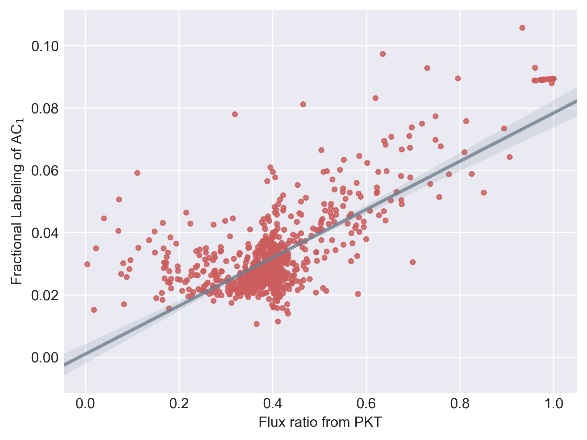
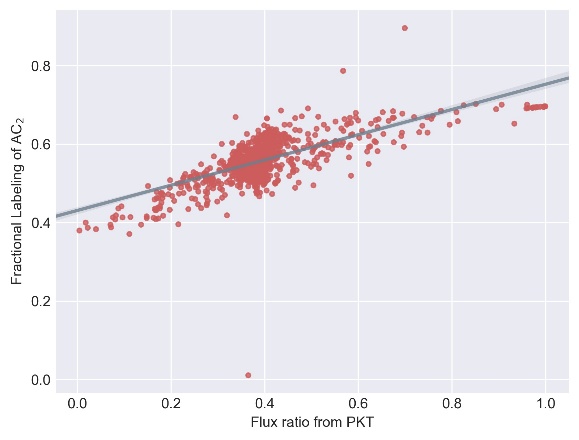
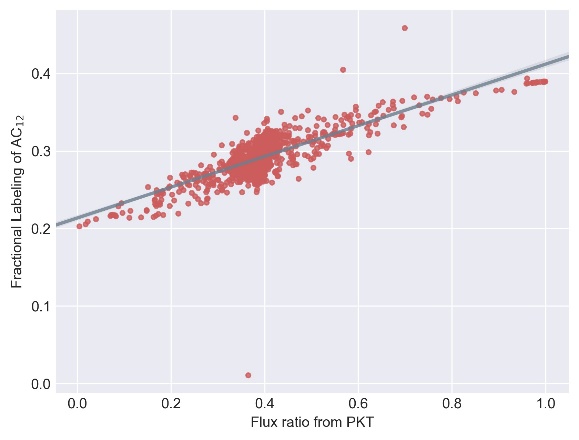
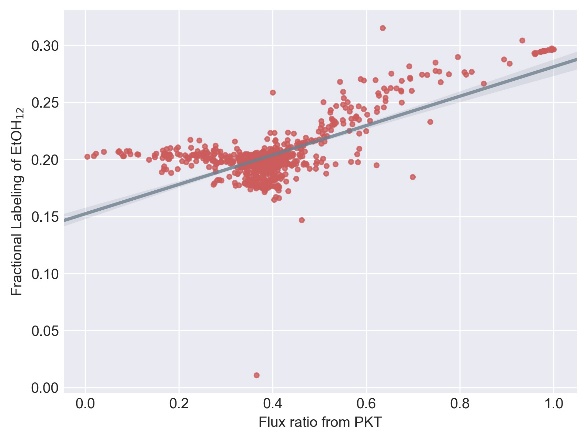
**Supplementary Table 1**. Biochemical reactions as well as atom transitions involved in xylose metabolism of *C. acetobutylicum*.

|  |  |
| --- | --- |
| **Reaction ID** | **Reaction with atom transition** |
| v1 | Xyl(abcde) => X5P(abcde) |
| v2 | X5P(abcde) => AcP(ba)+GAP(cde) |
| v3 | X5P(abcde) <=> Ru5P(abcde) |
| v4 | Ru5P(abcde) <=> R5P(abcde) |
| v5 | X5P(abcde) <=> TK(ab) + GAP(cde) |
| v6 | F6P(abcdef) <=> TK(ab) + E4P(cdef) |
| v7 | S7P(abcdefg) <=> TK(ab) + R5P(cdefg) |
| v8 | F6P(abcdef) <=> TA(abc) + GAP(def) |
| v9 | S7P(abcdefg) <=> TA(abc) + E4P(defg) |
| v10 | F6P(abcdef) => FBP(abcdef) |
| v11 | FBP(abcdef) <=> DHAP(cba)+GAP(def) |
| v12 | DHAP(abc) <=> GAP(abc) |
| v13 | GAP(abc) <=> G3P(abc) |
| v14 | G3P(abc) <=> PEP(abc) |
| v15 | PEP(abc) => Pyr(abc) |
| v16 | Pyr(abc) => AcCoA(bc) + CO2(a) |
| v17 | AcCoA(ab) <=> AcP(ab) |
| v18 | AcP(ab) => AC(ab) |
| v19 | AcCoA(ab) => EtOH(ab) |

