findings in this study as well as earlier causal evidence concerning vocational programs in general (Hall, 2012) point to negative consequences with respect shares of students completing their studies. Most importantly, the causal effects on the transition to university education (in general) have been found to be equal to zero (Hall, op. cit.). In this paper, a positive association between a broader curriculum and transitions to STEM university studies have been observed, but this association is uncertain and may be due to non-curriculum factors such as a general expansion of university education.

Second, a viable alternative to broadening the curricula of non-STEM academic educational programs by enhancing their STEM content may be to leave these programs unchanged and, instead, provide the option to supplement them by short ‘add-on’ STEM programs. Although further research is needed on this issue, the Swedish experience of a 1-year supplementary STEM program targeted at students which have completed an upper secondary education within Social sciences or Business administration seems promising. There are three attractive features of this strategy: it addresses students already acquainted with academic studies, it yields results faster than the transformation of entire upper secondary educational programs, and it appears to be particularly beneficial for females, among which the potential for increased recruitment to, and participation in, higher STEM studies is much larger than among males.

Third, trying to bring about additional studies of STEM subjects and/or increased numbers of STEM students by relaxing study requirements does not seem to be a good idea. Reductions in compulsory math and physics studies for the advanced upper secondary Science and Technology & Engineering students was followed by dramatic deteriorations of the Swedish results in the TIMSS advanced survey. Although this is only an association, rather than a causal relation, it is certainly suggestive.

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