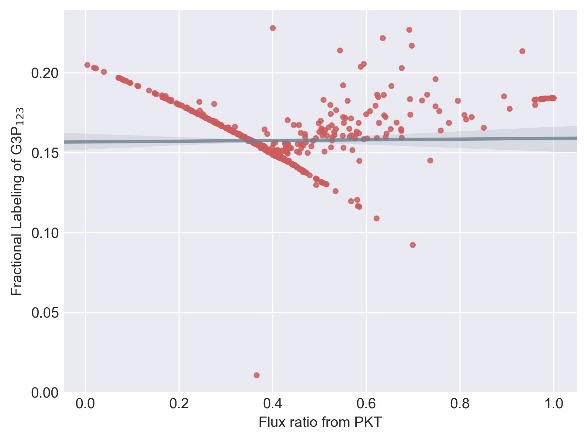
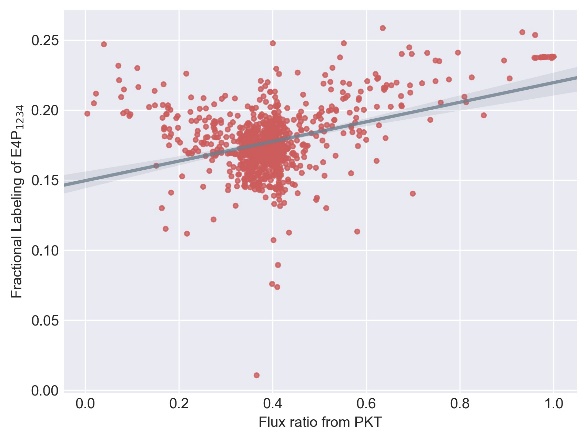
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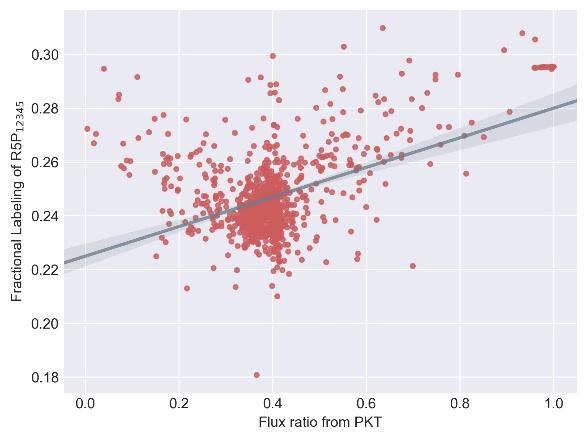
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(E) (F)

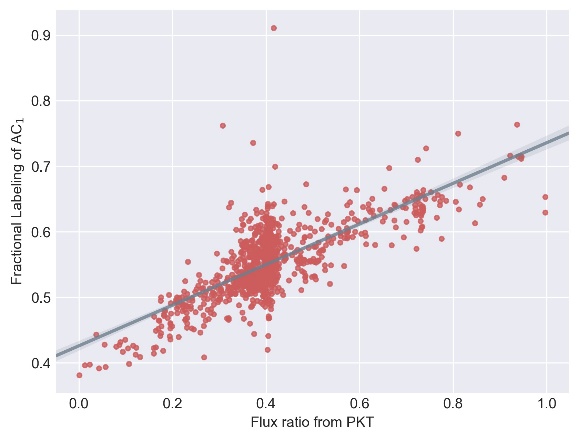
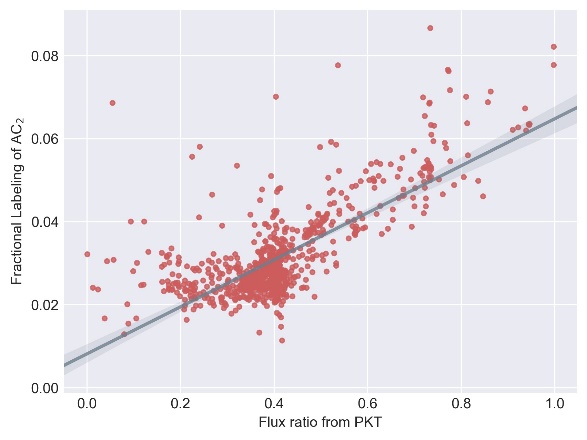
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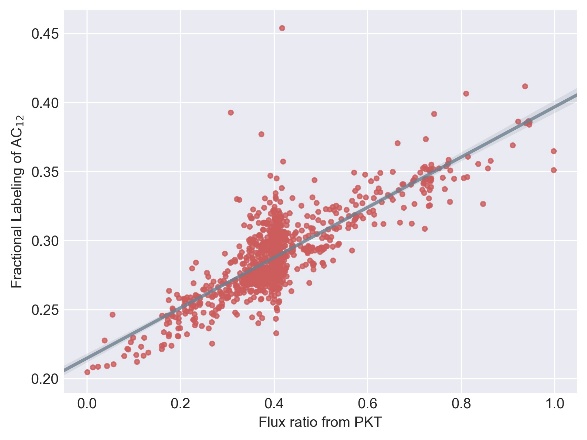
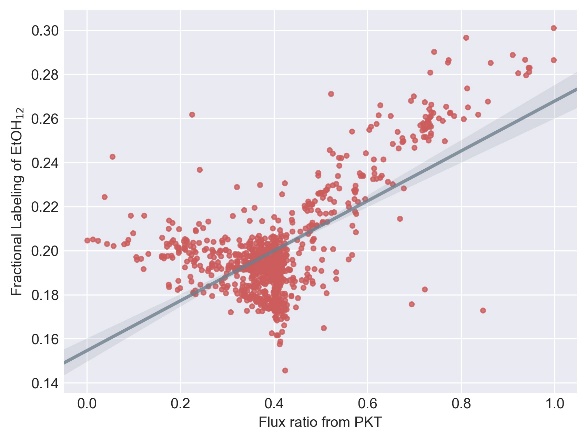
**Supplementary Figure 1**.

Simulated FL of metabolites at different flux ratio from PKT with 100% 1-13C xylose as substrate. Random fluxes are generated 1000 times subjecting to xylose metabolism network. MDVs of (A) AC1, (B) AC2, (C) AC12, (D) EtOH12, (E) G3P123, (F) E4P1234 and (G) R5P12345 are simulated using adjacency matrix based EMU decomposition method proposed in this work. Metabolite FLs and flux ratio from PKT are subsequently calculated and plotted correspondingly. Regression line and 95% confidence intervals are also plotted.

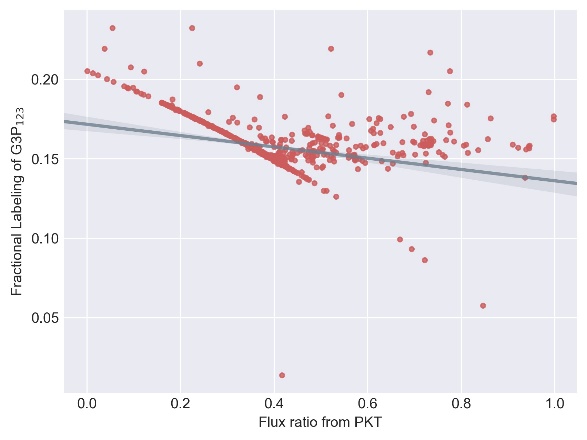
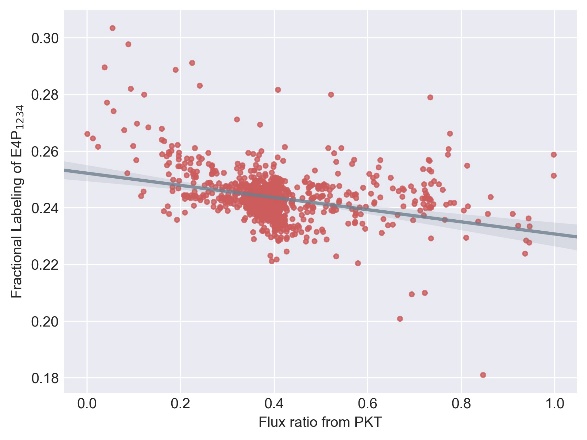
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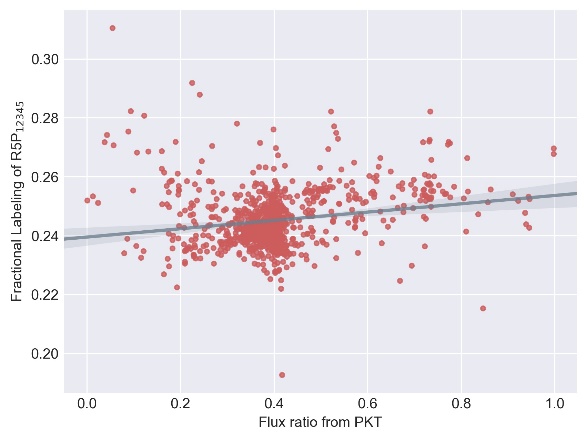
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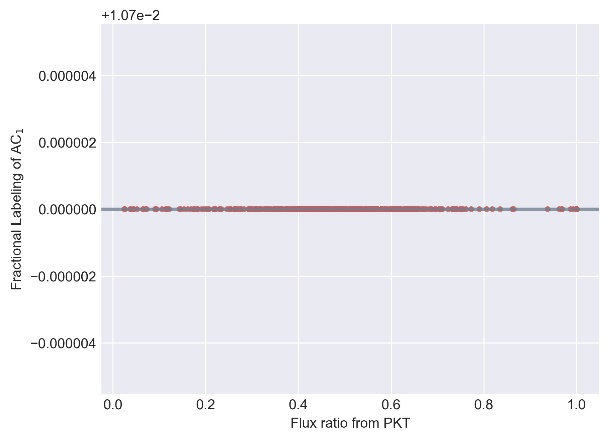
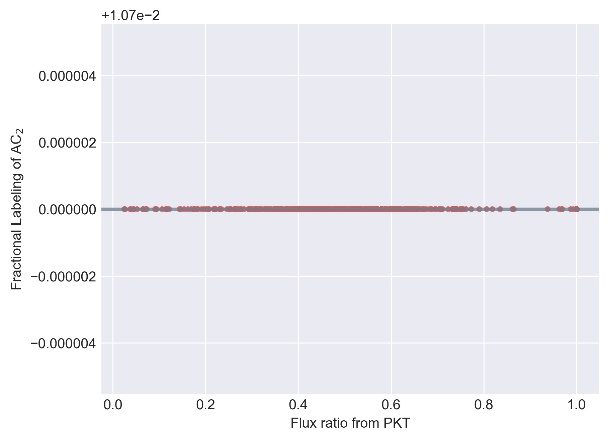
(G)



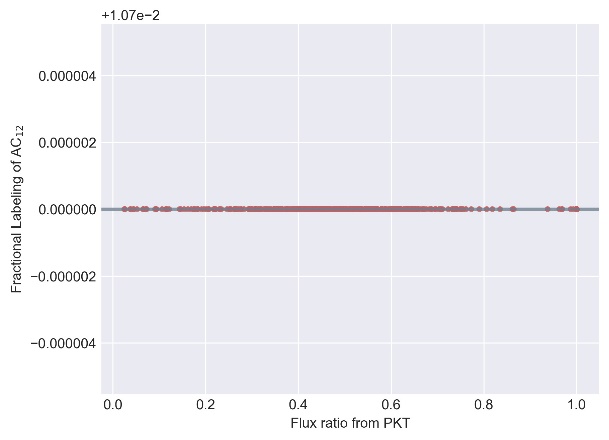
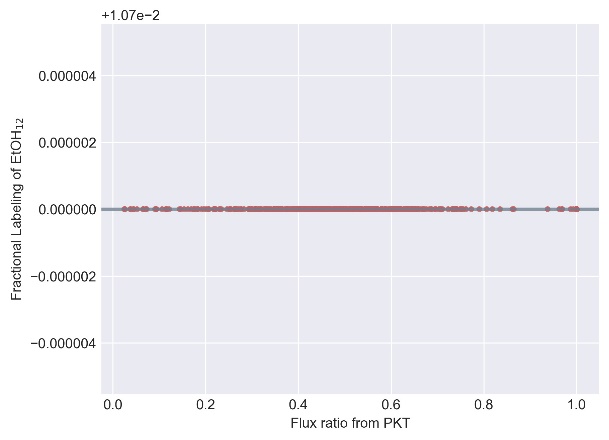
**Supplementary Figure 2**.

Simulated FL of metabolites at different flux ratio from PKT with 100% 2-13C xylose as substrate. Random fluxes are generated 1000 times subjecting to xylose metabolism network. MDVs of (A) AC1, (B) AC2, (C) AC12, (D) EtOH12, (E) G3P123, (F) E4P1234 and (G) R5P12345 are simulated using adjacency matrix based EMU decomposition method proposed in this work. Metabolite FLs and flux ratio from PKT are subsequently calculated and plotted correspondingly. Regression line and 95% confidence intervals are also plotted.

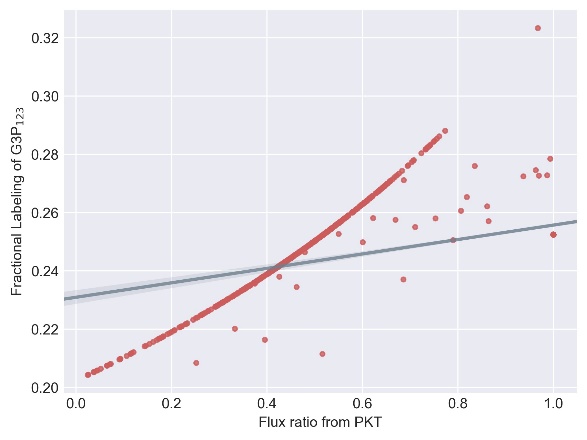
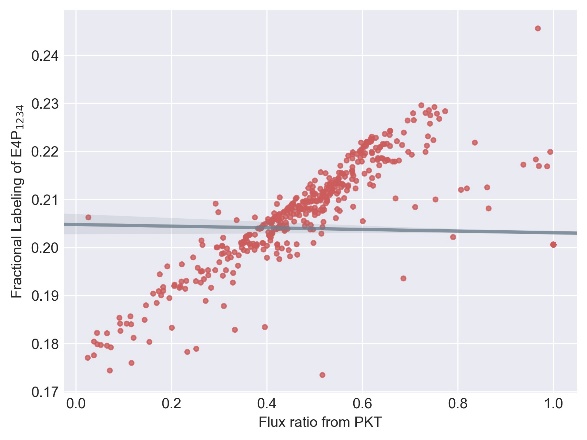
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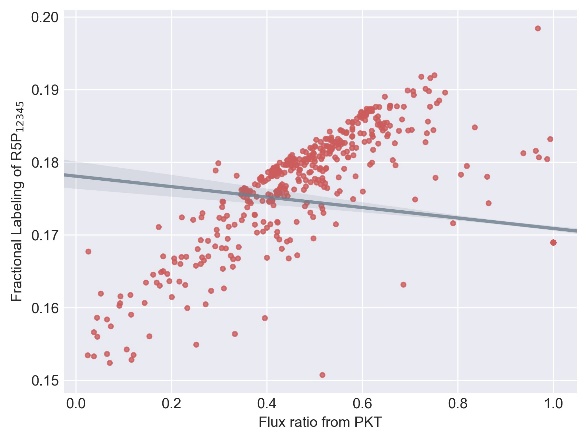
(C) (D)

(E) (F)

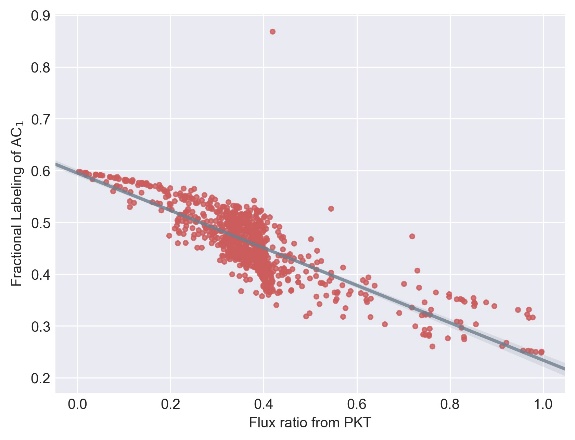
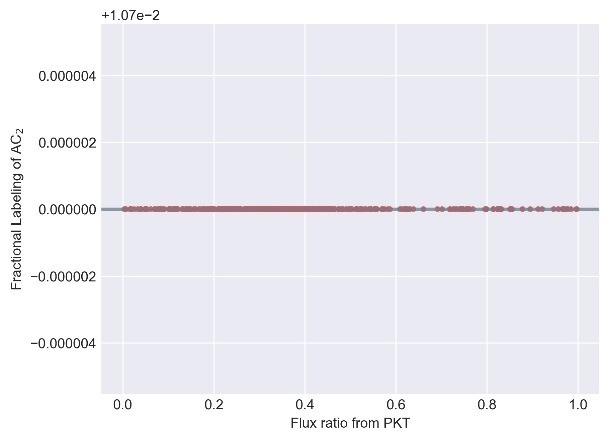
(G)



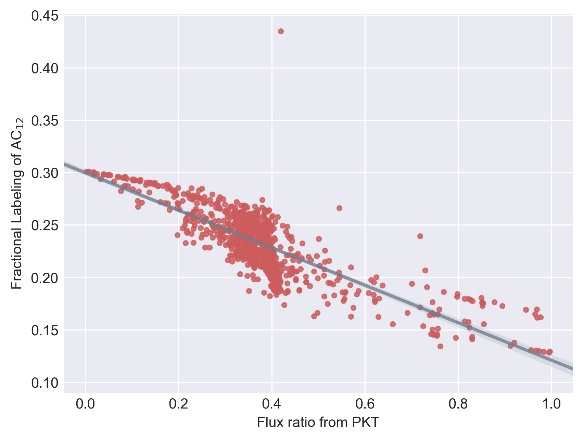
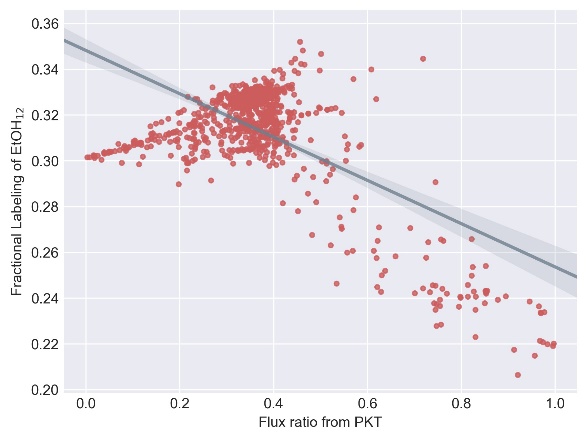
**Supplementary Figure 3**.

Simulated FL of metabolites at different flux ratio from PKT with 100% 3-13C xylose as substrate. Random fluxes are generated 1000 times subjecting to xylose metabolism network. MDVs of (A) AC1, (B) AC2, (C) AC12, (D) EtOH12, (E) G3P123, (F) E4P1234 and (G) R5P12345 are simulated using adjacency matrix based EMU decomposition method proposed in this work. Metabolite FLs and flux ratio from PKT are subsequently calculated and plotted correspondingly. Regression line and 95% confidence intervals are also plotted.

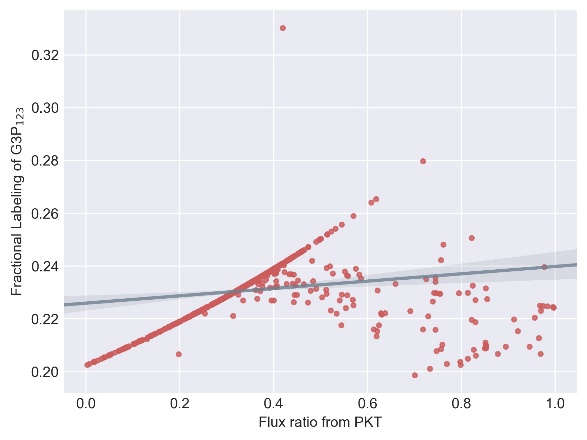
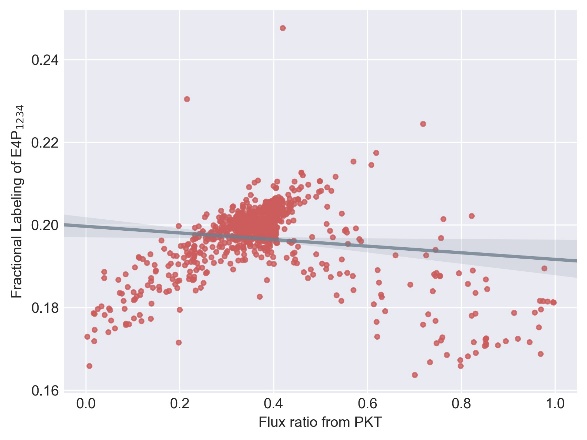
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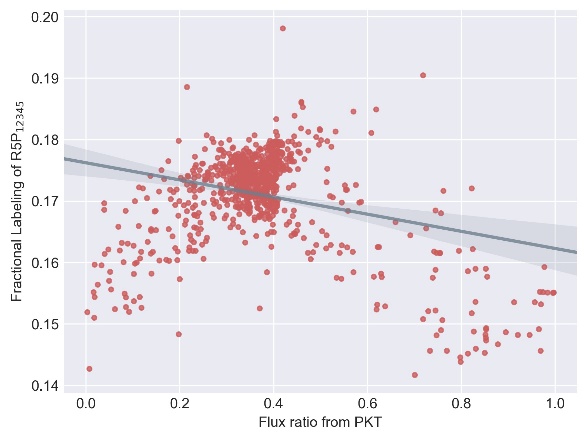
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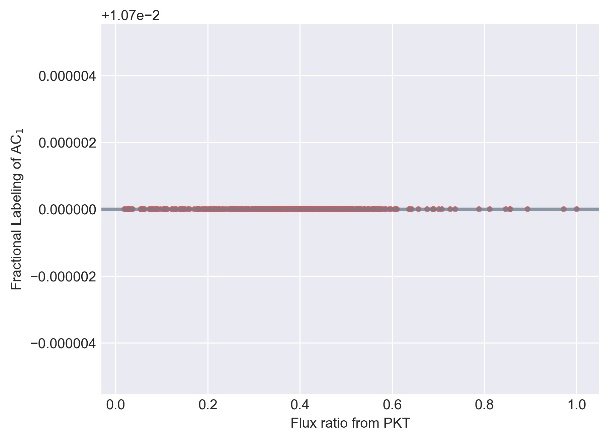
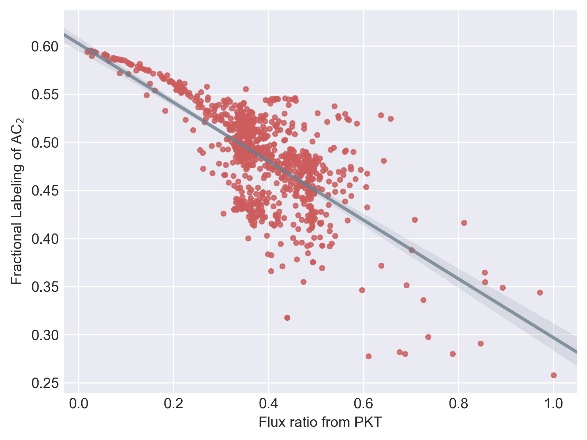
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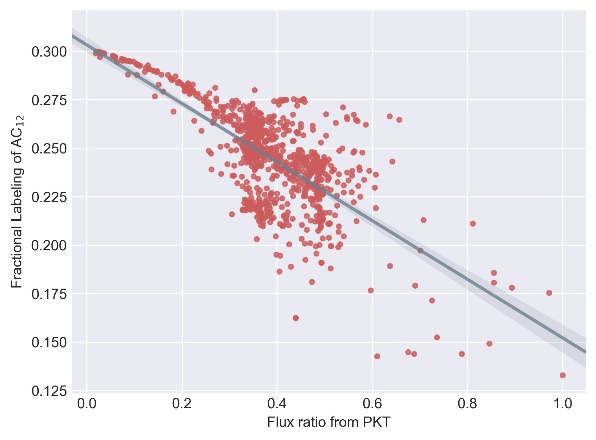
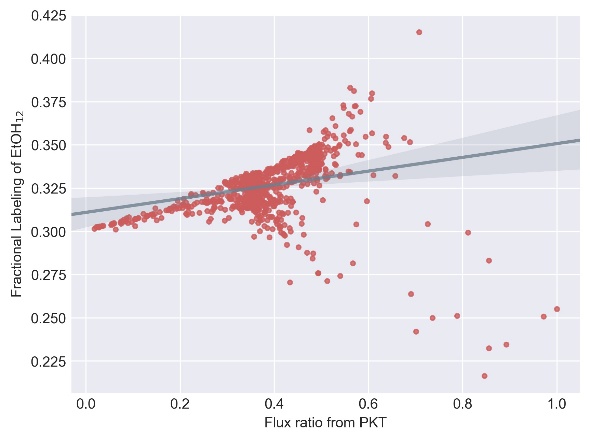
**Supplementary Figure 4**.

Simulated FL of metabolites at different flux ratio from PKT with 100% 4-13C xylose as substrate. Random fluxes are generated 1000 times subjecting to xylose metabolism network. MDVs of (A) AC1, (B) AC2, (C) AC12, (D) EtOH12, (E) G3P123, (F) E4P1234 and (G) R5P12345 are simulated using adjacency matrix based EMU decomposition method proposed in this work. Metabolite FLs and flux ratio from PKT are subsequently calculated and plotted correspondingly. Regression line and 95% confidence intervals are also plotted.

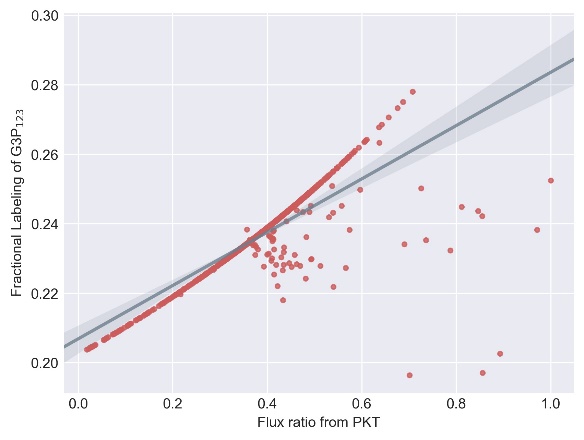
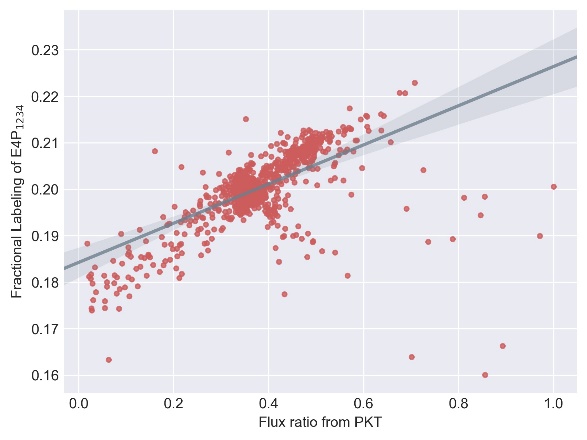
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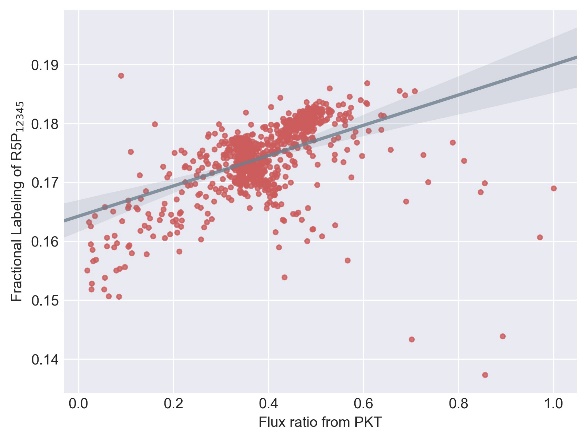
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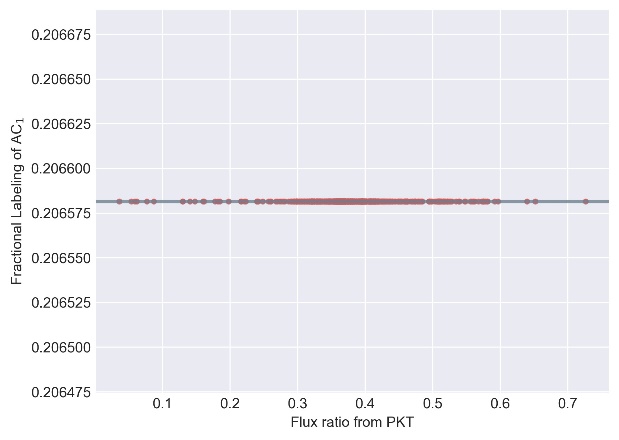
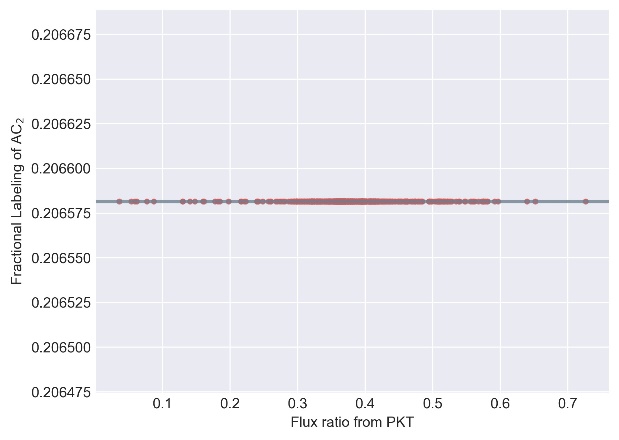
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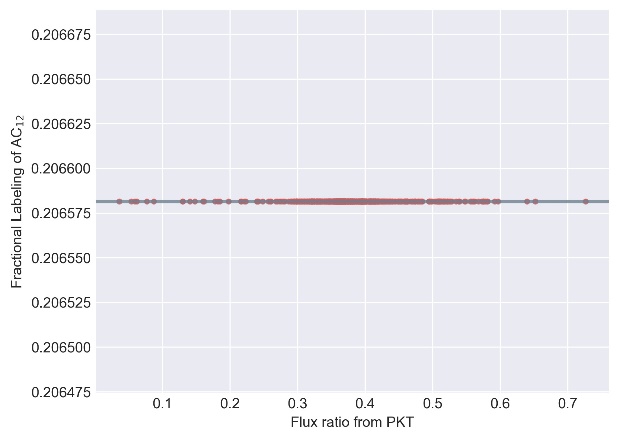
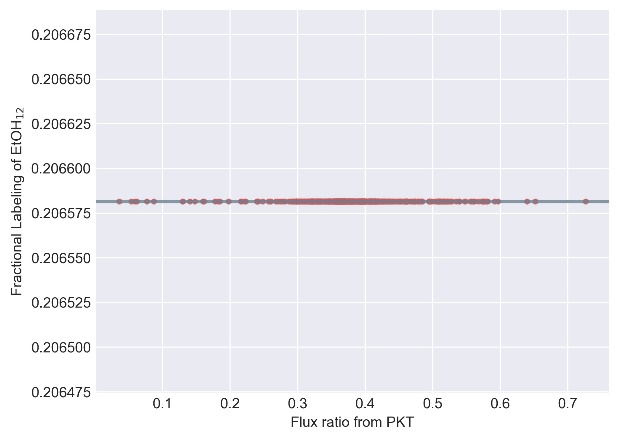
**Supplementary Figure 5**.

Simulated FL of metabolites at different flux ratio from PKT with 100% 5-13C xylose as substrate. Random fluxes are generated 1000 times subjecting to xylose metabolism network. MDVs of (A) AC1, (B) AC2, (C) AC12, (D) EtOH12, (E) G3P123, (F) E4P1234 and (G) R5P12345 are simulated using adjacency matrix based EMU decomposition method proposed in this work. Metabolite FLs and flux ratio from PKT are subsequently calculated and plotted correspondingly. Regression line and 95% confidence intervals are also plotted.

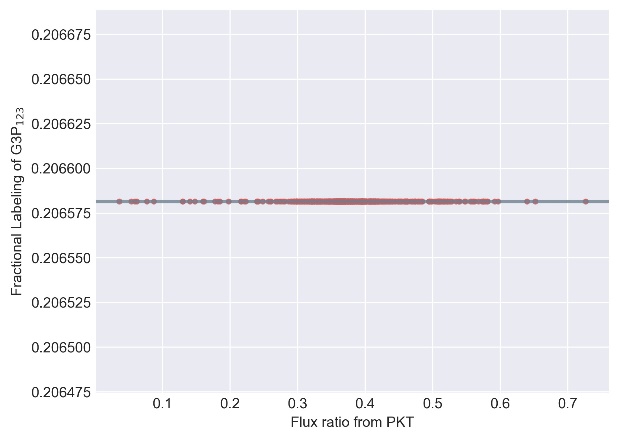
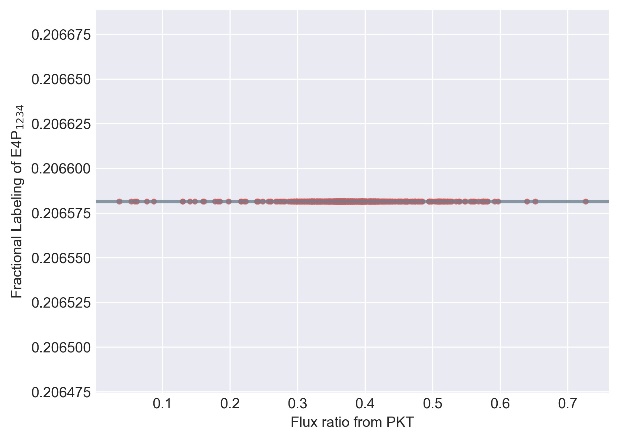
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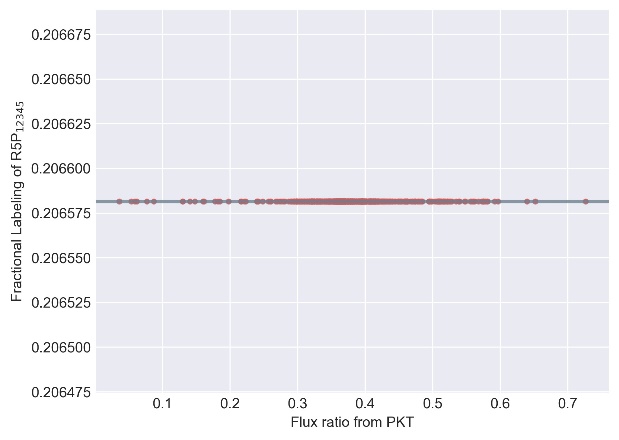
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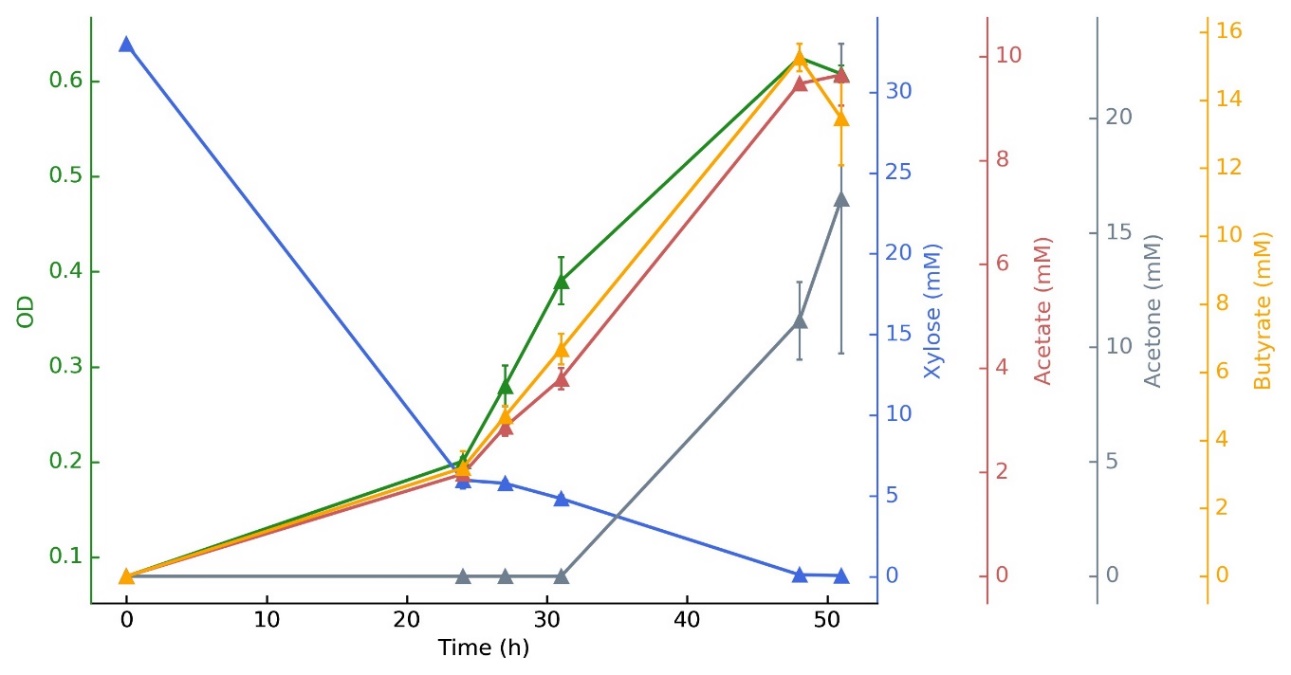
 

(G)



**Supplementary Figure 6**.

Simulated FL of metabolites at different flux ratio from PKT with mixture of 20% U-13C xylose and 80% natural xylose as substrate. Random fluxes are generated 1000 times subjecting to xylose metabolism network. MDVs of (A) AC1, (B) AC2, (C) AC12, (D) EtOH12, (E) G3P123, (F) E4P1234 and (G) R5P12345 are simulated using adjacency matrix based EMU decomposition method proposed in this work. Metabolite FLs and flux ratio from PKT are subsequently calculated and plotted correspondingly. Regression line and 95% confidence intervals are also plotted.



**Supplementary Figure 7**.

Cell Growth, substrate consumption and products formation of *C. acetobutylicum* at an initial xylose concentration of 5 g L-1. OD (green), xylose (blue), acetate (red), acetone (grey) and butyrate (yellow) are determined during cultivation. Data points represent the mean of three replicates.